ASSESSING THE POTENTIAL ECONOMIC BENEFITS OF TRANSGENIC COTTON IN MOZAMBIQUE

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ABSTRACT

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This study analyzes the potential economic impacts from adopting Bt cotton in Mozambique more specifically, (1) the benefits to farmers, (2) the benefits to the society. In history of Mozambican agriculture, this study is the first attempt to evaluate the potential economic benefits from adopting Bt cotton, expected to provide insights for decision making related to Bt cotton in Mozambique and in other countries with smallholder production of cotton that are likely to consider the adoption of Bt cotton in Sub-Saharan Africa.

The study concludes that under current practices, specially regarding to lower insecticide applications, Bt cotton is not expected to generate additional income to farmer but it is expected to do so for the society. However, it can be attractive to farmers if its yield increases by 6%, about 40 Kg/ha over the actual conventional cotton yield level. Alternatively, the Bt seed price would have to decrease by 17% to $13.78/ha. Moreover, if farmers were to pay full cost of pesticides, and get paid export parity price for cotton, they could pay full cost of Bt seed and earn more profit with Bt cotton than with conventional cotton. Finally, more focused research is still needed to fully assess the economic, environmental, and social benefits and risks of Bt cotton.

DEDICATION

In memory of my mother, Esperança Raúl. You always believed that life has good things that people can benefit from them as long as enough energy and self confidence are put to overcome difficulties along the way. Recognizing that your lesson was very important to achieve my goals, this is an ideal moment to express my gratitude. I'll always remember you.

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KEY TO SYMBOLS OR ABBREVIATIONS

GM	Genetically engineered
JVC	Joint Venture Companies
SODAN	Sociedade de Desenvolvimento de Algodao de Namialo
CANAM	Companhia Algodoeira de Nampula
SANAM	Sociedade Algodoeira de Namialo
JFS	Joao Ferreira dos Santos Group
NGOs	Non-Governmental Organizations
CLUSA	Cooperative League of the USA
IAM	Instituto de Algodao de Mocambique
MADER	Ministry of Agriculture and Rural Development
CIRAD	Centre International de Recherché Agronomic e Developpement
IFAD	International Fund for Agricultural Development
MSU	Michigan State University
CINSAM	Centro de Investigacao e Multiplicacao de semente de algodao de Namilao
a.i.	Active ingredient
IPM	Integrated Pest Management
OLS	Ordinary Least Square
BLUE	Best Linear Unbiased Estimates
IPC	Consumer Price Index
ICAC	International Cotton Advisor Committee
MO/DPL	Monsanto and Delta Pineland

CAAS	China Academy of Agricultural Sciences
ISAA	International Service for the Acquisition of Agri-biotech Applications

CHAPTER ONE

INTRODUCTION

This chapter provides the context, objectives, and organization of this study. We start by presenting the debate around genetically engineered plants, and we move to explain how these plants might be able to help improve the current low level of productivity of the cotton sub-sector. Finally we present the expected outcomes from the study.

1.1 CONTEXT

Genetically modified (GM) plants are the center of a heated debate on the value of agricultural biotechnology (Pray and Ma, 2001). Large biotechnology companies such as Monsanto and the biotechnology industry organizations see agricultural biotechnology as a tool that can help alleviate serious problems of hunger and excessive pesticide use.

A recent International Fund for Agricultural Development (IFAD) report makes a strong case that an effective use of this technology can provide a way to lessen poverty in developing countries (Ismail et al., 2001). The main arguments put forward by advocates of biotechnology are mainly that higher yields, lower levels of labor and pesticide use for crops such as cotton, soybean, and corn varieties can be achieved if biotechnology is adopted (Gianessi and Carpenter, 1999; Fernandez-Cornejo et al., 1998). On the latter point, recent experiences from India, China and South Africa do not indicate price difference between conventional and Bt cotton.

Those opposed to the adoption of Bt cotton have expressed concerns including the fear of damage to the environment, the development of pest resistance to Bt, reduction of biodiversity, increased profit for multinational companies and impoverishment of small farmers in developing countries (Ismail et al., 2001 and Altieri, 2001, and Altieri and Rosset, 2001). For instance, Altieri (2001) argues that GM crops have limited value for the less developed world for the following reasons: 1) where adopted, they have resulted in small yield gains, 2) GM crops pose a threat to crop diversity in developing countries. and 3) GMOs were introduced by private companies that have intellectual property rights to the main components of the technology, which may limit farmers' access to them. Unfortunately, such institutions, intellectual property rights, do not exist in the majority of African countries, although Zilberman et al (2004) recognize that this limitation can be overcome. Zilberman et al. (2004) challenge the second point, demonstrating conceptually that GM crops can serve to maintain and even enhance crop biodiversity.

Most studies on biotechnology impact assessment have been concentrated in the U.S., though a few farm level ex-post evaluations have been reported for China, India, South Africa, Mexico, and Argentina (Pray and Ma, 2001, and Pocket No.5, 2003). Clearly, more empirical evidence is required to develop a compelling and balanced assessment of the potential impact of these crops on poor farmers.

In Africa, commercial production of Bt cotton and maize is only taking place in South Africa and is in its initial stage (Ismail et al., 2001). It is believed that if the small-scale, resource poor farmers in developing countries gain the same benefits as suggested by the studies carried out thus far, they should have higher incomes, less health risk and live in a less polluted environment. Thus, the purpose of this study is to analyze the ex-ante economic impacts from adopting Bt cotton in Mozambique. The findings from this study are also expected to lend insights relevant to other African countries with smallholder production of cotton that are likely to consider the adoption of Bt cotton in Sub-Saharan Africa.

1.2 OBJECTIVES

The main objective of the study is to evaluate the ex-ante economic impacts of adoption of Bt cotton in Mozambique. More specifically, the objectives of the study are:

1. to determine the financial benefits of Bt cotton to the farmer, and
2. to determine the economic benefits of Bt cotton to the economy as a whole.

To achieve these objectives, a financial analysis is conducted to assess the expected net benefit from the adoption of Bt cotton from the farmer's standpoint. An economic analysis is also performed to evaluate the benefits that are expected from the standpoint of the economy as whole. This analysis constitutes an innovation into evaluating benefits since no study on recent experiences on Bt cotton in developing countries has provided information on the economic vs. private financial benefits of these crops; most studies have limited their analysis to financial gross margin assessment. The economic analysis carried out in this study provides an indication as to whether there is a basis for public sector investment or whether this should be a purely private sector activity.

1.3 JUSTIFICATION OF THE STUDY

According to Pray and Ma (2001) and Ismail et al (2001), more developing countries should seriously consider allowing the cultivation of Bt cotton because it offers an effective way of controlling a serious cotton pest, reducing pesticide use, and improving the health of farm workers. So, governments should be opened to other biotechnological advances according to their environmental (especially the resistance to a bollworm) and safety standard, so that the farmers could be able to choose what best fits their farming system. The lack of key information to pursue such an informed policy and strategy is the major limiting factor in Mozambique. As the popularity of biotechnology spreads worldwide, Mozambique would be interested in analyzing the benefits of adopting some of the GM crops such as cotton and maize. Inevitably, this adoption will depend on social, economic and political factors. The present study will be limited to the economic factors.

This study focuses on cotton because: 1) it is currently cultivated in more than 200,000 ha involving about 300,000 smallholder households (Osorio and Tschirley, 2003), 2) it is ranked second in merchandise exports (after shrimps), representing 10.6% of total exports during 1996-1998, and 3) there is evidence that this crop has a potential for significantly increasing smallholder per capita incomes. Empirical evidence reveals that in some cotton growing areas cotton sales ranges from 52% to 84% of the total value of household income (MAP, 1991). This report also conclude that the use of fertilizer and herbicide led to increases in per capita incomes of more than 100% in Northern Mozambique, and insecticide constitutes the major cost in cotton production. Since Bt cotton is designed to reduce insecticide use, assessing its benefits in Mozambican conditions is crucial. This study generates two main research outcomes. First, through yield estimation the study will analyze the factors affecting the production of cotton in Mozambique and their productivity. Second, pursuing financial and economic analysis, the study provides net gains to farmers' equity and to the economy as a whole, and its policy implications. These outcomes constitute the first attempt to evaluate ex-ante economic benefits from adopting Bt cotton in Mozambique, and are expected to contribute as a baseline study for decision making related to Bt cotton.

1.4 ORGANIZATION OF THE STUDY

The present study is composed of seven chapters. The first focuses on introductory issues such as context of the study, objectives, and justification of the study. The second chapter summarizes the Mozambican cotton sub-sector, and discusses the strengths and weaknesses of recent studies on performance of Bt cotton in developing countries. Chapter three presents the data and theoretical framework used to accomplish the objectives of the study. Fourth, we discuss the results of econometric models used to predict conventional and Bt cotton yields. Chapter five gathers yield estimates from a previous chapter and proceeds with financial analysis from the farmers' standpoint, whereas chapter six uses the same yield estimates to estimate Bt cotton's social profitability. The last chapter draws conclusions, and synthesizes research and policy implications of the study as well as its limitations.

CHAPTER TWO

BACKGROUND

This chapter has two main objectives. First, it describes the structure and performance of cotton production in Mozambique. Second, it reports the performance of Bt cotton in countries that have adopted it and discusses some limitations of those studies to be addressed on the present study.

2.1 COTTON SUB-SECTOR IN MOZAMBIQUE

This section describes and discusses the structure and performance of cotton sub-sector in Mozambique. It identifies the participants and their roles in cotton production in the study zone. In the performance sub-section, the main cotton varieties and their performance in cotton fields are presented, and related to yields obtained in neighboring countries.

2.1.1 STRUCTURE

Cotton production in Mozambique has a somewhat a unique history. Prior to independence in 1975, all cotton in Mozambique was produced by Portuguese settlers who mainly employed forced labor from the native people. Traditionally large companies played a major role in promoting the crop in the country. These companies typically operated as monopsonies.

After independence, Mozambique started to seek well-defined paths for sustainable agricultural development. The role of cotton in agricultural development continued to generate intense debate (MAP, 1991). Based on the consensus that the future of Mozambican agriculture attributed to the smallholder farmer (70-80% of the population), cotton was viewed by decision makers as an important crop to enhance smallholder income.

Since the colonial times, cotton production in Mozambique was under concession system[1]. The current concession areas were established in the early 1990's as part of a government strategy to improve agricultural performance. Since then, they have constituted monopolies. These monopoly rights were granted to large Joint Venture Companies (JVC's) between government and foreign investment. Currently the most active JVC's in Nampula[2], the study area are Sociedade de Desenvolvimento de Algodao de Namialo (SODAN), Companhia Algodoeira de Nampula (CANAM), Sociedade Algodoeira de Namialo (SANAM), and three others called the New Operators (NO's).

SODAN was established in 1992 as a JVC owned by the Joao Ferreira dos Santos Group (JFS) with 51% of the property and the government with 49%. This company was established in Meconta, Namapa, Muecate, Memba, and Erati districts of Nampula and in district of Chiure in Cabo Delgado province (Mabota, 2002).

CANAM was established in 1995 also as a JVC but this time between Portuguese shareholders and government of 75% and 25%, respectively. This company was assigned to Mecuburi, Ribaue, Lalaua, and Murrupula disctricts in Nampula province.

SANAM was established in 2000 as a private company and the government has

[1] A concession system is a contractual agreement between the government and a private company which gives the private company allocation of a cotton production area for a given period. The company agrees to provide technical assistance to smallholders in that area and in return, it receives exclusive rights to market the cotton from that area.

[2] Nampula is the traditional "cotton belt" but more cotton production is now being carried out outside Nampula, e.g. in Cabo Delgado, Sofala, and Tete.

no vested interest in it. Recently, SANAM built the most sophisticated factory to process cotton seed in Monapo District, Nampula province. It was granted a concession area in 2003.

The NO's also consist of totally private companies which operate without concession rights. Currently, there are three operators actively engaged in cotton production in Meconta and Monapo districts of Nampula province. They are viewed as potential competitors[3] by the JVC's but their scale of operation is currently small enough that they do not cause major concerns. As we can see, the special feature in cotton sector in Mozambique is the existence of buying agencies or middlemen. Companies are directly responsible for input delivery and seedcotton buying from farmers, and they have to cover extensive areas with poor infrastructure (Osorio and Tschirley, 2003).

Most of the smallholder production is carried out under contract. The smallholders engaged in cotton production in Mozambique are divided in two distinct groups. Those who plant parcel of cotton along with other farmers in a adjacent block of land generally made available by cotton companies, and those who produce cotton on their own fields with average field size between 0.5ha to 1.0 ha. These are mainly dispersed fields (Osorio and Tschirley, 2003). The NO's also provide cash credit or in-kind credit to be used for consumption (e.g., maize flour and dry cassava) as well as seed and pesticide on credit. In some cases they provide mechanized land preparation on credit to help farmers prepare land on time.

A small number of farmers are organized in farmer associations. Some of these

[3] Furthermore, it offers higher prices than the JVC's with concessions. As result, in many cases farmers from concession areas deliver their cotton to NO's instead of JVC's which provide them with technical assistance. This is currently a source of major conflict between NO's and JVC's. Efforts to resolve this are still in progress.

associations are locally organized groups that were promoted by the cotton companies as a way to reduce their costs of extension services and input distribution. Other associations are as a result of formal association creation by Non-Governmental Organizations (NGOs) such as the Cooperative League of USA (CLUSA). These associations serve as a collective way to link farmers with JVC's and NO's with mutual benefits, such as reduced extension costs for assistance provider and better opportunity to improve farmers negotiating power collectively, instead of isolated farmers.

The direct role of the government in the cotton sub-sector is via *'Instituto de Algodao de Mocambique", (IAM)*. This institution performs several tasks including statistical management, classification of lint to be exported, and supervision of cotton production regulations established by the Ministry of Agriculture and Rural Development, MADER.

In Mozambique there are seven agrochemical companies in inputs market. Syngenta is a major company, responsible for 20% of the global pesticide market. This company was formed when the Swiss company Novartis and Swedish-British AstraZeneca merged their pesticide and seed interests. The remaining companies are distributors of chemicals namely: Agri-focus, Joao Ferreira dos Santos (JFS), Agroquimicos, Novagro, Quinagra and Neoquimica.

Three main cotton varieties are planted in Mozambique. ISA-205, recently adopted from East Africa developed by *"Centre International de Recherche Agronomique et Developpement"* (CIRAD), is a higher yielding variety (with potential yield of 2,010 Kg/ha) but more susceptible to pests. It requires about 50% more sprays and expenditure on protection than the local hairy varieties such as A637-24 and REMU-

40. These are more tolerant to sucking pests such as Jassids. With five sprays and effective overall management, ISA-205 could easily yield more than a ton; A637-24's and REMU-40 levels of productivity are about 600 kg/ha with three sprays (Walker, 2003 and Rodrigues, 2002).

Cotton in Mozambique has a chronic attack of sucking-insects from the very beginning of the planting of cotton and bollworms in the middle stage to the end of plant growth. The *B*ollworms[4] are the most abundant and damaging cotton pests in Mozambique. To control for bollworms, farmers apply *Pyrethroid* insecticides three to four times as a norm. Organophosphates are typically used in the first two applications to control *sucking*-insect[5] attacks.

Motivated by the current situation of cotton sub-sector performance in Mozambique, Boughton et al.(2002) analyzed cotton sub-sector policies and performance in Sub-Saharan Africa and, based on lessons from Mozambique and Zambia, suggested four main actions that could be taken to improve the cotton sub-sector in Mozambique: (1) in the presence of rural credit, input market failure, and weak contract enforcement, liberalization of the sub-sector appears to be a solution to deal with high concentration of ginning sector. This solution requires a full revision of the actual concession system and Osorio and Tschirley (2003) believe that struggles over this system are likely to continue at the center of policy and program debate in Mozambique's cotton sector for some time, (2) exploitation of the capacity of the private sector to deliver public services without

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[4] The "bollworm complex" in Mozambique consist of a number of species including *Heliocoverpa armigia* (American bollworm), *Diparopsis castanea* (Red bollworm), *Earias sp*. (Spiny bollworm), *Pectinophora gossypiella* (pink bollworm), and *Dyscercus sp*. (lint steiner). These pests can heavily affect the yield and lint quality of cotton.

[5] This group consist of *Empoasca fascialis* (jassids known as leafhoppers), *Aphis gossypii* (cotton aphids), *Memisia tabaci* (white fly), and *Thrips tabaci* (Thrips)

expecting them to do so free of charge, (3) investment in development and multiplication of new varieties, improvement of pest management, and updating of the grading system. At least three companies (LOMACO, AGRIMO, and CNA) have attracted some donor funding for research, but these efforts have not yet resulted in the release of new cotton varieties (Osorio and Tschirley, 2003), and (4) achievement of effective partnership between private and public sectors to build institutional policy environments that encourage technology renewal. Until now, IAM has been primarily occupied resolving conflicts over price setting and contract enforcement. This result that a regulatory institution like IAM find it difficult to articulate a policy approach that balances the needs of farmers and of ginning companies as well as to keep focused on challenge of increasing productivity and quality throughout the system. This deviation of the main role of IAM have resulted that cotton companies succeeded several years ago to reduce the export duty rate from 5% to 2.5%, and now lobby to a complete elimination (Osorio and Tschirley, 2003).

2.1.2 PERFORMANCE

MADER (2001) and Pitoro et al. (2002) assessed the performance of the cotton sub-sector and concluded that farm level productivity of cotton in Mozambique was the lowest compared to neighboring countries (e.g., Zimbabwe, Zambia, and Tanzania). These studies reported that during the cropping season 1999/2000, average yields ranged between 460 Kg/ha and 750 Kg/ha in the most productive agro-ecological zone, compared to 800 Kg/ha and 900Kg/ha among small farmers in Zimbabwe. In addition, the International Cotton Advisory Committee (ICAC, 2000) and (Osorio and Tschirley,

2003) reported that the lint yield per hectare in Mozambique is the lowest in Sub-Saharan Africa. Osorio and Tschirley (2003) report that the ginning outturn ratio (GOR), defined as the proportion of cotton fiber obtained from seed cotton, is approximately 34%. This GOR is lower compared to 38% in Zambia, 40% in Zimbabwe, and as high as 42% in West Africa. Ceteris paribus, a 40% GOR in Mozambique would reduce the cost of production of lint by nearly 20%, with major implications for ginner and potentially, farmer profitability (Osorio and Tschirley, 2003) (See appendix H).

The combination of low productivity of cotton and the long-term downward trend of world prices (See the appendix A) results in lower profitability for small-scale farmers, who constitute 70-80% of the population in Mozambique. This has led Mozambique to seek alternative ways of increasing productivity in the cotton sub-sector. Bt cotton is one option that is currently being considered.

2.1.3 BIOSAFETY IN MOZAMBIQUE

The biotechnology research and legislation in Mozambique is still in its infancy stage. Mozambique after ratifying the Cartagena Protocol on Biosafety (CPB) in 2001, established the National Biosafety Working Group (NBWG), to co-ordinate the biosafety activities in Mozambique (Munisse, 2002). This is an inter-institutional and multi-disciplinary team with the task of setting up proper systems for regulatory and administrative issues, decision making process (risk assessment and management), and mechanism for public participation. But, these activities are facing several constraints such as inadequate financial resources, lack of personnel with sufficient competence, and poor infrastructure and equipment. All these limitations result that since the group was formed in 2001, the only output available from this is a legislation proposal that establish conditions at which Bt maize can be imported.

Monsanto would be interested in expanding its activities to Mozambique in other to spread fixed costs, and to clear the way for potential future GM maize seed sales, from the companies' long-term perspective, but the slow regulatory process is holding back this intention from the GM Company. At present, the production and commercialization of GM seeds are forbidden by law in Mozambique.

2.2 Bt COTTON

Bollgard® cotton (Bt) was first developed by Monsanto in the late 1980s by transforming and incorporating the Cry1Ac gene from a soil microorganism, *bacillus thuriniensis* var. *kurstaki* (Edge, J et al., 2001). The Bt gene causes the cotton plant to produce a protein that is toxic to certain species of bollworms, significantly reducing chemical pest control costs in infested areas (Falck-Zepeda et al., 2000).

The original goal was to provide farmers with more environmentally friendly and efficacious insect control at reduced costs (Edge, J et al., 2001). According to this author, the targets of Bollgard cotton are major caterpillar pests, including tobacco budworms (*Heliots virescens* Fabricius), bollworm (*Helicoverpa zea* Boddie), and pink bollworms (*Pectinophora gossypiella* Saunders), which are some of the most damaging insect pests worldwide. These pests together accounted for an estimated $391 million in cotton losses and treatment expenses in the U.S. in 1995, and $699 million in 1996 (Edge et al., 2001).

After receiving regulatory approvals, Bt cotton was launched commercially in the United of States in 1996, and subsequently in Canada, Argentina, Australia, China, Mexico, India, and South Africa.

The number of different GM technologies and their applications in the world are increasing. Statistics show that the area planted to Bt cotton worldwide increased by 11% (to 4.3 million hectares) between 1999 and 2001 (Cabanilla et al., 2003). According to a recent evaluation by Cotton International (2003), the area under Bt cotton is expected to reach half of worldwide cotton production by 2005, and two-thirds by 2008.

The majority of commercial GM releases, however, have been in the U.S., Canada, and Argentina. These three countries account for about 99% of the GM crop area of the World (Ismail et al., 2001).

So far, Bt cotton has demonstrated remarkable control of some bollworm pests, particularly the tobacco budworm and pink bollworm. But, since its commercial release, it has typically required supplementary insecticide control for these two pests (Stewart, S. et al., 2001). Cotton Bollworms have shown themselves more tolerant than tobacco bollworm to the *Cry1Ac* dendotoxin expressed in currently available Bt cultivars. Other common lepidopteran[6] pests such as fall armyworms, beet armyworms and soybean loopers are even more tolerant than bollworms to *Cry1Ac*. This is a clear indication that Bt cotton is not 100% effective in controlling these pests as claimed by Bt cotton advocates.

In the last few years, though there has been an increase in the number of hectares being planted to GM crops in developing countries (Pray and Ma, 2001), very few studies on the farm-level impact of biotechnology have been published about countries outside North America. The question that arises is whether small-farmers in developing

[6] A class of bollworms.

countries (Africa, Asia, and Latin America) will enjoy the same benefits.

Two positions are taken in this debate. On the one hand, biotechnology companies often claim that genetically modified organisms (GMO's) are essential scientific breakthroughs needed to feed the world, protect the environment, and reduce poverty in developing countries. On the other hand, some researchers (e.g., Altieri and Rosset, 2001), disagree and argue that most innovations in agricultural biotechnology have been more profit-driven than need-driven. They also argue that the environmental performance of transgenic crops needs more tests, not only on the direct effects on target insects or weeds but also on the indirect effects on other plants and on organism adaptation. They believe that the target insects are likely to develop resistance against the toxin spread by GMOs and that this may have unforeseen consequences. Below, we briefly discuss the available studies that focus on Bt cotton adoption by small-farmers in developing countries.

2.2.1 IMPACT OF Bt COTTON IN DEVELOPING AND DEVELOPED COUNTRIES

This section provides a literature review on Bt cotton performance around the world and identifies gaps in information that this study expect to complement. Table 2-1 summarizes key parameters of recent experiences in countries that adopted Bt cotton.

Table 2-1 Yield and Cost advantages of Bt over non-Bt cotton in selected countries.

Country/Year	Average Incremental Net Returns of Bt cotton		Yield Advantage				Cost Advantage			
					Difference		Number of sprays		Reduction in	
	($/ha)	% gain over Non-Bt	Bt Yield	Non-Bt Yield	Kg/ha	%	Non-Bt	Bt	Nr. Of sprays	Cost ($/ha)
India										
1998-1999	na	na	1501	802	na	80	4	0	4	45
2000-2001	na	na	856	619	237	38	4	1	3	42
China (2001)	470	na	3,371	3,186	185	6	28	14	13	626
West Africa[7]	33	48	946	860	86	10	na	na	3	17
South Africa										
1998/9, 2000										
Small farmers	43	44	576	395	181	46	na	na	5.8	23.6
Large Non-irrigated	23	11	947	832	115	14	na	na	na	11
Large irrigated	174	na	4,046	3,413	633	19	na	na	na	28
Indonesia (2001)	na	na	2,370	1,820	550	30	10	2	9	na
Mexico										
1997	na	na	1,580	1,540	40	2	5	3	2	154
1998	335	na	1,710	1,420	290	15	5	2	3	139
Argentina (1999-2001)	65	na	2,110	1,567	543	35	5	3	2	28
Philippines	na	15-86	Na	na	Na	60	na	na	na	na
Australia 98/00	2-28	na	Na	na	-40	-3	11.2	7.7	4.7	80
United States[8]	85	na	2,778	2,359	419	20	na	na	2.2	39.5

Source: Cabanilla et al. (2003), Traxler (2004), and ISAA (2001), Bennet et al. (2001), and Gouse et al. (2002)

n.a. – information not available

[7] At 30% yield gain the Bt net incremental returns were $89/ha (129% gain) and at 45% yield gain the net incremental returns of Bt cotton were $132/ha (191% gain). This is an ex-ante study.
[8] Average for two Bt (NuCOTN33B and NuCOTN35B) and two non-Bt varieties (DP5415 and DP5690).

MEXICO

The cotton area in Mexico was reduced significantly from 200,000 ha in the 1990s to about 80,000 ha in 2000 because of heavy insect infestation. In the Comarca Lagunera region in north-central Mexico, infestation of pink bollworm, tobacco budworm, and cotton bollworm in cotton fields reached critical levels. After the introduction of Bt cotton, significant reduction in insect pests was observed. Bt cotton provided better control of pink bollworm and budworm, and partial control of other major insect pests (Traxler et al., 2001). The average yields in 1997 were 1,580 tons/ha for Bt cotton and 1,540 tons/ha for non-Bt (2.6% yield gain) and in 1998 the Bt cotton yield rose to 1,710 tons/ha whereas the non-Bt decreased to 1,420 tons/ha, equivalent to 20.4% (ISAAA, 2001).

Compared to conventional cotton varieties, the use of Bt cotton resulted in substantial reduction in pesticide cost by more than $100/ha, and higher yields resulting in net profit of Bt cotton amounting to nearly $335/ha to farmers.

SOUTH AFRICA

Cotton is grown on about 100,000 ha in South Africa and suffers significant damage from bollworms (Ismail et al., 2001). In the Makathani Flats, small-scale farmers planted cotton on average between 1.5 and 3.0 ha with some planting up to 10 ha (Pocket No. 5, 2003). Only 12% of the 4,530 farmers started growing Bt cotton commercially in the 1998/99 crop season on 900 ha and in 1999/2000 on 2,155 ha (Ismail et al., 2001).

Since then, an increasing number of farmers are choosing to grow Bt cotton due

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Yield was converted from lint to raw cotton in Kg per hectare using 0.42 as conversion factor.

to multiple advantages of increased productivity and decreased use of pesticides (Ismail et al., 2001). In 98/99, 57% of those farmers in Makathani Flats with greater area than 10ha had adopted Bt cotton compared to 7% of those with less than 2.5ha. On average, non-adopters had a cotton area of about 4.0 ha, while the adopters had an average cotton area of 6.0 to 8.0 ha. In the 1999/2000 season, 65% of the farmers grew Bt varieties. Ismail et al. (2001) attributes this increase in the number of farmers growing Bt cotton to reduction in the number of insecticide applications, reduction in the cost of production, increased health benefits to less pesticide exposure, (although no value is attached to this statement), and time saved from having pesticide at a nearby outlet, located 20 Km away from the plains of Makhatini.

During the 1998/99 crop season, the average yield for adopters was 576 Kg/ha and for the non-adopters it was 395 kg/ha. In the 1999/00 cropping season, however, the average yield fell to 409 Kg/ha for adopters and 366 Kg/ha for non-adopters. The lower yields in this season are attributed to excessive rainfall (50% above the average), causing flooding and delaying planting of cotton, as opposed to the lower than average rain at the beginning of the 1998/99 season, which had favored the cotton crop. Observe that yields per hectare decreased with larger farm size (as expected, given more intensive cultivation on small areas) and the smaller farmers seem to have gained most yield advantage from Bt cotton.

Ismail et al. (2001) found that on average, the reduction in pesticide costs for adopters rose from 13% in 98/99 to 38% in 99/00, resulting in an increase in gross margins per hectare (without considering savings in labor) of 11% (R80) in 98/99 and 77% (R276) in 99/00 for adopters. Note that producers with the largest areas of cotton have lower yields and gross margins for Bt varieties than the conventional one.

A recent paper presented at the 6th International Conference on Global Economic Analysis, estimates that with 25% adoption rate of the Bt cotton, the cost of pesticides will decrease by 25%, labor savings will be 8%, seed cost will increase by 110%, and yield will increase by 18% in the Southern Africa Region (Elbehri and MacDonald, 2003). Regarding pesticide use, Bennett et al. (2003) provide findings which support Elbehri and MacDonald (2003) by demonstrating empirically that an additional litre of insecticide to control bollworm would increase cotton output by 46.5 Kg/ha for non-adopters and 94.8 Kg/ha for Bt adopters. Yet the study in South Africa concludes that yield increases are considered less important than pest control cost savings.

The study in Makhathini Flats provides a first impression of Bt cotton performance at the farm level in Africa, but a lot still to be said about it:

- A reasonable number of farmers, 1/4 of the sample, were using more chemicals than was recommended and 3% were using less. This can indicate two situations. First, those farmers are not comfortable with the new technology despite participating in training sessions. Second, under high pest pressure, the amount of pesticide to be used was higher than expected because Bt cotton does not control sucking pests such as Jassids and Aphids, which are often the most important pests in subtropical regions. Despite higher than expected pesticide application, this study did not quantify the health cost related to this fact, although information about human health risk in Makhathini Flats was available from Rother (2000) cited by the author.
- All input provision and cotton marketing in the Flats are concentrated in one

economic agent (**Vunisa**), resulting in a monopoly situation. As a result, seed cotton prices paid to farmers may not reflect the opportunity cost. To handle this problem, economic analysis would be necessary so that estimates of benefits from the standpoint of the economy as a whole can be obtained.

- This study does not discuss how and at what level pest resistance to Bt cotton are addressed,

All these observations suggest that in similar case studies, the expected costs and benefits should be built in the analysis to better assess the profitability of Bt cotton. This study has a merit to shed light on Bt cotton adoption in Africa but the author did not discuss any policy implications for South Africa in particular or to Africa and other developing countries in general.

WEST AFRICA

A major public policy issue to tackle in West Africa is whether to adopt or not, and how to introduce Bt cotton in this region. Cabanilla and Sanders (2003), using a linear programming model, showed significant benefits and more stable income at the farm level. Depending on the adoption rates and yield advantage of Bt cotton, they found fairly significant aggregate benefits. Their estimates indicate that the benefits could range from $7 million to $67 million in Mali ($/ha); $4 million to $41 million in Burkina Faso; $5 million to $52 million in Benin; $4 million to $ 7 million in Cote I'voire; and, $1 million to $7 million in Senegal. The reduction in insecticide use was found as an added environmental benefit. This paper ends up recommending that the most practical approach to introduce Bt cotton in West Africa is by allowing the developer of the variety that is currently in market, to locally adapt the technology possibly in collaboration with a local entity and later market it for profit ("*Gene for rent*" mechanism). If the cost to incorporate the gene to the local varieties is higher than to produce generic Bt cotton varieties, then the partnership between local and GM entity can be compromised if we consider that GM entities are more profit driven than need driven companies as Altieri and Rosset (2001) noted. This is not discussed at all in the paper.

This study starts by fixing the yield of conventional cotton at 860 Kg/ha and assesses the benefits of yield gains of 10%, 30%, and 45%, combined with reduction in average sprays of 3.5 based on experiences in developing countries. It is fine to hypothesize yield gain in an ex-ante study like this but, I feel that higher yield gains are hard to get and the most likely yield gain by Bt cotton seems to be of 11%. Cabanilla and Sanders (2003) cite a study indicating that even if the conventional sprays are applied, farmers in West Africa incur average yield loss of 23% depending upon the degree of insect incidence. When compared to reported potential loss of 34% if no insecticide application is made (Cabanilla and Sanders, 2003), this implies that only 11% of the loss from insects is saved by chemical sprays. In terms of research question, this study is not different from ours since both tackle the same problem.

The methodological approach followed by Cabanilla and Sanders (2003) differs from what we use in the sense that while they use the regional data with linear programming, we use an estimated yield from an econometric model and from there we estimated the incremental net income. Then, we estimated the yield gain that would allow 100% returns to investment in Bt cotton using a sensitivity analysis, having in mind the partial budget approach.

CHINA

At least three million small farmers in China adopted Bt cotton, growing a total of at least 0.5 million ha in 2000, resulting in multiple benefits. The smaller and lower income farmers gained almost twice as much income per unit of land from adopting Bt cotton as larger farmers and those with higher incomes. This study reports an average yield gain of 10% over Non-Bt cotton. Moreover, over 80% of the 1999 benefits from adopting Bt cotton varieties went to farmers. The remaining percent went to the seed companies (Pray and Ma, 2001).

In terms of insecticide use and related poisonings, the Bt adopters reduced insecticide use by about 15,000 tons or 49 Kg/ha (an average 13 sprays per hectare were saved as indicated in table 2-1) (Huang et al., 2002), although no value is attached to this. Farmers and farm workers were relatively less exposed by insecticide, and preliminary evidence indicates reduced pesticide poisoning as well.

There are also indications of an enhancement of biodiversity by adopting Bt cotton, confirmed by the local government authorities in Hibei province in 1997, which found 31 insect species in Bt cotton fields of which 23 were beneficial while non-Bt fields contained only 14 species of which five were beneficial (Pray and Ma, 2001). This is due to the fact that Bt cotton allow a reduced spectrum of insecticide application, meaning beneficiary insects are less affected.

This study contributes to the biotechnology discussion in developing countries by providing evidence on the farm level impact of Bt cotton, attempting to measure the economic, income distribution, environmental and health impacts.

Although the approach used in this study is different from that used by Ismail et al.(2001) in the Makhathini Flats, the conclusions are consistent in the sense that both found that a greater share of the benefits are captured by small farmers. Again, this study concludes that pest control cost savings are more important than yield gain. Some limitations can be observed in this study, such as:

- The study does not quantify economic benefits. This would improve the analysis because as mentioned by the author, China is liberalizing the marketing of cotton to let different enterprises trade cotton, which implies that at the moment the market is still not perfectly competitive, suggesting that economic and financial results could differ.
- The authors identified environmental benefits but did not quantify and include them in the benefits of Bt cotton.
- The authors ignored the resistance problem suggesting that it was not an important issue because farmers in China plant Bt cotton in small, scattered plots which allow alternative hosts for bollworms (corn and vegetable surrounding the Bt cotton plots). This is an optimistic point of view, but the reality is that as Bt cotton cultivation spreads rapidly, all cotton regions will be populated by Bt varieties and bollworm resistance may quickly increase, reducing the benefits that are mentioned here. So, to be more conservative, including these costs would improve the realism of the situation.

ARGENTINA

In Argentina, the adoption of Bt cotton revealed a similar impact on the local farmers to those observed in India and South Africa. For example, in the 1999/2000 growing season, there was an additional benefit over conventional cotton of $65.05/ha, due to a higher yield, better lint quality, and cost savings $27.55/ha from two fewer insecticide applications (Elena, 2000). Qaim and deJanvry (2002) reported yield gain of 35% over Non-Bt cotton.

UNITED STATES

Benefits from Bt cotton include an average increase of 20% in yield (Edge et al., 2001), a reduction of 2.2 insecticide sprays that translated to approximately 850 tons less insecticide used nationally in 2001, with significant positive implications for the environment (ISAA, 2003). Overall financial benefits are $50 to $85/ha, of which farmers capture the bulk of those benefits. The U.S. farmers, captured 59% of total benefits compared with 21% for the technology developers (Monsanto), followed by U.S. consumers (9%), the rest of the world (6%), and the germplasm supplier, Delta and Pine Land Company (5%) (Falck-Zepeda et al., 2000). Contrary to what was observed in South Africa, the main reason for adoption in the U.S. is increased yield (54% of sample) followed by cost savings (42% of the sample) (Klotz-Ingram et al., 1999).

INDONESIA

According to ISAA (2001), Bt cotton in 2001 was the first GM crop to be commercialized in Indonesia. Preliminary information confirms that Bt cotton provides effective control of the lepidopteran insect pests that cause significant economic loss (ISAAA, 2001).

Bt cotton has increased yield by about 30% and requires only 0 to 3 applications of insecticide compared with 9 to 12 for non-Bt varieties, and has increased farmers' income due to higher yields and saving on insecticides. Bt cotton in Indonesia has increased yield by 0.55 ton/ha in 2001(Cabannila et al., 2003).

AUSTRALIA

ICAC (2001) reports that in 2001/02 Australia grew 404,000 hectares of cotton, with the highest lint yield in the world of 1,658 kg/ha, for a total production of 670,000 tons; it consumed only 15,000 tons and exported 665,000 tons. Cotton production is highly mechanized and intensively managed with irrigation and inputs including fertilizer and insecticide. The deployment and impact of transgenic Bt cottons in Australia has recently been reviewed comprehensively.

The two principal insect pests are Australian budworm (*Helicoverpa punctigera*), and the bollworm, *H. armigera*. Bollworm has evolved a high degree of resistance to the various classes of insecticides which are employed in an integrated pest management (IPM) strategy. Other insect pests include *thrips, mirids, aphids, and spider mites*. Pest management accounts for 35 to 40% of operational costs and can range from $220/ha to $550/ha (ISAA, 2001).

Bt cotton was field tested and commercially released in 1996/97. The area of Bt cotton increased from 30,000 hectares in 1996/97 to 165,000 ha in regulated annual step increases of 5% up to a maximum of 30% which was reached in 2000/01, and held at that same level in 2001/02. Bt cotton was introduced with a license fee of $135/ha which was later reduced to $85/ha. Experience with Bt cotton in Australia showed that whereas Bt provides good control of *Helicoverpa* early in the season, its effectiveness decreases in late season requiring supplementary sprays; the performance of Bt cotton has also been found to vary by location.

A four year yield performance assessment indicates that there is no significant yield effect from using Bt cotton in Australia: the average yield of Bt cotton over the four year period was 1,560, and 1,600 Kg/ha for non-Bt cotton (ISAA, 2001). There has, however, been a 40% decrease in the number of sprays for Bt cotton compared with non-Bt cotton (6.5 compared to 11.2). This reduction appears to have high priority in Australia since it is a major contributor to a safer environment and also provides a foundation on which a more sustainable IPM strategy can be built. In the first two years, insect control costs, which included the technology fee, were actually higher for Bt cotton. However, in 1998/99 and 1999/00 the net benefit was in favor of Bt cotton at $50/ha and $40/ha; respectively. This was translated to a break-even or modest net incremental benefits ranging from $3/ha in 1998/99 to $28/ha in 1999/00. Despite modest returns from Bt cotton, farmers have purchased the full quota of seed available each year because they are convinced of its environmental benefits and that it provides a foundation for a sustainable IPM strategy.

The advantages of higher densities of beneficial insects and the reduced negative effects of broad spectrum insecticides are assigned a high "economic value" in Australia. Again, this is similar to what South African farmers consider the most valuable benefit from Bt cotton.

INDIA

Farm trials in India indicate an increase in yield and a significant reduction in pesticide use from Bt cotton. Based on experimental data, Qaim and Zilberman (2003) found that Bt cotton varieties produced by Monsanto Company and Mahyco are resistant to the three species of bollworms that plague crops in India, considered in previous studies as responsible for 50% to 60% of crop damages. This study found that average yields for Bt cotton hybrid (1,501 Kg/ha) were a remarkable 80% greater than their non-Bt counterparts (same hybrids but without Bt genes, with average yield of 833 Kg/ha), and 87% greater than the local cotton hybrid (which had average yield of 802 Kg/ha). According to Qaim and Zilberman (2003), the amount of insecticide applied on Bt plots was reduced by almost 70%.

While the studies in Mexico, South Africa, and Chin found reduction in production cost to be the most important factor in adoption of Bt cotton, the India study (similarly to that of U.S.) concluded that the yield effect of Bt cotton is the most important factor in adoption decisions, followed by savings in production costs.

CONCLUSIONS

From this literature review, one can see that Bt cotton performance can vary from region to region or even in the same region. One consistent finding is the savings in production costs, especially that accruing from pest control agents. Yield effect shows no conclusive pattern. For instance, the North American Bt varieties commercialized by Monsanto in China are considered ill-suited for handpicking, humid Chinese summers. In addition, the Bt gene cannot protect the crop against diseases or non-target pests, which can wipe out profit margins (Glover, 2003).

Moreover, Pemsl et al., (2004) analyzing the studies in detail found a number of factors that could have predetermined the positive results. In China, for instance, the sample size for adopters exceeded non-adopters on average by factor of four. This study found that non-adopters had negative net returns from cotton production. Another factor is that in general impact studies of Bt cotton assume that the alternative to planting Bt crops is routine pesticide application, thus leaving aside other possible pest management methods, as practiced in integrated pest management (IPM). Therefore, the reduction in pesticide use due to Bt adoption could have been overestimated by such studies. Furthermore, measurement of farmer's pesticide use in developing countries is prone to numerous sources of error (many brands of pesticide and the practice of mixing several pesticides). The uncertainty in data due to possible climate and ecosystem variability is another source of error on benefit estimates.

Although all these difficulties, Qaim and Zilberman (2003) based on recent cross-country experience hypothesize that the yield effects of Bt crops will be high in two regions of the world: South Asia and Africa because these regions suffer from high pest pressure, low availability of chemicals, and low adoption of chemicals. In this context, one must ask w*hat yield effect can be expected in areas of Sub-Saharan Africa, such as Mozambique, where there is high pressure of sucking pests such as Jassids and Aphids that Bt cotton does not control effectively?* We turn to these issues in the next chapter.

CHAPTER THREE

THEORETICAL FRAMEWORK AND DATA SOURCES

This chapter presents the framework used to accomplish the objectives mentioned in Chapter One. We discuss data availability and its implication for model specification to answer the question posed at the end of Chapter Two. We start by documenting the Bt cotton yield effect based on the experiences discussed in chapter two, and turn to the expected Bt yield in Mozambique based on available information.

3.1 APPROACHES

We start by suggesting that a rational farmer will adopt Bt cotton if he/she can earn a 100% return on his/her investment. Rough calculations suggest that this will require a yield increase of 10%-15%.[9] Our analytical challenge is to determine whether such yield gains can be expected in Mozambique.

The literature reviewed so far indicates that Bt cotton yield gains range from a minimum of 10% up to a maximum of 46%. If we consider that the South African experience may be similar to Mozambique, Shankar and Thirtle (2003) have demonstrated that at average rate of pesticide use of 2.2 litres/ha, non-Bt cotton attains 36% of potential yield, whereas Bt cotton at rate of 1.1 litre/ha attains 55% of potential

[9] We will present more detailed calculations later in the thesis. The farmer will pay about $17/ha for seed, and will save about $9 on pesticides and $4 on hired labor, resulting in a net additional cost (investment) of $4. At the 2003 farm gate price of $0.11/kg, the farmer will need 36 kg of additional production to recover this investment, and an additional 36 kg (72 kg/ha total) to earn a 100% return. This is 10-15% of mean yields. In this approach, cost savings are considered as part of the benefits.

output. This implies a 53% yield increase (19/36=0.53) from Bt cotton in addition to 1.1 litres/ha savings in pesticide.

In principle, several methodological approaches can be used to address our research question as described below according to their categories, including analytical methods, data needs, and yield estimation. For one of these categories, we present and discuss the potential approaches.

(a) Analytical methods: A potential framework to address our research question is a partial budget. The partial budget is a balance which measures the positive and negative effects of a change in the business. The left side of the balance shows the positive effects on net income including additional income and reduced costs. To counterbalance this positive effect, the right side of the balance includes reduced income and additional costs or the negative effects of the proposed change. The net income effect of the proposed change is calculated by comparing the sum of additional income and reduced costs with the sum of reduced income and additional costs. The down side of this approach is that it does not give the net profit of the farm production system at *status quo* to assess whether it is profitable or not at the beginning without incorporating changes. To address this issue, the enterprise budget approach is suitable. Since our research question is whether or not to grow Bt cotton, with the implicit assumption that for farmers grow conventional cotton if it is viable (likely profitable), then comparing a viable existent technology to a new technology makes the partial budget approach suitable. Partial budget analysis need information about Bt cotton yield gain that need to be measured. Below we discuss methods that would allow us to obtain this information.

(b) Data needs: To gather information on potential Bt cotton yield, three potential methods are considered. First, if we had a simple empirical relationship from ex-post assessments in another country that relates the number of pesticide applications and Bt cotton yield, we could use a "benefit transfer" approach to apply this information in Mozambique. But transferring such results to a specific case of Mozambique would not be easy because transferring data from one study area to another requires can imply to imposing strong restrictions or alternatively requires a set of complex adjustments.

Second, we could use experimental data adjusted to farmers' conditions in order to predict the shift factor linked to the technology change. However, such experimental data are not available in Mozambique. Although these approaches both involve data collection, they are not directly comparable because while the second approach uses raw data that can be used in statistical estimation, the first approach consists of transferring processed secondary data that can be adjusted and directly used in the partial budgets.

The third alternative is to use available data on non-Bt cotton production to predict the expected yield of Bt cotton after estimating the yield effect of insects that could be controlled by the Bt gene. The potential yield estimation approaches are described next.

(c) Empirical estimation: As discussed in section 3.5 of this study, the damage function and standard production function are candidates for empirical estimation. The damage function approach is one a candidate to estimate the productivity of pesticides, but data limitations, especially on the level of pest pressure and amount of pesticide used (active ingredient), force us to discard this approach. Instead, the standard production function was used to estimate the productivity of pesticide, hence the conventional and Bt cotton yields.

3.2 PARTIAL BUDGET

As we stated earlier, the main question of our study is whether farmers will be better or worse off growing Bt cotton. This is a typical farm management question that reflects changes proposed by a manager on a farm. Since all other components of the farm budget that are not affected by the proposed change will remain constant, a complete farm budget is not needed to determine the profitability of these specific changes in the operation of the farm. In this case, a farm manager analyzes only those costs and incomes that change with a proposed business adjustment.

This exercise can be accomplished by using the partial budget, which means that only the relevant costs and incomes are included in the analysis (Dalsted and Gutierrez, 1992). Our partial budget will contain benefits and costs that are constituted by four categories as described by Dalsted and Gutierrez (1992): additional income, reduced costs, reduced income and additional costs.

Benefits: Since Bt cotton will replace conventional cotton, the Bt cotton yield gain contributes to additional income. The yield gain will be evaluated at the official farm gate cottonseed price of $0.11 per Kg in the cropping season 2002/03. Since Bt cotton reduces pesticide costs, this constitutes a benefit. The reduced pesticide costs will be evaluated by assessing the cost of each saved insecticide application by using Bt cotton seed. Another benefit from adopting Bt cotton is the reduction of labor used in insecticide application. For this analysis, labor was evaluated at the actual wage rate, $0.30 per day. The additional income and reduced costs have positive effect on net income and their sum will indicate the total benefits.

Costs: The production of Bt cotton requires the use of refuge strategy and purchased Bt seed cotton. The refuge strategy cost is evaluated as the yield difference of the unsprayed cotton lost on 5% of the cotton plot. The Bt seed cotton financial and economic prices used in this study were drawn from Ismail et al. (2001) ($16.6 per ha equivalent to 202 Rands/ha in 1998/99). Since no reduced income factor is foreseen, the total cost will be constituted only by total additional costs.

Net income: Indicates the effect of the proposed change on net income by comparing the sum of additional income and reduced costs with the sum of reduced income and additional costs. If the additional income and reduced costs (benefits) are greater than the reduced income and additional costs (costs), then production of Bt cotton will increase net income to farmer compared to the production of conventional cotton. This analysis will be performed in financial and economic terms. Gittinger (1982) and Belli et al. (2001) argue that financial and economic costs/benefits differ only when there is a market distortion caused either by government policy or other causes. The financial costs/ benefits are those financially observable by any participants in the production process, whereas the economic benefits are not directly observable, and appear as a way to correct for market distortions.

So far we have discussed how we will assess whether or not to grow Bt cotton. But to make such decision, an estimate of Bt yield is needed. The next section discusses the framework used to generate these estimates.

3.3 YIELD ESTIMATION AND ASSUMPTIONS

The effect of Bt cotton was modeled as the difference between mean predicted yield of Bt and mean yield of conventional cotton under actual farmer conditions (Landis, 2003). Bt yield was modeled from the same data set assuming the recommended practice of six insecticide applications against bollworms. In economic terms, this means that when comparing conventional cotton (as actually practiced with an average of three insecticide applications for bollworms) to Bt cotton, we considered pest control cost for conventional and no such cost for Bt cotton. Because Bt varieties may not be as resistant to Jassids as the conventional cotton varieties currently in use, we discount this predicted Bt yield by the equivalent of one insecticide application to control for sucking-insects. Failure to discount for susceptibility of Bt cotton to Jassids would imply: 1) overestimation of the Bt yield effect, or alternatively, 2) that the Bt gene was introduced into the local hairy varieties, which is not likely to happen in the short- or medium-run.

Note that the Bt yield we estimate in this manner is likely to be the lower bound of the Bt cotton yield effect. The continual presence of toxin in Bt plants implies continual effective control of the most serious aspects of the bollworm complex. Replicating this control in farmer fields with conventional cotton would require that all farmers be well trained in pest scouting and IPM practices, that they have the time to apply this knowledge in a timely manner, and that they have all the chemicals they need at the time they need them. In practice, the data set we use to develop our estimates (see below) was generated by farmers with little if any training in scouting, and who operated under constraints on their time and on pesticide availability that lead to sometimes very imperfect timing of the applications that were made. It follows that the marginal productivity of a pesticide application from this data set will be lower than under optimal practices, and that we will therefore be reaching only a lower bound of the Bt effect. According to Silvie et al. (2001), accurate timing of spraying results in a 100-200Kg/ha, an 13% to 25% cotton yield increase in West Africa.

All other input levels are fixed at their sample mean. Categorical variables were fixed at their most common level. The calculations were made for the major cotton producing districts of Monapo and Meconta in Nampula province and Montepuez district in Cabo Delgado province. The yield effect of Bt cotton was analyzed in two input use levels (scenarios) described below.

Low-input Use: The cotton companies had two technology practices which were captured in the data set, high and low input use level. During the time the data was collected some companies were providing insecticide, fertilizer, herbicide and tractor for land preparation in a package to some farmers. These inputs were delivered to farmers of Montepuez District in the province of Cabo Delgado (Strasberg, 1997). In Nampula, the cotton companies did not provide more than seed and insecticide to farmers. Thus, farmers were classified as using high-input package if they received herbicide and fertilizer besides insecticide, and low-input otherwise. Fertilizer and herbicide use were obtained from the survey data.

The low-input scenario assesses the combined effect of planting date and insecticide application to control bollworms. The idea of including the planting date is based on the concerns about the current poor crop management practices expressed by cotton researchers in Mozambique, especially late planting. On average, farmers in

Mozambique perform crop management practices such as land preparation, planting, weeding and spraying, with 30 days of delay, which tends to reduce yield (Norberto, 2003). The reasonable way we found to include those concerns in the analyses is via planting date.

Under low-input scenario, in order to estimate yields using Cobb-Douglas (log-linear model), a constant of one was added to inputs with zero use level (fertilizer and herbicide).

High-input Use[10]: This scenario compares yields of conventional and Bt cotton produced under high-input use production systems (where herbicide and fertilizer are also used beside pesticides), varying seeding week and insecticide applications.

3.4 DATA SOURCES

The primary source of data for the present study is Strasberg (1997). The Strasberg data provide very detailed coverage on cost of cotton production in the Northern region of Mozambique, which we considered a good basis for evaluating technological change in a cost reduction framework and measure of productivity gain. This survey was conceptualized to collect data among the major stakeholders in the food and cotton belt (Strasberg, 1997). The central piece of the research was a survey of rural households, using a stratified random cluster sample according to whether and how the family grows cotton. Similarly, understanding the strategy and operating procedures of

[10] High-input dispersed farmers received each: No tractor use but 50% of them received 89 Kg/ha of fertilizer (12-24-12), 3.5 liters/ha of herbicide and a variable number of insecticide applications. But, fertilizer and herbicide had variation despite standard package being delivered to cotton growers.

JVCs with respect to smallholder within their respective concession areas was emphasized. This survey consisted of five rounds of interviews to cotton; maize and manioc farmers between 1994 and 1996, among the different aspects contained in the data set, there are information on farm budget, including detailed information on input use. Farmers were asked to provide information on number of insecticide applications, herbicide, and fertilizer and their application timing, planting date and rainfall, level of pest attacks that they have observed during the cropping season.

The second source of information consists of a survey of more than 900 cotton growers in 2000 in Nampula province designed to collect information on cotton productivity. To complement this information, other sources of information were used (e.g., National Agricultural survey 2002). Mabota (2002) and Maumbe and Swinton (2003) provide perceptions of health risks from pesticide spraying and farmer beliefs regarding the advantages of protective clothing. Information from these two sources was sufficient to obtain rough lower-bound estimates of the health-related costs of pesticide spraying.

Despite the richness of data on cotton production in Mozambique, none of these provided very specific information that was crucial in the present study. Ideally, we should be able to predict cotton yield considering the knowledge of damage agents, pest pressure in this study, because it has high value for economic study as argued by Lichtenberg and Zilberman (1986). Because this information was not provided in the data sets we just described for this study, the damage function recommended by some of the literature in pest management was not used in this study.

For the purpose of our study, the specific information on timing, length and intensity of pest attacks is important. To minimize the data limitation problem on these information, we conducted a complementary data collection, the third source of information, consisting of one-month of field work conducted in Mozambique from mid-July to mid-August 2003 under the supervision of Michigan State University (MSU) faculty, and counterparts in Department of Policy Analysis (DAP) within the Ministry of Agriculture and Rural Development (MADER), and in the National Institute for Agronomical Research (INIA). The goal of this work was to distinguish the major cotton pests, the typical timing of their attacks in the crop cycle, the specific pesticides used to control each of these pests, when and how they are applied, and how effective they are, in practice, in controlling the pests. For this work, a semi-structured questionnaire was designed to address these issues and the perceptions on expected performance of Bt cotton in Mozambique (See appendix B), interviewing key informants. The collected information allowed us to better interpret the Strasberg data set in order to estimate productivity of different types of pesticides. Knowing the typical timing of pest attacks in the crop cycle and its application date, we were able to separate the effect of the two major groups of cotton pests (bollworm and sucking-insect complexes), which was then used in our standard yield model presented in section 3.6.

Another limitation of the dataset used in this study is the omission of farmers management skills that could have lead to biased estimates of the productivity of those inputs (e.g. herbicide, fertilizer, pesticide, and labor). To get around this problem, we considered lagged maize yield as an instrumental variable, since maize is the most popular food crop planted by cotton growers in the study zone and also because it competes for resources, especially labor, with the production of cotton. We therefore estimated two yield models, **equation 1** and **equation 2,** which are presented in appendix C. Equation 1 does not include maize yield, while Equation 2 does include it in an attempt to control for selection bias. Regression results show that maize yield is not statistically significant. This suggests that there was no selection bias based on farm management ability. We remind you that the interpretation of this instrumental variable has to be made with caution, because the selection bias could be based on land quality and other factors that the model does not capture.

All these data limitation have implications on the accuracy of the yield estimation approach, including the fact that it probably establishes a lower bound on the Bt effect because for instance, if farmer skills are low, then the marginal productivity of managerial inputs in actual practice would be lower than under optimal practice, resulting that the Bt effect is lower.

3.5 THEORETICAL EMPIRICAL MODEL

For a long time, agricultural economists have modeled the output of systems involving damage agents, including pests, using standard production functions. By this we mean production functions that treat all inputs as if they affect yield directly, as fertilizer and labor do. The idea supporting a different approach – the damage function approach - is drawn from biological literature on pest control indicating that pesticides belong to a class of “damage control” inputs. These inputs are different from conventional inputs because they affect output only indirectly, by reducing the damage in case it occurs. So, their productivity depends on the presence of pest in the field. In contrast, conventional inputs like fertilizer and labor increase output directly, which makes them well suited to standard production function approaches. The standard production function was represented as follows:

(3.1) $Q = f(Z)$

Where **Q** is output, and is a function of **Z,** the vector of all inputs including damage control inputs.

Lichtenberg and Zilberman (1986) introduced a new way of modeling functions for inputs such as pesticides by recognizing that the final output is a mix of two components: the potential output and the losses caused by damage agents. These losses are a function of environmental conditions that dictate the destructive capacity of the relevant damaging agents, and of damage control agents through the damage reducing efforts. So, damage can at most be equal to potential output (at maximum destructive capacity of damage agent) and at least be equal to zero (maximum control capacity of damage control agent). Then, the abatement function **G(X)** is defined as a proportion of the destructive capacity of damaging agent eliminated applying **X** amount of damage control agent. Hence, this function will have properties of cumulative probability distribution [0, 1] (**G(X)** =1 meaning complete eradication of the destructive capacity and **G(X)** = 0 meaning zero elimination. Recalling that the characterization of actual output is a combination of potential output and losses as mentioned earlier, then, **Q** can be expressed as:

(3.2) $Q = f[(Z)G(X)]$

Where, **Q** is the actual output, the potential pest-free output is given by *f(Z.1)*, ***f (.)*** is concave in **Z** and **G(X)**, ***Z*** is a vector of all other inputs except damage control agents, **X** is a vector of damage control agents, pesticide in our case, and ***G(X)*** represents the pest damage function and is increasing in **X**. Recently, Shankar and Thirtle (2003) and Qaim and Zilberman (2003) used this approach to analyze the effects of Bt variety adoption on pesticide productivity in South Africa, and India, respectively, introducing also a dummy variable for Bt varieties into the damage control specifications.

Based on their ability to capture the biological response of damage to pesticide applications, the most popular damage function specifications are exponential, logistic, and Weibull distribution. Shankar and Thirtle (2003) indicate that damage control productivity is sensitive to functional form (distribution). They found the exponential form most advantageous because it allows that some output is still produced when no pesticides are applied, contrary to the other two functional forms.

This new modeling approach suggested by Lichtenberg and Zilberman demonstrates why the commonly used production functions were theoretically inappropriate for inputs that protect yield against damage, and why such functions may commonly lead to overestimation bias of the productivity of damage control inputs even in large samples. According to Chambers and Lichtenberg (1994), its dual representation offers ability to recapture pest damage directly from observed data and permits the specification of more flexible representations of damage control technology than currently exists.

Zilberman and Lichtenberg state that in econometric work, the measurability of **X** will be limited by data availability. So, failing to measure **X** it turns out that the actual output is determined by factors affecting the potential yield, and the production function becomes standard production function, resulting in overestimation of the marginal productivity of damage control inputs. But, Carrasco-Tauber and Moffit (1992) testing the modeling approach suggested by Lichtenberg and Zilberman using different models, concluded that in practice, pesticide productivity results did not differ significantly across models (Carrasco-Tauber and Moffitt 1992). In addition, recently, Shankar and Thirtle (2003) claim that the direction of the bias cannot be established theoretically[11], contrary to the overestimation bias suggested by Lichtenberg and Zilberman (1986).

Shankar and Thirtle (2003) found recently in South Africa using a Cobb-Douglas function that the only difference in estimated pesticide productivity using the standard production function approach and the damage function approach was the significance and not the magnitude of the pesticide elasticity. These authors found that while the standard functional form presented statistically insignificant pesticide elasticity, with the new approach the pesticide elasticity of production was significant.

[11] While one may expect a Cobb-Douglas (or other conventional functional form) to wrongly estimate the productivity of pesticides, whether the misspecification leads to an under or over estimation of pesticide productivity cannot be determined prior to estimation.

3.6 COTTON YIELD MODEL

We acknowledge the importance of setting the damage control function to better estimate the pesticide productivity but the limitation on data forced us to restrict the model to standard form. Thus, based on data limitation and considering Carasco-Tauber and Moffitt's findings, we proceeded hypothesizing that the level of cotton production per hectare among Northern Mozambican smallholder is characterized as follows:

(3.3) $Q = f(Z)$, where $Z = N, I, H, K, V$

Where, ***N*** represents the natural or agronomic factors (e.g., land quality, infestation level, etc.), ***I*** represents inputs and support services provided by cotton companies (e.g., insecticide, fertilizer, herbicide, etc), ***H*** represents household resource allocation and management decisions (e.g. farmers skill), ***K*** represents household characteristics, social and human capital (e.g., age, and education), and ***V*** is a vector of village dummy variables.

The rationale for and description of variables used to implement the theoretical model is discussed below by each category.

NATURAL FACTORS (N)

Land quality, rainfall and levels of pest infestation are the three major natural factors that are believed to affect cotton productivity. For land quality, the fertility level of fields was proxied with four-scale categorical land quality variable from (Strasberg,

1997) based on farmers' perception of the fertility their land. Under this approach, 61% of cotton fields were classified as extremely fertile, 32% as fertile, 6% as fairly fertile, and 1% as non-fertile.

The second natural factor is precipitation. Rainfall quantity and its distribution within the cropping season is essential to agricultural production, since irrigation is not common in cotton production in the study zone. In the absence of plot-level rainfall data, to proxy for abnormal precipitation on the farmers plots, farmers were asked to compare actual quantity and distribution of rain during the production season to a normal year[12]. This approach was used based on Strasberg (1997) data set to develop a dichotomous variable to control for the effect of rainfall on the plot-level production, where a value of zero was attributed to the cases with implicit normal precipitation and a value of one for excessive or insufficient rainfall cases.

The third natural factor hypothesized to influence agricultural production is the level of insect infestation observed during the cropping season. To proxy for insect infestation levels, a dichotomous variable was computed, where a value of zero was attributed to farmers that observed infestation levels insufficient to affect yield and a value of one to those farmers that had seen infestation levels high enough to have affected their yields.

[12] It is important to remember that the subjectivity of this question can affect the usage of the rainfall variable, since it depends much in the farmers' judgment. Normal season can be understood differently among farmers, but most of them considered a normal year the one that observed lower infestation level, and higher yield.

INPUT USE (I)

Planting date: Early planting dates are hypothesized to have a significant effect on cotton yields. The reason for this hypothesis is that the "Centro de Investigação e Multiplicação de Semente de Algodão de Namialo" (CINSAN) has reported a significant positive yield effect on cotton yield (Strasberg, 1997) from planting prior to November 15^{th}. In addition, field trials indicate that planting after December 30^{th} results in yield a decrease of about 100 Kg/ha per week (Rodrigues, 2002).

Surveyed farmers in 1995 by Strasberg (1997) reported the timing of each their crop management activities. With this information, we were able to compute an explanatory variable, seeding week as a proxy for seeding dates. For seeding week, an eight-scale variable was computed, where a value of one corresponds to planting during the second week of November, two for planting which occurred on the third week of November and so on until seed week eight.

Weeding labor: Weeding between two and ten weeks after germination is the most critical period of labor demand for cotton (Strasberg, 1997 and Rodrigues, 2002). Since the survey provides information on labor used in each activity, we calculated directly the total weeding labor as total adult-equivalent[13] weeding labor days per hectare.

Insecticide use: Insecticide is the main chemical input used by cotton farmers in cotton production. The cotton yield model uses the number of insecticide applications on each field, instead of the quantity of insecticides active ingredient applied because the

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[13] Labor adult-equivalent coefficients are: individuals 7-8 years old =0.3, 9-12 = 0.5, 13-15 = 0.7, males 15-54 =1.0, females 15-54=0.85 and individuals >55 = 0.7.

survey does not provide data on this.

According to Rodrigues (2002), farmers are recommended to apply insecticide to control bollworm starting eight weeks after germination, and to control for sucking-insects right after germination up to eight weeks. Combining information on seeding and insecticide application dates, we were able to separate the insecticide applications into two major groups according to their timing of application, implicitly equivalent to their effect in controlling bollworms and sucking-insects.

These two groups were developed to capture the effect of the two major cotton pests as mentioned before. Assuming that Bt cotton controls bollworm effectively, we captured the effect of Bt cotton by assuming it to be equivalent to the bollworm control provided by six insecticide applications on conventional cotton (i.e., six applications starting eight weeks after germination). In other words, Bt cotton is attributed the equivalent of three insecticide applications beyond current practice in conventional cotton.

HOUSEHOLD-CHARACTERISTICS (K)

Household characteristics such as education, age and information stock (access to extension service) were hypothesized to have a significant effect on cotton yield. Education (as number of years of formal schooling of the household head) and age of the head of household were constructed as continuous variables and the correlation coefficient between them is negative. We expected to see a positive relationship of both education and age (sometimes representing experience) with cotton yield. Information stock was instrumented as a dichotomous variable, where a value of one was attributed to the household that had access to extension services from the Cotton Company or other source and zero otherwise.

VILLAGE-LEVEL VARIABLES (V)

Village-level dichotomous variables (VIL_1,. . ., VIL_{16} are included in the yield model to control for spatial variation in infrastructure and natural endowment across the villages. Many infrastructure characteristics may affect productivity but the key types include distance to the cotton company depots, social infrastructures such as road quality, access to markets (not only for cotton but also for other goods and services), and availability of water. The identification of each village used in the model is presented in appendix D.

3.7 CHOICE OF FUNCTIONAL FORM FOR COTTON YIELD MODEL

The relationship expressed by equation (3.3) is assumed to be concave with respect to inputs, and Cobb-Douglas, Translog, and Quadratic functions are tested as described below. From these three models, we selected the one that best described our data without violating the assumption of concavity for theoretical consistency.

As Griffin et al. (1987) stated, determination of the true functional form of a given relationship is impossible, so the problem is to select the best form for a given task. For the purpose of this study, the choice was based in two major characteristics described by Griffin (1987): concavity and goodness-of-fit. We postpone the discussion of each characteristic to Chapter Four. The rationale for choosing and description of the functional forms to be tested are presented in the next section.

3.8 FUNCTIONAL FORMS

The yield model is estimated using a Cobb-Douglas production function as follows:

$$\begin{aligned} &\ln(Yield) = \alpha_0 + \beta_1 \ln(LANDQUAL) + \beta_2 \ln(RAINPROB) + \beta_3 INSPESTS \\ &+ \beta_4 \ln(TOTWAE) + \beta_5 \ln(SEEDWEEK) + \beta_6 \ln(BOLLW) + \beta_7 \ln(SUCKI) \\ &+ \beta_8 \ln(FERTQ) + \beta_9 \ln(HERBQ) + \beta_{10} \ln(AGE) + \beta_{v1} VIL_1 + \ldots + \beta_{v16} VIL_{16} \end{aligned} \quad (3.4)$$

Where[14]:

YIELD = Kg seed cotton production per hectare,

LANDQUAL = proxy for soil quality (1 if the land is fertile, 2 if is fairly fertile, 3 if is less fertile, and 4 if the soil is infertile) [N],

RAINPROB = 1 if the rainfall observed was higher than in a normal year (Floods) and 0 otherwise [N],

INSPESTS = 1 if excessive insect infestation reported on the field during growing season and 0 otherwise [N],

TOTWAE = total adult-equivalent weeding days per hectare, family and non-family are included, a continuous variable [I],

SEEDWEEK = seeding week, 1 = earliest seeding (2nd week, November), 2 = 3rd week, November and so on, integer taking values 1 to 8 [I],

BOLLW = number of insecticide applications assumed to control bollworms (after eight weeks following germination), an integer variable [I],

SUCKI = number of insecticide applications assumed to control

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[14] [.] Indicates variables according to their categories in the conceptual model.

sucking-insects (during the first eight weeks after germination), an integer variable [I],

FERTQ = quantity of fertilizer used in each field in Kg per hectare, a continuous variable [I],

HERBQ = quantity of herbicide used in each field in liters per hectare, a continuous variable [I],

AGE = Age of the head of the household in years, an integer variable [H],

VIL_1... VIL_{16} = village level dichotomous variables (see identification for each village in the appendix D) [V]. The summary statistics of the study sample are presented in table 3-1.

Table 3-1 Summary statistics of the variables used in the regression model, in Northern Mozambique

Variable	Mean	Standard deviation
YIELD	801	502.76
TOTWAE	49.8	25.91
SEEDWEEK	3 = 18% and 4 = 22%	
INSPESTS	1 = 7% and 0 = 93%	
FERTQ	21.0	40.56
BOLLW	2.3	1.56
SUCKI	0.6	.919
HERBQ	8.3	15.48
LANDQUAL	1 = 61% and 2 = 32%	
AGE	34.7	8.04
RAINPROB	1=18% and 0 = 82%	

Source: Author's computation based on Strasberg (1997)

The simplicity of algebra characterizing this type of production function, the fact that it facilitates the imposition of concavity (Bennet et al. 2003), and the fact that it enables coefficient estimates to be interpreted as elasticities, seems to be appeal to economists and agricultural economists alike in production analyses (Debertin, 1992). Although this functional form poses all these good properties, it also presents disadvantages, including its failure to represent details of the three-stage neoclassical production function, and the imposition of unitary elasticity of substitution (Debertin, 1992); moreover, it does not reveal damage function, so all inputs appear to contribute directly to yield (rather than some reducing damage).

The Cobb-Douglas function has convex isoquants, but it has unitary elasticity of substitution, not allowing for technically independent or competitive inputs, meaning that the marginal physical product and average physical product decrease monotonically for all inputs (Beattie and Taylor, 1985). However, it may be a good approximation for a production process with inputs that are imperfect substitutes. It is also parsimonious in parameters.

As referred by Wooldridge (2000), linear forms such as the Cobb Douglas impose a strong restriction regarding the marginal effect of explanatory variables on the dependent variables, and constant marginal effect, which is not realistic for many economic relationships that present diminishing marginal returns.

In order to model a variety of economic phenomena, nonlinear functions are seen as alternative to the strong restriction mentioned above. We have reasons to believe that most of our parameters of interest such as labor, seeding week and insecticide, fertilizer, and herbicide uses involve the second derivatives of the production function, implying the need for quadratic terms in the explanatory variables. The present study will accommodate this by considering and testing, the translog and quadratic functional forms in addition to the Cobb Douglas form.

The translog function was tested in this study because it is a flexible production function and is justified by its increased accuracy and generality (Beattie and Tailor, 1985). This functional form retains the ability to impose concavity (decreasing marginal returns for labor, seeding week and insecticide use). This flexible functional form not only shares the common characteristics of linearity-in-parameters, but in addition to the usual log linear terms of the Cobb-Douglas, it also allows quadratic terms, including interactions among the explanatory variables (Lau, 1986). Because our data possess some dummy variables, those variables were not considered in interactions and quadratic terms. The Translog model was estimated as:

$$\begin{aligned} \ln(Yield) &= \alpha_0 + \alpha_i \sum_{i=1}^{8} \ln(X_i) + \alpha_d \sum_{d=1}^{2} X_d + \frac{1}{2}\beta_{ij} \sum_{i=1}^{8}\sum_{j=1}^{8} \ln(X_i)*\ln(X_j) \\ &+ \frac{1}{2}\beta_{dj} \sum_{d=1}^{2}\sum_{j=1}^{8} X_d*\ln(X_j) + \beta_{v1} \sum_{v=1}^{16} X_v \end{aligned} \tag{3.5}$$

where α_0 is the intercept term, X_d a vector of dummy variables (the pest infestation, rainfall probability) and X_v the village dummy variables (location effect), X_j and X_j vectors of all other variables as presented and defined in equation 3.4 (continuous and integer variables), and α_i, α_d, β_{ij}, and β_{dj} are unknown parameters. $B_{ij}= \beta_{ji}$ when $i \neq j$ and $B_{dj}= \beta_{jd}$ are assumed throughout to maintain consistency with Young's theorem. In the equation 3.5, we separated the two dummy variables from village in order to test the interactions between those and other variables (integer and continuous variables). For instance, we had interest on testing the interactions between INSPESTS and BOLLW as well as SUCKI and INSPESTS. This kind of interactions would not make sense with the village dummy variables. Therefore, there was a need for separating those two dummies from the village dummy group and from the group of the rest because the dummies do not allow logarithm transformation.

The quadratic functional form provides some additional desired characteristics beside flexibility (linear, quadratic, and interaction in inputs). The ability of this functional form to handle data sets with zero values confers a distinct property compared to the previous two, allowing that the output not equal zero when one or all input levels are zero, which is consistent with plant biology. This functional form is not asymptotically convergent and is concave in some cases. The application of this type of functional form here is intended to capture the decreasing marginal return of seeding week, weeding labor, and insecticide use level since planting too early can depress yield and so does planting too late; less weeding labor and insecticide use can also depress yields. This notion of optimal input use can be modeled with quadratic form as:

$$(3.6) \quad Yield = \alpha_0 + \alpha_i \sum_{i=1}^{10} X_i + \frac{1}{2}\beta_{ij} \sum_{i=1}^{10} \sum_{j=1}^{10} X_i * X_j + \beta_v \sum_{d=1}^{16} X_v$$

where α_0 is the intercept term, X_v a vector of village dummy variables (16 village locations), X_j and Xj vectors of all other variables as presented and defined in equation 3.4. The linear summations for X_j in the equation 3.6 go to 10, instead of 8 shown in equation 3.5 because in the quadratic form we grouped the non-village dummy variables with the other variables, in order to allow interactions. (In the equations 3.4 and 3.5, the linear summations go to 8 because the two dummy variables cannot be transformed into logarithms). α_i, β_v, and β_{ij} are unknown parameters. $B_{ij}= \beta_{ji}$ when $i \neq j$ is assumed throughout to maintain consistency with Young's theorem.

CHAPTER FOUR

EMPIRICAL YIELD MODEL AND YIELD ESTIMATES

This chapter discusses the properties of the tested models, evaluates alternative specifications for the cotton yield model, lays out the evaluation criteria for model selection, then uses the selected model along with other information to generate estimates of Bt cotton yields.

4.1 MODEL PROPERTIES

To ensure good properties of the models, heteroscedasticity was tested using the Breuch-Pagan/Cook-Weisburg test (BP/CW) and non-normality using *Jarque-Bera test (JB)*. The BP test consists in hypothesizing that the variance of each observation in the dataset is some function of the nonstochastic variables, some or all our explanatory variables. It tests whether the variance is homoscedastic, and assumes that the error term is normally distributed (Gujarati, 1995). This test has some limitations, such as the identification of the auxiliary regression, but the reason why it was chosen is because it is an asymptotic test. The auxiliary regression specification problem was solved by considering all our explanatory variables as non-stochastic.

The JB test is an asymptotic test and consists of computing the skewness and kurtosis measures of OLS residuals and uses them to test whether residuals are normally distributed: the skewness is equal to zero and kurtosis is equal to three. If the p-value of the computed Chi-square statistics is sufficiently low the hypothesis that the residuals are normally distributed is rejected, otherwise is accepted (Gujarati, 1995).

Results indicated both non-normality and heteroscedasticity were present. To correct for heteroscedasticity problem, the weighted least square regression was performed (variance of each observation was used as weights). This procedure resulted in correction for non-normality problem, and then no correction for non-normality was necessary.

4.2 EVALUATION AND SELECTION OF A YIELD MODEL

Table 4-1 presents results for the alternative models. We use these results, along with structural characteristics of each model, to evaluate and select among them based on the criteria: goodness-of-fit, and concavity for theoretical consistency.

Criteria 1: Goodness-of-fit

Having estimated a particular regression, a natural question is how well the estimated regression line fits the observations. A popular measure, which we use here, is the goodness-of-fit (R^2), which assesses the proportion of variance of the dependent variable (y) that is explained by the model. Models that have similar R^2 are not easily judged whether one is superior in terms of the fit of the data. To complement this limitation of goodness-of-fit, we compared those models in terms of their functional form specification. The model specification tests were conducted for nested models (Cobb-Douglas and Translog).

Table 4-1 Estimated production functions in Northern Mozambique, 2003[15].

	Quadratic			Translog			Cobb-Douglas		
Variable[16]	**Coef.**	**S. E**	**p-value**	**Coef.**	**S. E**	**p-value**	**Coef.**	**S. E**	**p-value**
LANDQUAL	-68.2	37.6	0.071	-0.23	0.097	0.021	-0.22	0.102	0.031
INSPESTS (dummy)	-326.3	90.3	0.000	-0.36	0.141	0.012	-0.29	0.149	0.053
TOTWAE							0.43	0.090	0.000
$TOTWAE^2$				0.05	0.011	0.000			
SEEDWEEK				2.52	0.993	0.012	-0.39	0.151	0.011
$SEEDWEEK^2$	-4.1	1.34	0.003	-0.88	0.294	0.003			
BOLLW				-0.83	0.25	0.001	0.15	0.07	0.021
$BOLLW^2$	15.3	3.55	0.000	0.63	0.156	0.000			
SUCKI	40.8	26.75	0.129	0.21	0.905	0.020	0.04	0.043	0.331
FERTQ	5.0	2.78	0.073				0.11	0.043	0.012
HERBQ	11.7	2.47	0.000	0.27	0.043	0.000	0.12	0.057	0.031
AGE	6.07	3.06	0.049	0.30	0.165	0.070	0.12	0.173	0.115
Constant	718.1	231.8	0.002	2.63	1.083	0.016	4.76	0.589	0.000
Dependent Variable is Yield in Kg/ha	$R^2 = 0.6038$ Adj $R^2 = 0.5561$ F(31,183) = 12.66 Prob > F = 0.0000			$R^2 = 0.5923$ Adj $R^2 = 0.5408$ F (30, 184) = 11.50 Prob > F = 0.0000			$R^2 = 0.5447$ Adj $R^2 = 0.4925$ F(24,190) = 9.60 Prob > F = 0.0000		

Source: Author's computations based on Strasberg (1997).

[15] These data were collected in 1994/95 survey but adjusted to reflect 2003. The village locations also explain some portion of yield variation. To keep the table 4-1 compact, we present the village effect in the appendix D. Only significant variables are reported in this table.

[16] The variables that were reported in theoretical models but are not reported in this table were dropped from these models because we failed reject the hypothesis that are jointly equal to zero (F-test was used).

This consisted of testing for multiple linear restrictions (F-test) that the quadratic terms on Translog were jointly equal to zero. Using the nested test of Cobb-Douglas against Translog, we observe that the parameter estimates of the additional variables, especially the quadratic terms from the Translog, are significantly different from zero (table 4-1). Consequently, the Translog model is superior in representing our data set, with an adjusted R-square of 0.55 compared to 0.49 of Cobb-Douglas. Since the Translog appeared to be superior to Cobb-Douglas, it was then compared to quadratic model using a non-nested test.

For this, the PE test from Mackinnon, White, and Davidson (MWD) was used, since nonlinear models are being tested and we assumed that the errors are normally distributed (Gujarati, 1995). This test consists on testing the null hypothesis that the difference in predicted values of each model is zero. To implement the MWD test, we proceeded as follows. We set the null and alternative hypothesis as:

H0: Quadratic model: Yield is a function of regressors, the X's.

H1: Translog model: lnYield is a function of logs of regressors, the logs of X's.

Step 1: We estimated the quadratic model and obtained predicted values, h_0,

Step 2: We estimated the translog model and obtained its predicted values, lnh_1,

Step 3: we computed $z_1 = lnh_1 - lnh_0$,

Step 4: regressed log of Yield on X's and z_1 in the translog model. We rejected H1 if the coefficient z_1 is statistically different from zero by the usual t-test, then the translog is not the true model,

Step 5: we computed z_2 = (antilog of $lnh - h_0$),

Step 6: regressed the Yield on X's and z_2 on quadratic model. We rejected H0 if the coefficient z_2 is statistically different from zero by the usual t-test, then the quadratic is not the true model. The results are summarized in the appendix E.

From the regression, it resulted that both z_1 and z_2 are not statistically significant. Therefore, both models are correct, so they cannot be rejected. To select the model that better describes our dataset, we relied on goodness-of-fit (R^2) comparison. One methodological concern arises since different functional forms cannot be compared directly using R^2 because the units of measurement between the two models differ. The reason for this is that the R^2 measures the explained proportion of the total variation in whatever dependent variable is used in the regression, and different functions of dependent variables will have different amounts of variation to be explained (Wooldridge, 2000).

To overcome this problem, the box-cox transformation was made for Translog model to have comparable R^2 to the Quadratic model. This consisted on taking the anti log of the predicted yield from translog model and correlated to the observed yield. The square of the correlation coefficient is the R^2 of translog model equivalent to that of quadratic. The results from this comparison led us to accept the translog function as the one that is superior in terms of fitting our data.

Criteria 2: Concavity for theoretical consistency

The concavity property is important in economic studies mainly for two aspects. On the one hand, it is an accurate description of the production process, because it reflects a situation in which output increases at a decreasing rate (diminishing marginal returns) as the level of inputs increases. This links to the asymptotic convergence property, since only concave functions can achieve a maximum output level. On the other hand, only if the function is concave can inputs that maximize profit be computed from first order conditions (Griffin et al., 1987).

So far we described how each model fits the data. Then we proceed to discuss their theoretical consistency. Lau (1986) defines theoretical consistency as the ability of all chosen algebraic functional forms to capture all theoretical properties of that economic relationship for an appropriate choice of parameters. Though the quadratic and translog functional forms have the best fit to the data, the coefficients on the squared BOLLW term is positive, which means that they violate the diminishing marginal returns property in this variable of interest. The Cobb-Douglas form does not violate this property.

Unfortunately, the U-shape of the quadratic curve suggests exponentially increasing returns to pesticide use, which is not consistent with theory, and from what is known, yields do not grow unboundedly with increasing pesticide use. Another theoretical problem is presented by the translog model where the linear BOLLW term is negative, which suggests that, with less insecticide applications to control bollworms, the yield effect is negative. With all these facts, we have reasons to believe the theoretical inconsistency is serious enough to reject these models. Table 4-2 summarizes the performance of each functional form regarding the three choice model selection criteria presented above.

Table 4-2 Choice criteria for cotton yield model

Criteria	Cobb-Douglas	Translog	Quadratic
Concavity in BOLLW (desired)	Yes	No	No
Goodness-of-fit (R^2) in log units	0.49	0.55	-
Goodness-of-fit (R^2) in level units[17]	-	0.61	0.58

Source: Author's computations.

As we can see from the table 4-2, no one functional form performs well in all selection criteria. To select the preferred yield model, some properties were treated as more important than others. We treated concavity as the most important property because it is consistent with biological growth patterns. Although the R^2 was used to compare the how well the functional forms fit the data, it was attributed low importance compared to the concavity criteria. Based on this approach, we choose Cobb-Douglas as the preferred model.

A weakness of the Cobb-Douglas model is that it is not asymptotically convergent, which implies that no maximum yield will be reached, i.e., yields will increase indefinitely as herbicide and insecticide are used. This is not consistent with production biological theory indicating that in plant production there is a level of input mix that results in maximum yield. This implies that the use of these inputs will be constrained by the farmers' income, not by biological characteristics of production. Shankar and Thirtle (2003) in South Africa, observed that Bt cotton reduces the marginal

[17] Transformed R^2 = squared correlation coefficient between anti log of the predicted yield from translog model and the observed yield.

productivity of pesticides as pesticide use increases because Bt cotton acts as a natural substitute.

We acknowledge that Cobb-Douglas functional form probably underestimated the Bt yield effect due to omitted insecticide application timing that result in the discussed problem in the quadratic and Translog models. With late insecticide applications, inadequate pesticides, and lower application rates than the recommended, *ceteris paribus*, it is likely to result in lower (possibly negative) pesticide marginal product; hence, lower cotton yield, and consequently lower Bt cotton yield gain since our Bt cotton yield estimation approach depends heavily on the productivity of the pesticide. The omission on insecticide application timing data cannot be tested but the final result on predicted yield can give insights about the aggregate effect of the omission as summarized in table 4-3.

Table 4-3 Mean observed yield and predicted yield from the three models in Kg/ha in Northern Mozambique.

Data	Observations	Mean (Kg/ha)	Std. Error	Yield difference with observed	95% Confidence Interval
Mean observed yield from our data set (Strasberg, 1997)	215	801	34.28794	-	734 - 869
Mean predicted yield from quadratic model	215	809	26.77509	+8	756 - 862
Mean predicted yield from translog model	215	763	30.67088	-38	703 - 824
Mean predicted yield from Cobb-Douglas model	215	745	29.03898	-56	688 - 802

Source: Author's computations based on Strasberg (1997), MADER (2002).

Our preferred model underestimates the average yield by 7.0% compared to the average observed yield in Nampula province of 801 Kg/ha, while the translog model underestimates yields by 4.7%. The quadratic model yield prediction is nearly equal to observed average yield.

To conclude, although the model specified may explain a part of our results, the environment in which the estimates were generated from can be contributing the most on the yield estimates that we have. This is due to the fact that since the data were drawn in actual farmers' practices, the productivity of pesticide and other inputs may not reflect their highest levels.

Insecticide endogeneity

One problem with direct estimation of the production is that the inputs are treated as exogenous data, when actually their levels are decided by farmers during the course of the growing season (Shankar and Thirtle, 2003). Although the problem applies to all inputs, we are interested in looking at insecticide. Insecticide in particular, sometimes is applied in response to pest attacks, in which a correlation is created between insecticide variable and the error term in the production function (Bennett et al., 2003). This problem is known as endogeneity. Where endogeneity is present, consistent estimates can be obtained by suitably including a relevant variable as an instrument. Where endogeneity is not a problem, the least square estimator is more efficient with the original variable than instrumental variables (Shankar and Thirtle, 2003). Thus, the original variable would be preferred in the empirical analysis instead of the instrumental variable.

Accordingly, the endogeneity problem of insecticide was tested using the

Hausman test. This consisted of running a regression of BOLLW on exogenous explanatory variables of the original model. The residuals from this regression are then added to the original model as an additional explanatory variable. If the coefficient on the residual term is insignificant in the new regression, the null hypothesis of no correlation between the input and the error term (no endogeneity) cannot be rejected. Appendix F shows that in fact we cannot reject the null in this case, so we include the actual insecticide applications in our model. This result is consistent with actual practices in Mozambique where farmers apply insecticide commonly on calendar basis rather than in response to pest attacks (Chitlhango, 2001) and the same opinion is expressed by Shankar and Thirtle (2003) in the context of South African farmers.

4.3 INTERPRETATION OF RESULTS

Overall, the model reported in table 4-1 indicates a high degree of explanatory power indicated by a p-value of 0.000 for F-statistic. The goodness-of-fit is reasonable, the adjusted R-square is around 0.49 and the explanatory variables are all consistent with our expectations.

The positive sign of number of insecticide applications to control for bollworms and the significance level is consistent with Rodrigues (2002). The marginal product of insecticide applications on average is 87 Kg for bollworm complex, equivalent to elasticity of 0.15. Tauber and Moffitt (1992) found 0.136 in 1987 and reported 0.055 using Cobb-Douglas function found by Headley in 1963. Shankar and Thirtle (2003) found that, compared to no pesticide application, the non-Bt cotton with current average application rate of 2.2 liters per hectare can recover 36% of the potential yield. The Bt cotton with an average pesticide use rate of 1.1 liter per hectare, recovered 55% of potential output. All these pesticide productivities are well within the confidence interval of our estimated BOLLW coefficient (95% c.i. = [0.023 – 0.286]). The marginal products found in our study in table 4-4, are lower than that estimated by Strasberg (1997) for conventional cotton, who estimated 89 Kg under low-input and 154 Kg under high-input.

The marginal value product (MVP) of insecticide application is $9.57/application, about triple its cost ($3.31/application). Similar to Tauber and Moffitt's (1992) findings, our results suggest that pesticide is under used (below their optimal level), in contrast with a number of studies of productivity of chemical pesticides in agriculture, which have concluded that pesticide is over used. Our result is not a surprising outcome if we take into account that the number of insecticide applications that farmers apply is limited by how much the cotton companies makes available. Moreover, the insecticide applications may be late or adequate insecticide may have not been available, hence not effective.

The negative sign and significance level on seeding week coefficient (-0.39) is consistent with CIMSAN's findings concerning the importance of early seeding as cited by Strasberg (1997). The marginal product for a one week delay in planting is equal to 94 Kg of yield loss, which corresponds to a financial loss of $10.34 at a farm gate price of $0.11/Kg. On average, these figures are higher than that estimated by Strasberg (1997), who found yield losses from one week seeding delayed of 51 Kg under low-input use, and 88 Kg under high-input use.

The elasticity of weeding labor per adult equivalent day (0.43) is positive and significant at 5% significance level. Its marginal product is on average 12 Kg per day;

much greater than 1.6 Kg under low-input and 3.1 Kg under high-input estimated by Strasberg (1997). At farm gate cottonseed price of $0.11/Kg, the marginal value product is $1.32 per weeding labor-day adult equivalent. Compared with current wage rates paid for agricultural labor of $ 0.30[18] (Low et al., 2002) and a minimum wage of $1.25 per day (RM, 2003), we can observe that cotton production does provide incentives for labor supply because its productivity in cotton is higher than the wage rates paid for this activity. Again, this means that the weeding labor is under-used.

The cotton production elasticity of fertilizer use is positive (0.11) as hypothesized and significant at 5%. This figure is in the range between 0.166 found by Headley in 1963 and 0.082 both in Tauber and Moffitt (1992) using Cobb-Douglas function. Its marginal product is 8 Kg, corresponding to a marginal value product of $0.88/kg of fertilizer. Compared with its farm-gate price, one can see that its productivity is above its cost (under used). Thus, farmers' efficiency can be achieved encouraging its use until the marginal value product is equal to the marginal factor cost.

The village effect of three locations (Namacopa in Monapo, Nacimoja and 25 de Setembro in Montepuez districts) is statistically significant. Although the village coefficients of the other locations in the zone appear to be insignificant, they are correlated with most of the other explanatory variables in the model (see appendix D). This is an expected outcome in Mozambique were rainfall, which was not well-captured by the model because of data limitation (no information on quantity of rainfall is available from those locations), is expected to be localized, which can explain part of yield variation.

The coefficient of herbicide use is positive (0.12) and significant at 5%. Its marginal product estimates indicate that using this input increases cotton yield by 20 Kg/l, which is equivalent to a marginal value product of $2.20/l at cotton seed farm-gate price. This figure is almost 26% higher than its cost. Again, similar to insecticide and fertilizer (although farmers receive this input at subsidized price), they are still not efficient using it (under-used). The main reason for this may be because farmers do not have much experience in using herbicide because it is not common, but also the idea that the cotton companies define the application rate may result in this level of productivity similar to pesticides.

Table 4-4 Marginal products, marginal value product, and marginal factor cost for Bt cotton production at mean values of independent variables.

Variables	**Marginal products (Kg)**	**Marginal Value Products ($/unit)**	**Input cost ($/unit)**	**Ratio MVP/MFC**
Insecticide for bollworms (No. of applications)	87	9.57	3.31	2.89
Seed Week (No. of weeks)	-94	-10.34	-	-
Weeding labor (days)	12	1.32	1.25 and 0.30	1.06 and 4.4
Fertilizer (Kgs)	8	0.88	0.38	2.32
Herbicide (litres)	20	2.20	1.74	1.26

Source: Author's computations based on Strasberg (1997).

4.4 COTTON YIELD ESTIMATES

This section presents and discusses the Bt cotton yield estimates based on the Cobb-Douglas model. The yield estimates presented in table 4-5 were computed as described in the section 3.3 (for more details see appendix G).

The Bt cotton yield gain was computed as the difference between the mean predicted yields of Bt and conventional cotton, discounted the Bt cotton yield impact of one insecticide application to control for sucking-insects. The Bt cotton yield was hypothesized as equivalent to an effective bollworm control (six insecticide applications), whereas the conventional yield was estimated under farmers' conditions (three insecticide applications on average). All other inputs were fixed at their most common levels.

According to table 4-5, under typical production practice (seeding week four with one additional insecticide application), the average yield gain from adopting Bt cotton is about 6% under both input use levels. As the insecticide is more intensively used, the Bt yield gain decreases to a minimum of 3.4% when three additional insecticide applications are made. This has an implication regarding adoption of Bt cotton. Since farmers have weak purchasing power, they would adopt new technology if its yield advantage is relatively higher because the actual low pesticide application rates lead to higher yield loss since Mozambique is located in high pest pressure zone. But, our study does not provide high yield gains.

Table 4-5 Estimated Bt cotton yield and Bt yield gain over non-Bt cotton by seeding week and number of additional insecticide applications, in Kg/ha in Northern Mozambique, 2003[19].

Level of input use		Item	Seeding week					
			3	4	5	6	7	8
LOW-INPUT USE	No additional pesticide application	Conv. cotton yield (Kg/ha)	833	745	683	637	618	570
		Bt cotton Yield (Kg/ha)	901	806	739	689	667	616
		Bt cotton Yield gain (%)	8.2	8.2	8.2	8.2	7.9	8.1
	One additional pesticide application	Conv. cotton yield (Kg/ha)	870	779	714	665	627	595
		Bt cotton Yield (Kg/ha)	922	824	756	705	664	630
		Bt cotton Yield gain (%)	6.0	5.8	5.9	6.0	5.9	5.9
	Two additional pesticide applications	Conv. cotton yield (Kg/ha)	901	806	739	689	649	616
		Bt cotton Yield (Kg/ha)	940	841	772	719	677	643
		Bt cotton Yield gain (%)	4.3	4.3	4.5	4.4	4.3	4.4
	Three additional pesticide applications	Conv. cotton yield (Kg/ha)	926	828	760	708	667	633
		Bt cotton Yield (Kg/ha)	957	856	785	732	689	655
		Bt cotton Yield gain (%)	3.3	3.4	3.3	3.4	3.3	3.5
HIGH-INPUT USE	No additional pesticide application	Conv. cotton yield (Kg/ha)	1,546	1,383	1,269	1,182	1,114	1,057
		Bt cotton Yield (Kg/ha)	1,672	1,496	1,372	1,278	1,204	1,143
		Bt cotton Yield gain (%)	8.2	8.2	8.1	8.1	8.1	8.1
	One additional pesticide application	Conv. cotton yield (Kg/ha)	1,616	1,445	1,326	1,235	1,164	1,105
		Bt cotton Yield (Kg/ha)	1,711	1,530	1,404	1,308	1,232	1,170
		Bt cotton Yield gain (%)	5.9	5.9	5.9	5.9	5.8	5.9
	Two additional pesticide applications	Conv. cotton yield (Kg/ha)	1,672	1,495	1,372	1,278	1,204	1,143
		Bt cotton Yield (Kg/ha)	1,745	1,561	1,432	1,334	1,257	1,194
		Bt cotton Yield gain (%)	4.4	4.4	4.4	4.4	4.4	4.5
	Three additional pesticide applications	Conv. cotton yield (Kg/ha)	1,719	1,538	1,410	1,314	1,238	1,176
		Bt cotton Yield (Kg/ha)	1,777	1,585	1,458	1,358	1,280	1,215
		Bt cotton Yield gain (%)	3.4	3.1	3.4	3.3	3.4	3.3

Source: Author's computations based on Strasberg (1997), MADER (2000), and MADER (2001a).

[19] No additional insecticide application = three insecticide applications for conventional cotton and zero to Bt cotton. One additional insecticide application = four applications for conventional cotton and one for Bt cotton, etc. Under low-input and high-input production systems, the Bt cotton yield is 621 Kg/ha (95% c.i. = [583-660]) and 1,133Kg/ha (95% c.i.= [1,063-1,204]), respectively.

With lower Bt cotton yield effect estimated in our study compared to what was observed in other developing countries, then we ask: 1) What is the farmer's incremental net profit with the estimated yield gain, and 2) Given risk, weak purchasing power and actual farmer's experience in cotton production, we believe that farmer will adopt such technology only if it results in higher profit in order to recover fully their investment. Therefore, we ask what Bt yield, Bt seed price (license fee), and pesticide savings would allow a representative farmer to repay the forgone income and earn 100% return on his/her investment in this technology. These issues are addressed in the next two chapters.

Although the predicted Bt cotton yield, 824 Kg/ha, is higher than that obtained by South African smallholders (576 Kg/ha from table 2-1), the predicted Bt yield gains are extremely lower compared to what recent experiences have reported so far in developing countries such as China, and South Africa. In India where bollworms have a high destructive capacity that is not well controlled in conventional cotton, researchers found that pest-related yield losses are 50 to 60% (Puri et al.,1999), and Bt cotton achieved yield advantage of 37-38% over non-Bt cotton in 1998/9 and 2000/01 cropping seasons (Cabanilla et al., 2003, and Cabanilla and Sanders, 2003).

In South Africa farmers surveyed showed a Bt cotton yield advantage of 46% in small farms, 14% in large dryland farms, and 19% in large irrigated farms (Ismail et al., 2001), and an empirical study estimated 77% yield gain for the average farmer (Bennett et al., 2003). These high yields are attributed primarily to effective control of bollworms provided by Bt toxins that is active throughout the growing season, irrespective of level of infestation (Edge et al., 2001). Those two countries have similar pests to Mozambique, and we expected that the figures suggested by our study would be close to theirs.

The difference between our estimates and theirs can be explained by many factors. On the one hand, our econometric model failed to capture the size of pest management technical and allocative inefficiencies that could explain part of the differences in yield attained in other countries. As we can observe from experiences in developing countries that no one of the experiences in table 2-1 farmers apply insecticide three times during the cropping season on cotton fields. This can mirror two situations (1) the pest pressure is higher in those countries compared to Mozambique, as a result, the use of Bt cotton gives the best performance, and (2) if pest pressure is higher, farmers are likely to be well skilled to control them.

Our yield estimates are more than 50% lower than the experimental data reported by Rodrigues (2002). For instance, under recommended six insecticide applications, planting on fourth week the conventional cotton yield estimate is in average 828 Kg/ha. Rodrigues (2002) reported that under experimental conditions, yields range from 1,585 Kg/ha for A637-24 to 2,010 Kg/ha for ISA-205 with six insecticide applications under perfect scouting plan. Many reasons can explain this difference, but the environment where the data was collected explains larger part of the difference, although the estimation may have also contributed. Since our data was drawn from farmer's conditions with poor pest management practices, it is likely to result in an underestimated marginal product of pesticide. Based on Rodrigues' (2002) yield results, it is likely that the returns to Bt cotton would be higher, hence attractive to farmers, because the Bt cotton yield gain is much higher than the 6% yield gain needed for Bt cotton to be attractive to farmer.

Overall, the average, under typical practice, Bt cotton effect is 5.8%. The average estimated Bt cotton yield under low-input use is 824 Kg/ha[20], and 1,530 Kg/ha under high-input. These results suggest that the Bt cotton yield gain is not attractive enough to encourage farmers to adopt it. Since the insecticide reduction is not likely to occur because Mozambican farmers already have low application rates, the motivation for adoption would come from large yield gain, which is not observed from our results or if the cost of insecticide increases dramatically. Chapters Five and Six estimate these levels.

The analyses done in the following chapters are based on the yield estimates presented in table 4-3. This analysis is based on the assumption that the resistance capacity of conventional against sucking-insects (especially Jassids) is equivalent to one more insecticide application compared to Bt cotton. If the real resistance is greater than what we hypothesize here, all this little advantage of Bt cotton will disappear completely.

[20] The average yield found by Strasberg (1997) in two major producing zones was 574 Kg/ha, and the average estimated for cropping season 1999/2000 in four major cotton production zones by Pitoro et. al. (2002) was 602 Kg/ha. The 95% c.i. = [Yield +/- 0.23] estimated in the week four with one additional insecticide application along the six insecticide applications.

CHAPTER FIVE

FINANCIAL ANALYSIS

This chapter assesses farmers' profitability of adopting Bt cotton by estimating the financial incremental net benefit of adoption. Partial budgeting is used to compare the effect of Bt cotton production on the net income of the farmer compared to conventional cotton production. Crop budget information was drawn from Strasberg (1997), Pitoro et al. (2002), MADER (2000), MADER/MSU/FSP (2003b), and IAM (2003).

5.1 PARTIAL BUDGET

Using the partial budget approach, additional costs and benefits and the difference among these are calculated, resulting in incremental net benefit. This value indicates whether the production of Bt cotton will or not increase a farmer's net income compared to conventional cotton.

Farm-level partial budgets are presented for high and low-input use cotton production schemes for conventional and Bt cotton in Northern Mozambique. Since we are dealing with Strasberg's data that were collected some time back, prices were inflated to 2003 levels using the national consumer price index (CPI) to facilitate the use of more recent complementary data.

To analyze Bt cotton profitability from the farmer's standpoint, two key profitability indicators are estimated: net incremental return per hectare and net incremental return per adult equivalent family labor day (ae).

5.1.1 RELEVANT ADDITIONAL COSTS

The relevant additional production costs are seed and refuge. This section explains how we evaluated these costs.

Bt COTTON SEED

The additional cost of Bt seed to farmers was evaluated at $16.60 per ha at a seeding rate of 25 Kg/ha[21]. This figure is equivalent to 202 Rands/ha reported by Ismail et al. (2001) in South Africa in 1998/99. Because conventional cotton seed is currently distributed to all cotton growers free of charge by cotton companies, the full cost of Bt seed is incremental.

REFUGE STRATEGY

Resistance to the insecticidal proteins produced by the soil bacterium *Bacillus thuringiensis* (Bt) has been documented in more than a dozen species of insects (Tabashnik et al., 1998a). This situation is raising concerns about environmental hazards and driving a search for alternatives to decrease the speed at which the resistance is spreading. For this purpose, two tactics have been recommended by the literature: refuge and high-dose strategy (Genissel et al., 2003). The refuge strategy consists in establishing conditions to ensure that a large proportion of the pest population develops on non-

[21] Note that farmers in Mozambique use seeding rate of about 40 Kg/ha for conventional cotton seed. We assume 25 Kg/ha because cotton companies in Mozambique have expressed the intention to reduce the actual seeding rate to 25 Kg/ha.

transgenic *"refuge"* hosts, generally the crop itself. For cotton, it is recommended that 5 to 20% of the area planted should be non-transgenic. Three main structural refuge options were suggested by EPA (2001):

1) 95:5 external structured unsprayed refuge. Five acres of non-Bt cotton is planted for every 95 acres of Bt cotton. The refuge must be planted half a linear mile from the edge of the Bt cotton field and may not be sprayed with any insecticide labeled to control budworm, cotton bollworm, or pink bollworm. The refuge must be at least 150 feet wide. Given the smaller farm size that characterizes the smallholder cotton production in Mozambique; this strategy is likely not to be viable;

2) 80:20 external sprayed refuge. Requires that at least 25 acres of non-Bt cotton are planted as refuge for every 100 acres of Bt cotton. All cotton may be treated with insecticides to control bollworms, and the refuge must be planted within one linear mile or preferably half a linear mile from the edge of the Bt cotton field, and

3) 95:5 embedded refuge, which requires that at least five acres of non-Bt cotton is planted for every 95 acres of Bt cotton. The refuge must be embedded as a contiguous block within the Bt cotton field. The refuge may or may not be sprayed with any insecticide labeled to control budworm, cotton bollworm, or pink bollworm. The size of the block must be at least 150 feet wide. Similar to this refuge strategy is seed mixture. With seed mixture the Non-Bt and Bt seed are mixed in the same bag before seeding so that refuge plants are randomly interspersed in rows (Tabashnik et al., 2003).

Given the lack of a strong theoretical or empirical basis favoring any particular spatial arrangement, to select the appropriate arrangement will depend on farmer's managerial skills and biological factors. What is important is to guarantee that the refuge is close enough to the Bt cotton field in order to facilitate the pest movement from Bt cotton to the refuge field (Tabashnik et al., 2003).

Another resistance strategy suggested in the literature is high-dose. The high-dose strategy consists of "staking" two or more toxins through transgenic technology in the crop. This strategy not only delays resistance for an extended period but also reduces the amount of refuge required (Roush, 1998). Such a technique has been used in many new transgenic cotton crops, including Bollgard II used in the U.S. Such varieties have achieved pest resistance as high as 96% against a broader range of insects (Cabanilla and Sanders, 2003).

Since production of conventional cotton does not require a refuge strategy, the introduction of Bt will add this cost to the farmer. For the present study, the 95:5 unsprayed embedded refuge strategy was used. The unsprayed refuge was chosen because Gould (2000) have observed that the frequency of alleles in the sprayed refuge had increased by about 2%, but in the unsprayed refuge the frequency had decreased by about 12%. The cost of establishing a 5% refuge was evaluated as the yield loss due to refuge as described by USDA (2001). This cost was incorporated in the output side by considering only 95% of the expected Bt yield as total output.

5.1.2 RELEVANT ADDITIONAL BENEFITS

The additional benefits of producing Bt cotton are increased yield and reduced insecticide use and labor. Their financial values are calculated as follows.

OUTPUT

The additional yield that Bt cotton generates is evaluated at $0.11/Kg. This was the official price in the study zone during the cropping season 2002/03 of 2,750 Mt/Kg, converted to U.S. dollars using the official average exchange rate of June-2003 of 23,963.00 Mt per dollar[22]. Cotton seed in Mozambique is classified in two main grades (first and second grade). We assume that all cotton would be of first grade, since the companies in practice classify nearly all cotton as first grade.

PESTICIDE SAVINGS

The use of Bt cotton in many countries has been associated with a reduction in insecticide costs. In our study, we evaluated this benefit at $3.31/application saved by using Bt cotton. Since typical practice in conventional cotton is three applications, Bt cotton will need none for bollworm control. The Bt cotton savings in insecticide applications is evaluated at $9.43/ha (95 % of $9.93/ha because refuge is unsprayed).

[22] The cotton companies paid the official cotton price and the official exchange rate was close to parallel.

LABOR SAVINGS

The use of Bt cotton saves labor used to apply pesticides. For financial analysis only hired labor by the family is included since it represents a cost saved[23]. An accurate hired labor evaluation was possible because the survey distinguished within each activity the amount of family and non-family labor used and the total compensation paid. In our study, the hired labor used to apply pesticide represents 15% of total hired labor used under low-input and high-input levels. This summed up to $4.05/ha of total labor savings at $0.30 per day.

5.2 PARTIAL BUDGETS AND ANALYSIS

This section presents and discusses the profitability of adopting Bt cotton from the farmer's standpoint and determines the level that will allow farmers to repay the forgone income and earn a 100% return to their investment. Table 5-1 presents a summary of partial cotton budgets, with mean incremental returns to labor and land (see appendix F for more details).

5.2.1 ANALYSIS OF PARTIAL Bt COTTON BUDGETS

Table 5-1 shows that Bt cotton grown under actual condition and practices, low-input use, will generate lower returns than conventional cotton; incremental net return is negative. A similar pattern is observed under high-input level. According to the partial budget presented in table 5-1 (see appendix H), under low-input use, Bt cotton on seeding week four with one additional insecticide application[24] (typical practice hereafter), the incremental net returns to land and family labor is expected to be -$2.03/ha and -$0.04/adult equivalent, respectively. Similarly, under high-input use, the average Bt incremental net returns to land is -$1.51/ha and the incremental returns to labor is -$0.03/adult equivalent day although it gives positive incremental returns with no additional insecticide application. The positive net incremental benefit of Bt cotton under high-input level occurs only when Bt cotton does not use additional insecticides. Moreover, it is an unrealistic scenario because Bt cotton although effective in controlling bollworms, will need additional insecticide applications to control other pests, including some lepdopterans not controlled by Bt toxins (Wally, 2004).

The general pattern shown by results in table 5-1 is that the net incremental benefit of Bt cotton decreases with insecticide applications and with later seeding dates under both input use levels. Two outcomes can be visualized: 1) the impact of late planting is again highlighted as we observed from yield estimates, and 2) under high-input use, the combined marginal effect of insecticide, herbicide and fertilizer in Bt cotton yield does not result in sufficient yield gain to offset the costs that Bt cotton poses (seed and refuge) even with pesticide cost savings.

Comparing our results with those of South Africa, we observe that Mozambican farmers observe lower yield gains and profitability from Bt cotton. Results in table 5-1

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[23] Family labor is not included in the budget. Instead, returns are expressed per unit of family labor.
[24] The minimum number of insecticide applications required to control bollworms on Bt cotton as low as one but in most cases two mainly for the control for Jassids (Wally, 2004).

indicate that under a low-input regime (typical practice) the net incremental benefit of Bt cotton is -$2.03/ha, lower compared to $29.00/ha obtained by small farmers in South Africa.

In terms of net benefits, Mozambican farmers are likely to observe with three additional insecticide applications, on seeding week three Bt cotton net return equal to 40% ($39.36/ha) of what South African small farmers get, $97.77/ha.

Mozambican farmers, moreover, are likely to observe lower production cost under both low-input use ($0.08/Kg) and high-input use ($0.06/Kg) compared to farmers in South Africa ($0.15/Kg excluding weeding labor), and Argentina ($0.13/Kg). This low cost of production suggests that profits could increase substantially if yields can be improved while controlling costs.

Finally we note that the higher returns in South Africa are driven by a price of $0.30/Kg[25] (Gouse et al., 2002), nearly three times that received by Mozambican farmers.

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[25] Gouse et al. (2002) indicates that cotton price in South Africa was SAR 2.75 per Kg.

Table 5-1 Bt cotton financial partial budget by seeding week, and insecticide application, in Northern Mozambique, 2003.

Level of Input use		Items	Financial Net Returns by seeding week						Mean
			3	4	5	6	7	8	
LOW - INPUT USE	No additional pesticide application	Net returns to land ($/ha) for conv. cotton	51.99	42.31	35.49	30.43	28.34	23.06	35.27
		Incr. Net return to land ($/ha) for Bt	-0.09	-0.33	-0.52	-0.68	-0.89	-0.94	-0.57
		Net returns to fam. labor ($/ae) for conv. cotton	0.91	0.74	0.62	0.53	0.50	0.40	0.62
		Incr. Net return to fam. labor ($/ae) for Bt	0.00	-0.01	-0.01	-0.01	-0.02	-0.02	-0.01
	One additional pesticide application	Net returns to land ($/ha) for conv. Cotton	51.40	41.39	34.24	28.85	24.67	21.15	33.61
		Incr. Net return to land ($/ha) for Bt	-1.80	-2.03	-1.98	-1.92	-2.03	-2.06	-1.97
		Net returns to fam. labor ($/ae) for conv. cotton	0.90	0.73	0.60	0.51	0.43	0.37	0.59
		Incr. Net return to fam. labor ($/ae) for Bt	-0.03	-0.04	-0.03	-0.03	-0.04	-0.04	-0.03
	Two additional pesticide applications	Net returns to land ($/ha) for conv. Cotton	50.15	39.70	32.33	26.83	22.43	18.80	31.70
		Incr. Net return to land ($/ha) for Bt	-3.16	-3.06	-2.90	-2.93	-2.92	-2.85	-2.97
		Net returns to fam. labor ($/ae) for conv. cotton	0.88	0.70	0.57	0.47	0.39	0.33	0.56
		Incr. Net return to fam. labor ($/ae) for Bt	-0.06	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05
	Three additional pesticide applications	Net returns to land ($/ha) for conv. Cotton	48.23	37.45	29.97	24.25	19.74	16.00	29.28
		Incr. Net return to land ($/ha) for Bt	-3.97	-3.74	-3.68	-3.50	-3.48	-3.30	-3.61
		Net returns to fam. labor ($/ae) for conv. cotton	1.89	1.58	1.36	1.19	1.06	0.95	1.34
		Incr. Net return to fam. labor ($/ae) for Bt	-0.07	-0.07	-0.06	-0.06	-0.06	-0.06	-0.06

Table 5-1 (Cont'd).

HIGH-INPUT USE	No additional pesticide application	Net returns to land ($/ha) for conv. cotton	107.95	90.02	77.48	67.91	60.43	54.16	76.33
		Incr. Net return to land ($/ha) for Bt	2.05	1.59	1.17	0.92	0.67	0.56	1.16
		Net returns to fam. labor ($/ae) for conv. cotton	1.89	1.58	1.36	1.19	1.06	0.95	1.34
		Incr. Net return to fam. labor ($/ae) for Bt	0.04	0.03	0.02	0.02	0.01	0.01	0.02
	One additional pesticide application	Net returns to land ($/ha) for conv. Cotton	110.99	92.18	79.09	69.08	61.27	54.78	77.90
		Incr. Net return to land ($/ha) for Bt	-1.41	-1.51	-1.59	-1.61	-1.74	-1.73	-1.60
		Net returns to fam. labor ($/ae) for conv. cotton	1.95	1.62	1.39	1.21	1.07	0.96	1.37
		Incr. Net return to fam. labor ($/ae) for Bt	-0.02	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03
	Two additional pesticide applications	Net returns to land ($/ha) for conv. Cotton	112.49	93.02	79.49	69.15	61.01	54.30	78.24
		Incr. Net return to land ($/ha) for Bt	-3.85	-3.61	-3.56	-3.46	-3.36	-3.24	-3.51
		Net returns to fam. labor ($/ae) for conv. cotton	1.97	1.63	1.39	1.21	1.07	0.95	1.37
		Incr. Net return to fam. labor ($/ae) for Bt	-0.07	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06
	Three additional pesticide applications	Net returns to land ($/ha) for conv. Cotton	112.99	93.08	79.00	68.44	60.08	53.26	77.81
		Incr. Net return to land ($/ha) for Bt	-5.51	-5.66	-4.85	-4.74	-4.53	-4.51	-4.97
		Net returns to fam. labor ($/ae) for conv. cotton	1.98	1.63	1.39	1.20	1.05	0.93	1.37
		Incr. Net return to fam. labor ($/ae) for Bt	-0.10	-0.10	-0.09	-0.08	-0.08	-0.08	-0.09

Source: Author's computations based on Strasberg (1997), MADER (2000), and MADER (2001a).

The uncertainty on environmental impacts of Bt cotton is crucial in making conclusions on the impact of Bt cotton in Mozambique economy. According to Maumbe and Swinton (2003), distorted policies that subsidize pesticides worsen health hazards in most African countries. If we agree that pesticides have negative effect on farm workers' health and that health has a positive effect on productivity, then a technology that uses less pesticide could provide additional health cost savings and productivity increase as some experiences with Bt cotton have shown. In this direction, using benefit transfer approach, we consider that at least 45% to 83% of the farmer's annual pesticide expenses correspond to farmer's health cost, as was found in Zimbabwe. This translates to \$4.75/ha and \$8.25/ha that Mozambican farmers are likely to save by using Bt cotton. This would increase the financial incremental net benefit to a maximum of \$2.72/ha and \$6.22/ha under low-input use level, turning Bt cotton attractive to farmer[26].

5.2.2 SENSITIVITY ANALYSIS FOR FINANCIAL PROFITABILITY

Following Byerlee and Hesse de Polanco (1986), we assume that farmers will adopt Bt cotton only if it can repay the forgone income and generate a 100% return to the farmers' incremental investment (at typical practice), which is considered as the

[26] Caution should be exercised interpreting the estimated health cost savings because benefit transfer approach although is increasingly being used by decision makers as a way of estimating environmental values suitable for use in benefit cost analysis. However, recent studies examining the validity of benefit transfer of passive use values estimated using contingent valuation have rejected the hypothesis of convergent validity (Morrison, et al., 2002). Debate on which approach is correct can be found in literature but what seem to be consensus is that instead of transferring average values the better way is to transfer the functions. Although most studies seems to suggest that transferring functions is betters than transferring average values, both are subject to subject to significant margins of error Pearce and Howarth (2000). So, the intention of introducing the health cost transferred from Zimbabwe was to have an idea of possible health cost savings from Bt cotton to farmers' household.

incremental cost per hectare that farmers incur to produce Bt cotton ($16.60/ha for Bt seed cost, $10.19/ha for pesticide savings, and $4.05/ha for labor savings = -$2.36/ha of investment, $2.36/ha for 100% return of investment). Therefore, the sensitivity analysis carried out here identifies the level of: 1) Bt cotton yield, 2) Bt cotton seed price, and 3) pesticide savings that will result in the stated level of return to the investment. The switching values for this analysis are presented in table 5-2.

Table 5-2 Estimated switching values for a representative farmer to achieve 100% returns to investment on Bt cotton, Northern Mozambique, 2003[27]

Variable	Switching value (percent)	
	LOW-INPUT USE	HIGH-INPUT USE
Bt seed price (%)	-23	-17
Bt cotton yield (%)	6	3
Insecticide savings (add. number of applications for bollworms)	1.1	0.8

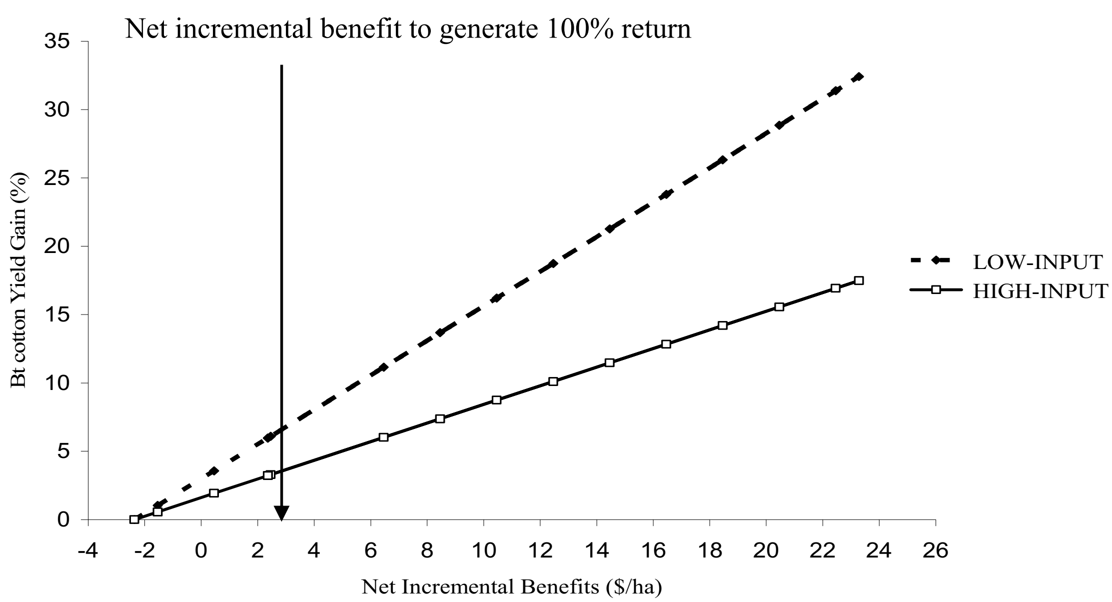
Source: Author's computations based on Strasberg (1997), MADER (2000), and MADER (2001a).

Results from table 5-2 indicate that for a representative farmer to earn 100% return to investment on Bt cotton, the Bt seed price would have to decrease by 23% to $12.78/ha from $16.60/ha under low-input and by 17% to $13.78/ha under high-input. Alternatively, Bt cotton would have to allow the farmer to save an extra 1.1 insecticide

[27] The switching values were estimated based on 6% Bt cotton yield gain, considering the average average conventional cotton yield, average pesticide savings, average seed cost, and average refuge cost under typical practice.

applications beyond the current three under low-input and 0.8 under high-input use levels. In other words, to allow farmers to earn 100% return on investment, Bt would have to save a total of 4.1 and 3.8 insecticide applications to control for bollworms under low and high-input use levels, respectively. These estimates are close 3.5 insecticide applications saved in the recent experiences with Bt cotton. Under low-input use, the Bt cotton yield (including refuge loss) would have to increase by 6% to 826 Kg/ha, whereas under high-input use it would need to increase by 3% to 1,488 Kg/ha. Figure 5-1 presents an illustration of yield gain effect on net incremental benefit for Bt cotton.

Figure 5-1 Bt cotton yield and net incremental benefits



CHAPTER SIX

ECONOMIC ANALYSIS

This chapter performs economic analysis with the objective of evaluating the net contribution of Bt cotton adoption to society's welfare. The economic analysis is designed to account for the fact that market prices often do not reflect economic values due to imperfect market structures or policies which change relative prices (Aller, 1987). Gittinger (1982) define economic values (shadow prices) as any price that is not market price, but it carries the connotation that is an estimated of opportunity cost of the good or service. The financial values are market prices. The financial and economic values are equal in an economy free of political or market distortions.

6.1 ECONOMIC PARTIAL BUDGET

To address these issues, economic partial budget analysis is used. Once financial prices for costs and benefits have been determined, their economic values can be estimated by adjusting the financial prices for market distortions. This process generates so-called "shadow prices". Gittinger (1982) defines shadow price broadly as any price that is not a market price, but its common usage carries the connotation that it is an estimate of the economic value of the good or service weighted to reflect income distribution and savings objectives.

In Mozambique, for instance, farmers in Monapo district paid a subsidized insecticide cost of $9.93 to treat one hectare of cotton, instead of the full cost of about $33.13 per hectare ($11.04 per application). The difference is covered by the cotton companies. Seed, sprayers, and extension service are also provided free by the companies. The level of subsidies varies from company to company, but seed and pesticide application are subsidized to some extent by all companies. A typical thing that the cotton companies do is to give inputs "free of charge" to farmers, but pay them lower cotton prices than they would otherwise pay. So, the effect that the monopoly concession system and government price setting means prices may not equal opportunity cost, so that these also have to be adjusted.

Converting the prices of internationally traded goods such as cottonseed and pesticides to local currency using the official exchange rate may not be correct. Because the official exchange rate may be protected or controlled, and thus, may not reflect the true economic value of the country's currency (Belli et al., 2001). When this distortion exists, border prices need to be converted to domestic currency equivalents using a shadow exchange rate. To correct for this difference between financial and opportunity cost of capital, a shadow exchange rate is calculated as:

$$(6.1) \quad SER = OER*(1+FXP) = OER*\left[1+\frac{M(1+t_m)+X(1-t_x)}{(M+X)}\right]$$

Where, $\boldsymbol{SER}$ is the shadow exchange rate, $\boldsymbol{OER}$ is the official exchange rate, $\boldsymbol{FXP}$ is the percent overvaluation of domestic currency; $\boldsymbol{M}$ is the CIF price of imports in domestic currency; $\boldsymbol{t_m}$ is the average ad valorem import tarrif rate, $\boldsymbol{X}$ is the FOB value of exports, and $\boldsymbol{t_x}$ is the average ad valorem export tax rate. Using this expression, the average overvaluation from 1998 to 2002 was 1.18. This figure was used to compute the shadow exchange rate to calculate the economic price at farm gate of seed cotton, Bt seed, and pesticide.

6.1.1 RELEVANT ADDITIONAL COSTS

Similar to financial analysis, Bt cotton seed and refuge strategy constitute the additional cost of producing Bt cotton. Using the decision tree for determining economic values developed by Gittinger (1982), Bt cotton seed is valued at the import parity price. The refuge strategy replaces Bt cotton with conventional cotton in a particular area of the field. Therefore, the cost of this strategy is valuated at the opportunity cost of forgone Bt cotton yield and is incorporated as a reduction in output value (see appendix I).

6.1.2 RELEVANT ADDITIONAL BENEFITS

Producing Bt cotton saves pesticides. Like cotton seed, pesticides are traded goods and involve real resource use; their economic prices should therefore be estimated at import parity (Gittinger, 1982). However, data limitations prevented us from proceeding in this way. Instead, we adjusted the Metical (Mozambican currency) financial farm gate price by removing the subsidies and dividing by ***SER***. This resulted in an estimated economic cost of $9.34/application[28]. As we observed in Chapter Four, Bt cotton production involves yield gain compared to conventional cotton production. Since

[28] This is close to the what cotton companies claim that farmers should be paying: $11.04/application..

seed cotton is a traded good and is exported, it is evaluated at the export parity price (see appendix I for more details). Data limitation on port farm costs, forced us to use a rule of Thumb that cotton companies in Mozambique use that, to cover costs and earn a "reasonable" profit, they can pay farmers not more than 55% of the FOB price (See the formula used by cotton companies to propose farm gate price in Appendix A). This approach resulted in a farm gate cotton price of $0.27/Kg, is equivalent to a 245% increase, from $0.11/Kg. This price suggests that adjusting for market distortions imposed by government policy; farmers would be able to sell their cotton at higher prices than they do. But, as result of those distortions, farmers receive inputs at subsidized prices on credit, and this credit is not completely recovered by the cotton companies, so they charge the credit losses as well as profit margin from that higher price, which result in a lower farm gate price of $0.11/Kg. Two problems can be visualized by situation:

First, the monopsony rights attributed to firms in environment where the government does not regulate the firm's behavior against abusive practices, encourage those firms to pay lower prices to farmers with the claim that those companies incur higher costs in providing inputs and services to farmers. As a point of comparison, from 2000-2002, when Mozambican farmers were paid an average price of $0.13/kg, other countries paid the following averages: Zambia $0.23/Kg; Zimbabwe $0.20/Kg; Tanzania $0.18/Kg; Uganda $0.19/Kg, Benin $0.27/Kg; Mali $0.25/Kg. To visualize this problem we refer to example of Dunavant paying something like $0.12/Kg in Tete, and $0.18/Kg right across the border in Eastern Province of Zambia. Clearly, the concession system has impact on prices paid. Second, the mechanism used by the government of Mozambique to define minimum price does not reflect the world market cotton prices (Strasberg, 1997), as consequence, the minimum price policy benefit more JVC's than cotton growers.

Cotton production, like that of all other crops, involves the use of farmers' household capital that usually does not enter in their balance sheet. This capital was evaluated at its opportunity cost, assuming that is equal to 10% of farmers' cost on purchased inputs. Since Bt cotton use less pesticides, it implies also labor savings as we observed in Chapter Five. Under economic analysis, both hired and family labor is evaluated at their opportunity costs. The family labor used for insecticide application represents only 6% of the total family labor, equivalent to a cost of $1.03/ha summing to $5.08/ha the total labor savings with Bt cotton. Table 6-1 summarizes the economic costs and benefits used in cotton production in Northern Mozambique (see Appendix I).

Table 6-1 Farm-gate economic cost summary in Northern Mozambique, 2003.

Item	Economic cost ($/unit)
COSTS[29]	
Bt cotton seed (Kg)	1.15
BENEFITS	
Insecticide (per application)	9.34
Labor (per adult equivalent day)	0.30
Opportunity cost of farmer's capital ($/ha)	0.78 to 0.40
Seed cotton (Kg)	0.27

Source: Author's computations based on Strasberg (1997), Howard et al (1998), MADER (2001b), and MADER (2003b).

[29] Similarly to chapter five, the refuge cost is incorporated in the output value.

6.1.3 NET ECONOMIC PROFIT FOR Bt COTTON

Table 6-2 summarizes the economic net incremental returns to Bt cotton by seeding week and number of insecticide applications. Contrary to what we observed in Chapter Five, the results in table 6-2 show that Bt cotton production will increase the net income of the society under both input use levels.

Similarly to what we observed in table 5-1, results in table 6-2 suggest that Bt cotton will be more attractive over conventional cotton with less use of insecticide. This pattern is due to the fact that with intensive pesticide use, less pesticide savings are obtained using Bt cotton. These savings are lower to offset the decreasing marginal returns to pesticides well captured by the estimation model. Shankar and Thirtle (2003) observed the same pattern with real data on Bt cotton in South Africa. The relatively higher incremental benefit when no additional insecticide applications are used is basically due to the fact that at this level a zero cost of pesticide is imputed.

The positive net incremental benefit on Bt cotton is driven by the insecticide cost savings of about $29.00/ha, labor savings of $5.08/ha, and seed cotton price of $0.27/Kg. Since Bt cotton uses less insecticide compared to conventional cotton, removing insecticide subsidies (economic price) will make Bt cotton more profitable than conventional cotton. This result turns out to be a benefit for cotton companies, which pay all input subsidies to farmers, but a disadvantage to farmers, who benefit from these subsidies.

Overall, the economic net incremental return to land for Bt cotton under typical practice is on average \$9.61/ha under low-input and \$11.30/ha under high-input use. This results in net returns of \$116.14/ha and \$228.36/ha under low and high-input uses; respectively (see Appendix I for indicative economic enterprise budgets).

Table 6-2 Economic returns to conventional and Bt cotton in Northern Mozambique by seeding week and insecticide use, 2003.

Level of input use		Items	Economic Net returns by seeding week ($/ha) (Bt – Conventional cotton)					
			3	4	5	6	7	8
LOW-INPUT USE	No additional insecticide application	Net returns to land ($/ha) for conv. Cotton	127.32	103.32	86.41	73.87	68.69	55.60
		Net returns to land for Bt cotton ($/ha)	142.47	117.86	100.50	87.55	81.85	68.64
		Incr. Net return to land ($/ha) for Bt	15.15	14.54	14.09	13.68	13.16	13.04
	One additional insecticide application	Net returns to land ($/ha) for conv. Cotton	126.24	106.53	88.80	75.44	65.08	56.35
		Net returns to land for Bt cotton($/ha)	137.20	116.14	98.53	85.31	74.69	65.88
		Incr. Net return to land ($/ha) for Bt	10.97	9.61	9.72	9.87	9.61	9.53
	Two additional insecticide applications	Net returns to land ($/ha) for conv. Cotton	123.90	97.99	79.72	66.09	55.18	46.18
		Net returns to land for Bt cotton ($/ha)	131.16	105.52	87.64	73.91	63.03	54.22
		Incr. Net return to land ($/ha) for Bt	7.27	7.53	7.92	7.83	7.85	8.04
	Three additional insecticide applications	Net returns to land ($/ha) for conv. Cotton	117.51	90.79	72.24	58.06	46.88	37.61
		Net returns to land for Bt cotton ($/ha)	122.83	96.66	78.27	64.54	53.40	44.59
		Incr. Net return to land ($/ha) for Bt	5.32	5.88	6.03	6.48	6.52	6.98
HIGH-INPUT USE	No additional insecticide application	Net returns to land ($/ha) for conv. Cotton	254.29	209.84	178.75	155.02	136.48	120.94
		Net returns to land for Bt cotton ($/ha)	274.36	228.77	196.64	172.29	153.12	137.32
		Incr. Net return to land ($/ha) for Bt	20.08	18.93	17.89	17.27	16.64	16.38
	One additional insecticide application	Net returns to land ($/ha) for conv. Cotton	263.69	217.06	184.61	159.79	140.43	124.34
		Net returns to land for Bt cotton ($/ha)	275.25	228.36	195.71	170.84	151.16	135.09
		Incr. Net return to land ($/ha) for Bt	11.56	11.30	11.11	11.05	10.73	10.75
	Two additional insecticide applications	Net returns to land ($/ha) for conv. Cotton	269.27	221.01	187.46	161.83	141.65	125.02
		Net returns to land for Bt cotton ($/ha)	274.83	227.17	193.75	168.36	148.41	132.09
		Incr. Net return to land ($/ha) for Bt	5.56	6.16	6.28	6.53	6.76	7.08
	Three additional insecticide applications	Net returns to land ($/ha) for conv. Cotton	272.40	223.05	188.14	161.96	141.24	124.33
		Net returns to land for Bt cotton ($/ha)	273.91	224.17	191.27	165.36	145.15	128.31
		Incr. Net return to land ($/ha) for Bt	1.50	1.12	3.13	3.40	3.92	3.98

Source: Author's computations based on Strasberg (1997), MADER Cotton growers Survey (2000), and MADER Cotton production Survey (2001).

Figures 6-1 and 6-2, highlights the positive impact of early seeding has on Bt cotton profitability. Moreover, these figures illustrate that either the net benefit or the incremental net benefit of Bt cotton under high-input is about twice that under low-input use level.

Figure 6-1 Financial and Economic Net Incremental Returns to Bt cotton by Seeding weeks with One additional Insecticide application in Northern Mozambique, 2003.

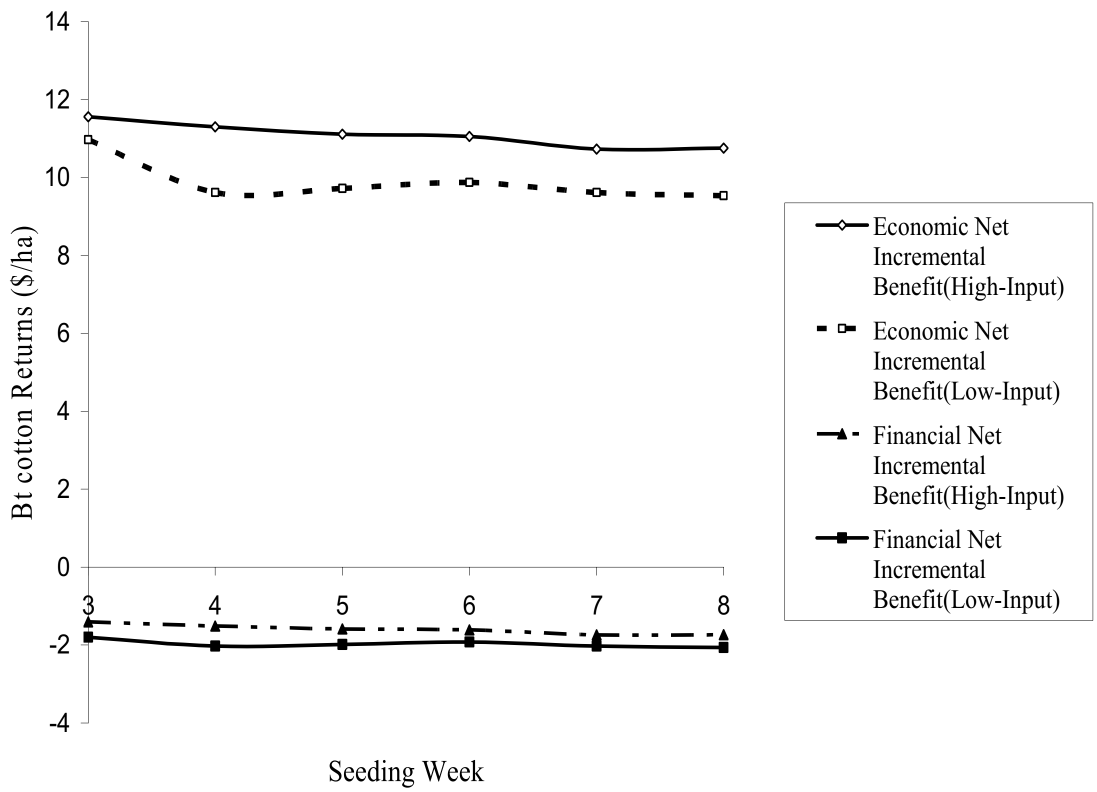
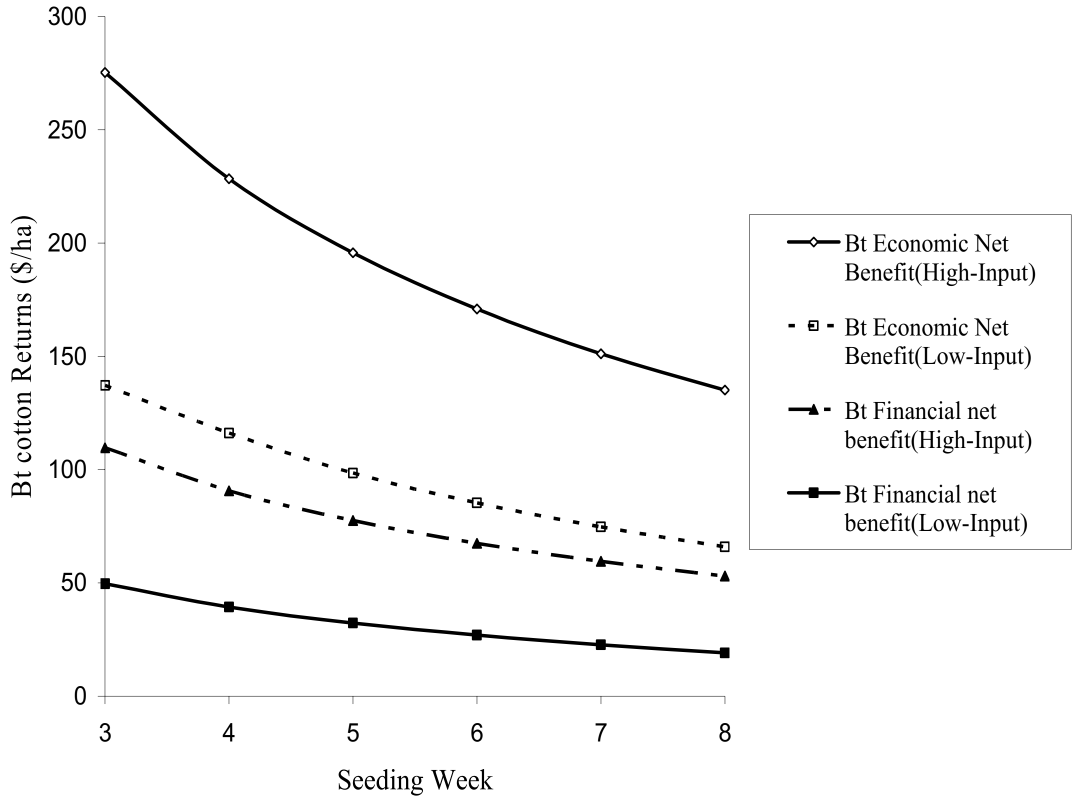


Figure 6-2 Financial and Economic Net Returns to Bt cotton by Seeding weeks with One additional Insecticide application in Northern Mozambique, 2003.



Comparing economic partial budget results with those obtained in Chapter Five, under typical practice, as shown in figure 6-3, one can observe that the net profit from Bt cotton for a private farmer is lower than that generated to the economy as a whole in all scenarios. Why? First, is because with subsidized inputs, the amount of input savings due to Bt cotton is lower. On contrast, when the subsidy is removed, the economy generates transfers, which add to the national gain. Transfers represent the value of the market and policy distortions in an economy. It is the difference between the financial and economic prices. For instance, with pesticide economic price of $9.34/application, a transfer of

$6.03/ha over the financial is created, which is a benefit for the society since it is part of the savings due to Bt cotton. The source of these market distortions is discussed in section 6.3.

Figure 6-3 Financial and Economic Returns to Bt cotton by number of insecticide applications on seeding week four in Northern Mozambique, 2003.

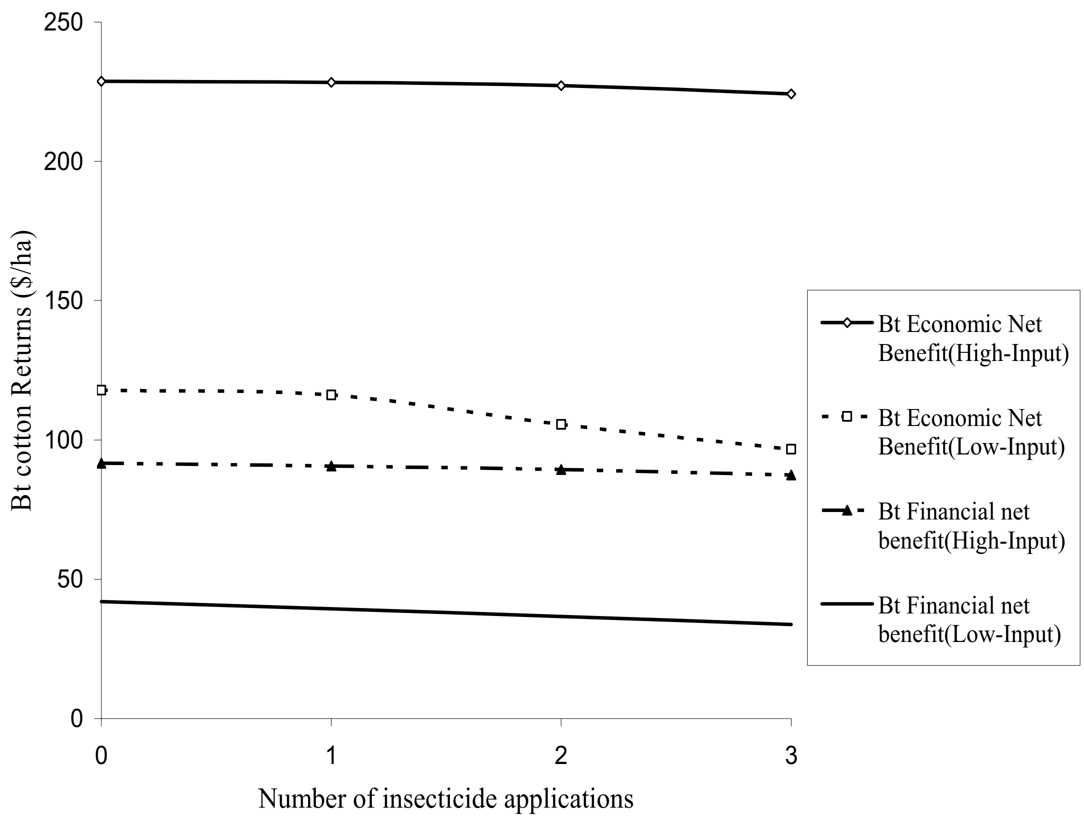
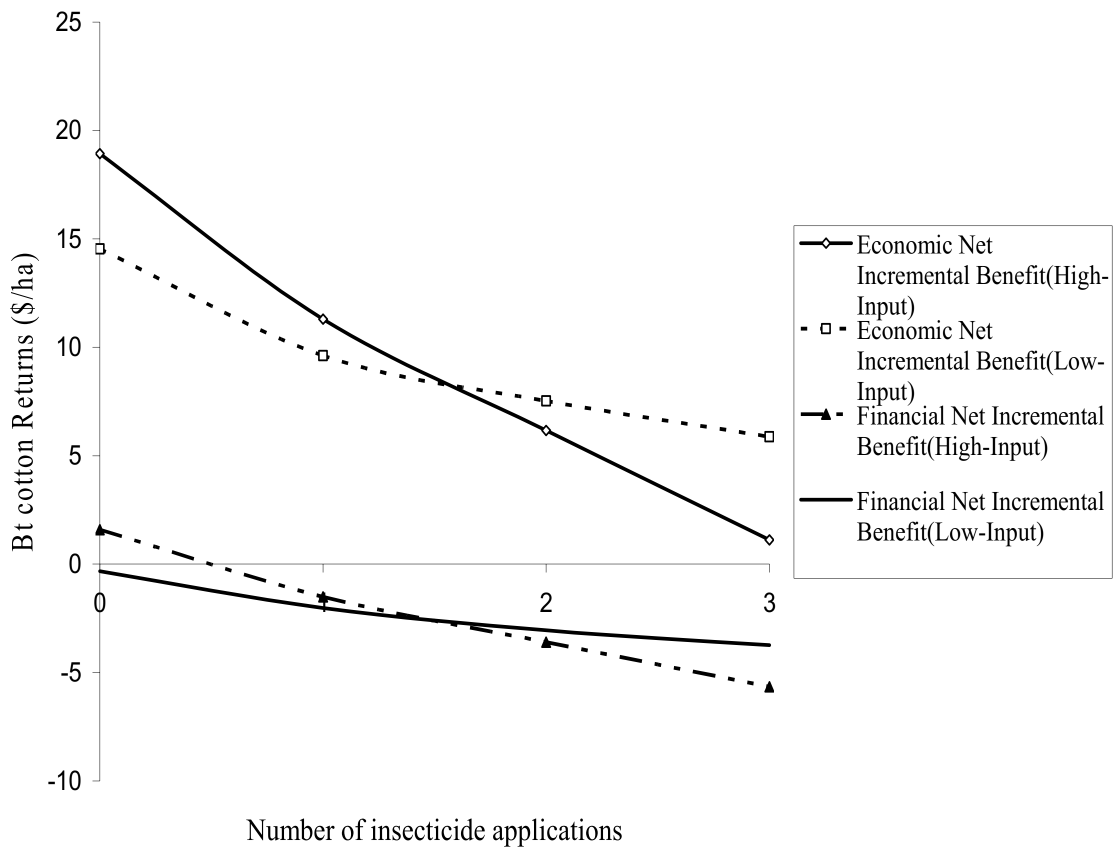


Figure 6-4 illustrates that the net incremental benefit for Bt cotton under high-input use level, decrease rapidly with insecticide application than under low-input. From this figure, we observe that while with one additional insecticide the net incremental for Bt cotton under high-input is greater than that under low-input, with two additional insecticide application, the low-input use level presents higher net incremental benefits than under high-input.

Figure 6-4 Financial and Economic Net Incremental Returns to Bt cotton by number of Insecticide applications on seeding week four in Northern Mozambique, 2003.



To conclude, Bt cotton with insecticide subsidies totally removed, and Bt seed price is not higher than $28.78/ha, Bt cotton becomes attractive for society as shown in figures 6-1 to 6-4. The low-input use systems perform better than high-input use with intensive use of insecticide.

6.2 SENSITIVITY ANALYSIS FOR SOCIAL PROFITABILITY

Since the net incremental returns for Bt cotton to the society is positive and more than 100% return to investment, we were interested in performing the sensitivity analysis to examine how much costs could increase or benefits decrease and still have the country break-even in economic terms. The switching values at typical practice are presented in table 6-3.

Table 6-3 Switching values by input use level, under typical practice in Northern Mozambique, 2003.

Variables of interest	LOW-INPUT USE	HIGH-INPUT USE
	Switching values (percent)	
Bt seed price	23	40
Bt cotton yield	-5	-2

Source: Author's computations based on Strasberg (1997), MADER (2000), MADER (2001a)

For the economy to break- even producing Bt cotton compared to conventional cotton, the Bt cotton yield would have to decrease by 5% to 808 Kg/ha under low-input and by 2% to 1,454 Kg/ha under high-input.. Regarding the Bt seed price, the maximum Bt seed price that the society would be willing to pay is $35.40/ha (23% increase) under low-input and $40.29/ha under high-input. These figures are lower compared to Bt seed price of $ 50.00/ha (SAR 350) and Technology Fee of $107.00/ha (SAR 750) that

Monsanto charges to South African farmers as indicated by Wally (2004). This suggests that Bt cotton production will neither be profitable to farmers nor to the Mozambican economy if these prices were to be applied in Mozambique. This has a political implication, which is to the government provide seed at lower cost to the society. How? Discussion on this issue is beyond the scope of the present research but Everson (2004) suggest two mechanisms by which modern GMOs can affect productivity in developing countries, including *"Gene for Rent"* where the recipient country agrees with a GMO company to incorporates the trait in local varieties and pay the technology fee, and the *"Transgenic Breeding"* mechanism in which National Agricultural Research System breeders use modern technology to produce GMO traits of economic value in crop varieties. In a resource-poor country like Mozambique, spending government funds in research like this has to be well justified. According to Evenrson (2004) and Bennett et al. (2001), only few developing countries are positioned to pursue such mechanisms (notably China, India, Brazil, Argentina, South Africa, and Kenya).

From the two situations we just described, one can see that Bt cotton production in Mozambique is much more sensitive to Bt yield than to the Bt seed price. So, more efforts would be devoted on yield improvement, seeking for alternatives to improve cotton productivity and increase cash income to smallholders that also guarantee positive social profitability than to concentrate on Bt seed price, which require a complex mechanism as noted by Evenson (2004) and Bennett et al (2001).

6.3 NET TRANSFERS

Gittinger (1982) defines transfers as representing shifts in claims to goods and services from one entity to another and do not reflect changes in national income. For instance, in the case of subsidized seed and pesticides, farmers simply pay lower price, reducing his cost, and thereby increases his net benefit. In the economic analysis, when removing these subsidies, the direction of transfer shift is from farmers to cotton companies or government. The higher cotton price represents transfer of resources from cotton companies to farmers if this is full paid by cotton companies, but can also represent a direct subsidy by the government that is added to what farmer receives in the market. Therefore, removing seed and pesticide subsidies and other types of distortions, represents a loss but it is a gain to cotton companies or government, whereas removing distortions in cotton price will represent a gain for farmers but losses for cotton companies or government. The net transfer is calculated as the difference between the gains and losses The average net transfers resulting from market distortion adjustments under low-input is $7.98/ha and under high-input use level is $9.29/ha. These transfers are basically composed by input subsidies, especially in pesticides, labor savings and import/export taxes removed from the financial prices resulting in increased revenues. The table 6-4 summarizes gains, losses, and the resulting net transfers within the economy.

Table 6-4 Total net transfers in the national economy with Bt cotton production, 2003.

Level of input use	Item	Gains ($/ha)	Losses ($/ha)	Net Gain ($/ha)
LOW-INPUT USE	Revenues	1.04		
	Pesticide	18.09		
	Labor	1.03		
	Bt seed cost		12.18	
	Total	20.16	12.18	7.98
HIGH-INPUT USE	Revenues	2.32		
	Pesticide	18.09		
	Labor	1.03		
	Bt seed cost		12.18	
	Total	21.44	12.18	9.26

Source: Author's computations based on Strasberg (1997), MADER (2000), and MADER (2001a).

The lower contribution of revenues on gains is also due to yield difference as resulted from the establishment of refuge to slow down the development of pest resistance to Bt toxins. Table 6-4 also indicates that the production of Bt cotton results in an average loss to the economy of $12.18/ha due to higher Bt seed price.

Adopting Bt cotton for benefit of society, has a diverse set of benefits and costs such as: 1) removing the market distortion on cotton price, farmers benefit from having the possibility of selling their cotton at higher price. They also lose the opportunity of getting subsidized inputs (especially pesticides), but because Bt cotton uses less insecticide, farmers end up absorbing those pesticide cost savings using Bt cotton. Note that only the efficient farmers are likely to benefit from Bt cotton as found by Gouse et al (2002) in South Africa. With the establishment of refuges in cotton fields, the society in general will be better off in sense that the resistance will be delayed. Now, we ask to what extent the society in general would be worried about pest resistance in cotton if the Bt cotton was not introduced, 2) the JVC's are likely to pay higher cotton price, but because most of them have their own ginners, they are likely to observe gains in volume of yield processed that can reduce variable costs (economies of scale). By introducing Bt cotton, new input delivery structure is likely to be launched, this can increase their management cost in short run, but it can be compensated in the long run by volume of cotton processed. As we observed in table 6-4, pesticide savings are the larger part of the gains, cotton companies will benefit from removing the subsidies, since they are the ones that covers these subsidies (70%). The pesticide subsidies amount $4 million in 225,311 ha on cotton production in Mozambique. Introducing Bt cotton will cost them to establish new input delivery structure, resulting in increased management cost in short run, but it can be compensated in the long run by higher volume of cotton processed. The JVC's are likely to benefit from removing the subsidies, since they are the ones that cover the whole subsidies (70%), and 3) the Government is likely to lose on cotton export and input import duties, but since new business opportunities can be created, the government can still generate revenues from licensing fees, and value added tax from increased sales of Bt seed and other inputs.

CHAPTER SEVEN

SUMMARY, KEY FINDINGS, POLICY IMPLICATION, STUDY LIMITATIONS, AND RECOMMENDATIONS

7.1 SUMMARY OF OBJECTIVES, FRAMEWORK, AND STUDY CONTRIBUTION

The objective of this study was to analyze the potential economic impacts from adopting Bt cotton in Mozambique. More specifically, we analyzed 1) benefits to farmers, and 2) benefits to the economy as a whole. To address the research objective outlined above, we first estimated mean conventional and Bt cotton yield using a regression model, followed by the partial budgets to estimate the net incremental benefits from adopting Bt cotton for farmers and for society. Given the limitation of the partial budget approach in providing estimates of net returns, we complemented the analysis by developing enterprise budgets (See Appendix J).

This study is the first attempt to analyze the potential economic benefits of introducing Bt cotton in Mozambique. It makes a methodological contribution by illustrating an approach to conduct an *ex-ante* analysis with limited information on pest management practices. This approach can be useful in benefit to other developing countries with smallholder cotton production, who may want to assess the potential benefits of Bt cotton where similar data limitations may complicate predicting the potential economic benefits of Bt cotton. The estimates presented in this study are preliminary and should be refined as more information becomes available, especially regarding factors not included in the analysis.

7.2 SUMMARY OF FINDINGS

The main findings of the study are:

- **Under current practices, especially low level of insecticide applications, adoption of Bt cotton is not expected to increase net income for farmers**. For Bt cotton to be attractive to farmers, its yield including refuge loss would need to increase to 826 Kg/ha (6%) and to 1,488 Kg/ha (3%) under low and high-input use, respectively. Alternatively, the Bt seed price would have to decrease at least by 17%, to $13.78/ha. These results are driven by the estimated Bt cotton yield effect. The estimated yield gain from Bt cotton in this study is lower compared to what recent experiences have reported so far in developing countries such as China, India, and South Africa, which obtained yield gains of 6% to 80%. The high yield gains obtained in some of those countries are attributed primarily to effective control of bollworms provided by Bt toxins, which are active throughout the growing season, irrespective of level of infestation (Edge, J. et al, 2001). Our estimation approach did not capture this full effect. Instead, only the lower bound of Bt toxins effect was captured. Lower Bt cotton yield gain is also partly due to lower pest infestation in Mozambique, where farmers with only three insecticide applications obtain higher yields than what South African farmers obtained with higher application rates. If farmers were using recommended pest management practices (higher application rates), it is likely that Bt cotton would be attractive to them because there would be more savings of pesticide costs.

- **Many other factors could be affecting the level of yield gain besides bollworm infestation level and input market failure.** Qaim and Zilberman (2003) have hypothesized high yield effect in countries with high pest pressure and weak input-markets, such as in Southern Africa and areas of Asia. Mozambique and South Africa are located in a medium- to high lepidopteran pest infestation zone where theoretically we would expect to see high to reasonably high yield gain, but the evidence in this study is not conclusive, although South African experience has shown higher yield gain.

- **Mozambican farmers have lower production costs under the low-input use regime ($0.08/Kg) compared to farmers in South Africa ($0.15/Kg excluding weeding labor), and Argentina ($0.13/Kg).** These lower production costs mean that profits could increase substantially if yields are improved while controlling costs, taking into account that all inputs are under-used.

- **From society's point of view, Bt cotton appears to increase net income to the Mozambican economy under both input use levels**. Yields could fall as much as 5%, to 808 Kg/ha under low-input and by 2%, to 1,454 Kg/ha under high-input, and the country would still break even. The society also will observe gains from adopting Bt cotton with seed cost as high as $35/ha and $40/ha under low and high-input, respectively.

7.3 POLICY IMPLICATIONS

The key research finding of this study is that, if farmers were to pay economic cost of pesticides and be paid export parity prices for seed cotton, they could pay the economic cost of Bt seed and still earn more profit with Bt than with conventional cotton. In fact, due to lower pesticide use in Bt cotton, its advantage over conventional is higher when farmers pay full pesticide costs, which is more likely to be achieved with more competition. The need for more competition is driven by the finding that the economic price of raw cotton is far above what companies are actually paying. This very low price paid to farmers inhibits the adoption of new cotton technology, including Bt cotton, which is likely to affect the coordination along the product chain. Boughton et al. (2002) and Tschirley and Zulu (2003) analyze the key performance dimensions for the cotton production chain in several African countries, including the level of productivity and quality achieved throughout the chain and the extent to which it pays a competitive share of the chain's total value-added found that there is a need to find an effective balance between the often conflicting needs for coordination and competition in the sector as illustrated by the Zambian experience. Based on the fact that Mozambique presents lower average export value and lowest average producer share of any Southern African (SA) country (Boughton et al. 2002), the challenge for Mozambican's cotton sector can be conceived as how can it generate a workable level of competition while strengthening the coordination that is needed to increase export value per hectare. In the presence of lower productivity as noted earlier by Pitoro et al. (2001) due to inadequate technical assistance provided by cotton companies and lower seed quality, there is an urgent need for a strong collaboration between government, private companies, and farmers to build an institutional policy environment that encourages technology renewal, helps solve endemic rural credit market failure, and ensures necessary coordination to meet strict quality requirements of modern spinning and weaving technology (Boughton et al., 2002). This partnership should facilitate obtaining funds to invest in the main areas of the suggested public/private partnership such as 1) development and multiplication of new varieties (including biotechnology research), 2) implementation of pest management, and 3) update the grading system.

1. **Based on the key findings of the study, an issue of concern is how to open the sector to greater competition while not exacerbating credit repayment problems taking into account the impact of the concession system in cotton pricing policy in Mozambique.** In principle, the simple policy (liberalization or regulated monopoly) is not sufficient for cotton sector achieve desired performance in the absence of rural input and credit markets. Thus, identifying the elements of joint public/private strategies is necessary to improve cotton sector performance as indicated above**.** The varying experiences in Africa suggest that some level of competition does not necessarily worsen credit repayment as long as there is a favorable environment for innovation in the input

distribution and credit systems. Zambia and, until recently, Zimbabwe have been good models of relatively concentrated but competitive systems that combined good prices to farmers with effective input delivery and credit repayment.

Boughton et al. (2002) indicate that Mozambique's experience shows that a high level of policy-induced coordination is a necessary but not sufficient condition for innovations where participation is imbalanced and dialog is not transparent. Therefore, two new institutional innovations might help such as: 1) incentive-driven performance contracts between the government and cotton companies with transparent reporting of results, and 2) the transfer of government shares in JVCs to farmers, with support from cotton trust to act on behalf of the new farmer shareholders.

Elimination of price fixing by government would remove one source of intense conflict in the sector, and would also allow IAM to spend more time on productive activities to improve sector performance.

2. Establish a favorable GMO policy. Currently, GM seeds are forbidden by law in Mozambique. The adoption of Bt cotton depends on the legal approval of commercialization of GM seed. Mozambique does not have a comprehensive biosafety regulatory framework in place and is unlikely to have one in the near future (Wally, 2004). The recently created working group for this purpose has only three years of existence and it still in its infancy. To have a full biosafety regulation in place is a challenging activity and requires a considerable amount of time and effort so, there is a need to develop a basic framework for a pragmatic approach that will allow forward movement before a full biosafety framework is in place. This approach should consist of:

(a) Initial identification of priorities: This part of the framework will help to ensure that resources are dedicated to biosafety procedures that best serve the country's most relevant need. The step-by-step basis could be adopted, including confined small- and large field trials of GMOs, and finally unconfined release of a GMO. The step forward would be to recognize that biotechnology in nonfood cash crop like cotton raises fewer controversial issues than it does in maize, and to move forward with a framework that would allow the testing of Bt cotton.

(b) Design of framework for implementing biosafety: In this phase, the recently formed Biosafety working group should benefit from McLean et al.'s (2002) paper that lays out the linkage between policy, capacity, and regulation based on the experiences from other countries in Africa. Regarding regulation, the biosafety working group should bear in mind that regulation does not need to be a restrictive activity, rather a protective one, information provider, and development facilitator of a certain area.

(c) Identification of priorities for training and capacity building: The steps (a) and (b) should illuminate needs for training and capacity building. In this phase, the task would to be identify specific people in Mozambique who have required the skills, and find resources. The UNEP-GEF Project on Development of National Biosafety Frameworks is one potential source of long-term support for development of national biosafety capacity.

3. Establishing a *"closed-loop"* system. Under current practice, farmers are not explicitly charged for cotton seed. This practice would need to change if Bt cotton is to be introduced. The "closed-loop" system intends to provide assurance to the GM company, through an organized system, that the seed would not be replanted by farmers, instead bought every year. The current input delivery system consists of cotton companies delivering inputs to farmers. The cotton seed would be distributed in the same way other inputs are delivered currently, but farmers would need to be educated in such a way to recognize that the cotton seed is not free. This would ensure that the GMO company or its partner in the country trace all Bt cottonseed by-product from ginning through to final use.

If Mozambique could ensure a closed-loop system, and give regulatory approval, then the country could access Bt seed. But, the challenge is that establishing a "closed-loop" system requires a fairly high level of institutional sophistication – good organization and management, good use of information – which Mozambique will not easily attain. So, just as the country needs to take a step-by-step, pragmatic approach on biosafety regulation (as indicated above), in this case moving forward just on one crop, it needs to take a step-by-step approach in creating and operating a closed-loop system. This approach could be implemented under focused regulations that allow testing of Bt cotton, then by experimentation in farmer fields along with testing of a closed-loop system. Hence, this approach would benefit from the available research project designed by University Eduardo Mondlane (UEM) and cotton company (AGRIMO) with the objective to test Bt cotton (evaluating its production costs and adaptability).

7.4 LIMITATIONS OF THE STUDY

This study relies on a dataset that was collected with the desire to understand the effects of cash-cropping on smallholder income, not with the objective of comparing alternative pest management strategies, which is the focus of this study. Consequently, it gathered partial information on pest management, and as result, that two functional forms that seem most suitable from theory generated opposite coefficient signs inconsistent with expectations, forcing reliance on the simpler Cobb-Douglas model. Data specifically collected to assess pesticide productivity would improve the empirical results of the study. The estimated average yield gain that turns Bt cotton attractive to farmers is 6%, well within the confidence interval around the BOLLW yield function coefficient of 0.150 (95% c.i. = [0.023 – 0.283]).

The appropriate dataset for this study should have had information on pest management practices, including what material was sprayed in each spray (quantity of active ingredient); what was the target insect, timing of each application, and pest pressure at the time of application.

In addition to data limitations, it is likely that estimated Bt cotton yields are affected by the environment in which the estimates were generated. These data were collected under actual farmer practices, which are known to be far less than optimal with regard to pest control. Specifically, farmers at the time of this data collection had relatively little knowledge about scouting and proper timing of pesticide application. As a result, the marginal productivity of pesticides in this data set is likely to be much lower than it would be under optimal practices – and lower than that achieved by Bt cotton which has continual presence of the toxin.

The final judgment of the impact of Bt cotton has to take into account other factors not included in the analysis such as the biosafety risks that Bt cotton may have, including the non-market effects on health and environment, including the impact on the ecosystem. Edge et al., (2001) for instance indicate that the reduction of broad-spectrum insecticidal sprays reduces harm to beneficial insects. These authors also indicate that the reduction in insecticide use due to Bt cotton reduces the direct contact of birds and other types of wildlife with insecticides, runoff of insecticides, air pollution, and related waste. Therefore, more focused research is still needed to fully assess the economic, environmental, and social benefits and risks of Bt cotton as discussed in the next section.

7.5 RECOMMENDATIONS FOR FURTHER RESEARCH

The analysis in this paper implicitly assumes that the Bt traits are integrated into existing cotton varieties in Mozambique. In fact, integration is not likely to happen unless the country pays a fee to a company to do this work. Zilberman (2004) notes that when the local variety is modified genetically, the combination of the genetic modification and chemicals will reduce pest damage, thus increasing output. Therefore, there is a need to evaluate what the likely value of such a fee would be and whether it would still be profitable for the country to pursue Bt.

These existing Mozambican cotton varieties are hairy and thus have reasonably good resistance to sucking insects, but their yield potential is very low. Therefore, it is worthwhile to determine the profitability of Bt cotton if better varieties were available for integrating the Bt trait.

More research into why plantings are so often delayed in farmer fields would also have a high payoff. As we estimated, the marginal product for a one week delay in planting is equal to 94 Kg of yield loss, which corresponds to a financial loss of about $10/week at a farm gate price of $0.11/Kg. Farmers planting two or three weeks late have yield losses of 39% and 52%, respectively. Given that the average farmer in Mozambique performs crop management practices such as land preparation, planting, weeding and spraying with 30 days of delay, the impact of late seeding becomes an important factor to consider. Many factors could be determining the seeding date, and so more research is needed. This research objective would fit well with the new socio-economics unit to be established in the consolidated agricultural research institute, *Instituto de Investigação Agrária de Moçambique (IIAM)*.

Producing cotton in Mozambique is almost impossible without the use of pesticides, which poses serious environmental impacts. It would be useful to complement this study by evaluating the environmental impact of pesticides, given that pesticide savings from Bt cotton use could result in an environmental benefit for the society. Environmental concerns on Bt cotton are gene flow to wild relatives that can possibly result in economic consequences since crop-to-weed flow can promote the evolution of more aggressive weeds. So, we recommend assessing the possible harmful effects on the environment.

Although the pesticide cost in Mozambique to farmers is lower than its economic cost, farmers still use these chemicals at less than optimal rates. Some possible reasons are discussed in this thesis but none of them are scientifically tested in the case of Mozambique. So, we recommend that research be done on factors determining the low insecticide application rates.

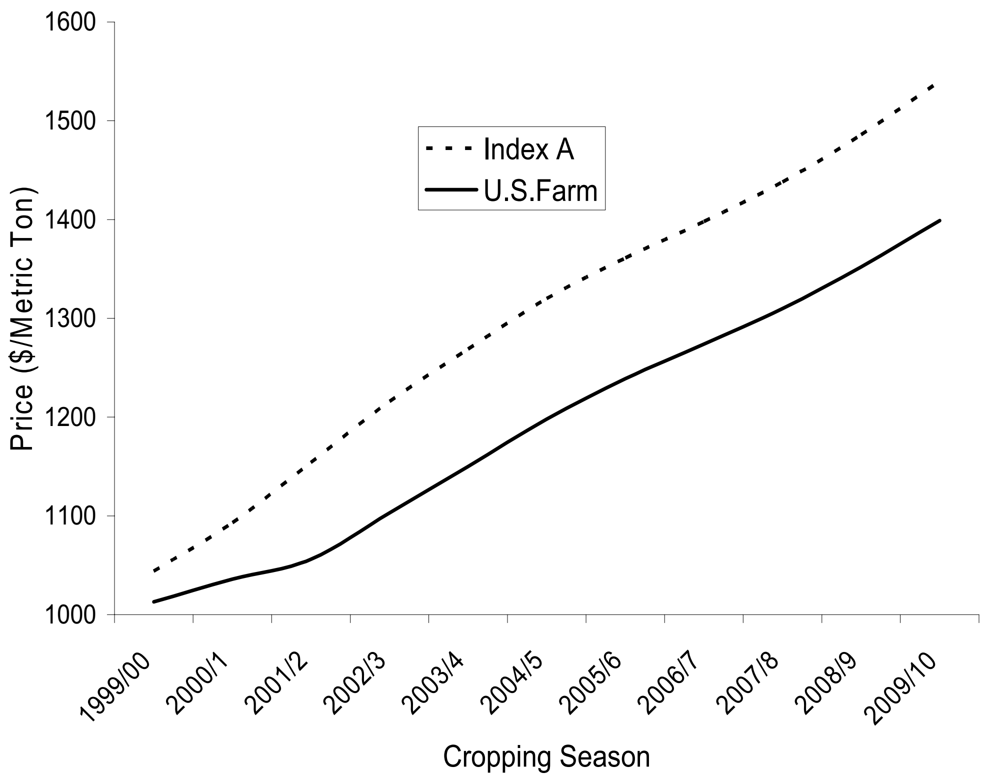
This study did not perform a risk analysis of the probability of various outcomes from the adoption of Bt. We recommend that to complete this research, a risk analysis could be carried out.

Finally, according to Schmitz (2004), when assessing benefits and costs of GM crops as we do, the size of segregation costs and trade implications are important. Our results indicate that Bt cotton is attractive from society's point of view. However, Mozambique exports lint to European Union (EU) members, which have strict treatment of GM crops, and so logical questions are: 1) to what extent will the adoption of Bt cotton in Mozambique result in possible trade "barriers" from EU, and 2) what is the magnitude and nature of gains expected from trade. This is one potential area for further research because its outcome will help to decide whether or not Mozambique will gain from trade by adopting GM technology. Tothova and Oehmke (2004) observe that for food-insecure countries, the trade implication can force tradeoff between maintaining export market and food availability.

APPENDIX A

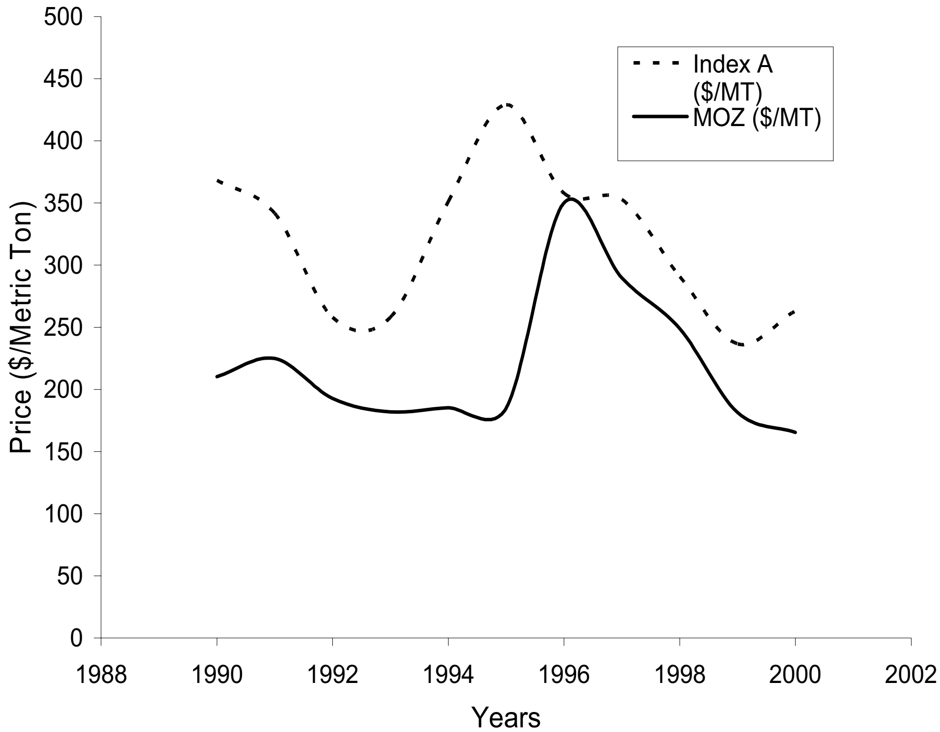
World Price Projections

Figure A-1 Cotton Price Projections



Considering the average cotton price projected in the next 6 years ($1,423.80/ton), result in farmer price in Mozambique of $0.63/Kg.

Figure A-2 Cotton Price Trend between 1990 and 2000.



Formulae used to calculate the farm gate cotton price in Mozambique

Cotton price (Mt/Kg) = {(INDEX A – Qdiff.)*COVER *OER + SEEDCOST}*55%
Where:
Qdiff. = quality difference based on cropping (for season 1999/00 = 4.12 cents/Lb)
OER = official exchange rate,
SEEDCOST = 1.2 Kg of seed (by product) evaluated at 850 Mt,
CONVER = conversion factor from Lb to Kgs (2.22046),
Freight and insurance is assumed to be 10 cents/Lb

APPENDIX B

Questionnaire

Ministério de Agricultura e Desenvolvimento Rural
e
Universidade Estadual de Michigan

<u>Percepções sobre Algodão Transgénico ("*Bt cotton*")</u>

Entrevista aos informantes-chave
[Melhoradores, empresas de Agroquímicos, empresas algodoeiras e pesquisadores]

Julho - Agosto de 2003

AVISO

A sua participação nesta intrevista é inteiramente voluntária. Qualquer informação que fornecer será tratada com sigilo e confidencialidade de acordo com o <u>Decreto 12/82 de 22 de Julho de 1982</u> e, em nenhuma circunstancia o seu nome sera associado a nenhuma resposta.

VARIÁVEIS DE IDENTIFICAÇÃO

Provincia	**PROV**	
Distrito	**DIST**	
Nome da empresa	**COMPAN**	
Tipo de empresa (Marque com circulo)	**SERV**	1-pesquisa/entomologia, 2-Agroquimicos, 3-empresa algodoeira, 99-outra (especificar)
Nome do respondent	**RNAM**	**S/Funcao:**
Data da entrevista	**SURDAT**	

As Plantas geneticamente modificadas constituem um centro de acesos debates da actualidade acerca da utilidade da agricultura biotecnologica (Pray and Ma, 2001). Enquanto as grandes empresas em biotecnologia como a Monsanto e as organizações de indústrias biotecnológicas acreditam que a agricultura biotecnologica pode ser uma alternativa para resolver os problemas de pobreza bem como os de uso intensivo de pesticidas, os contra biotecnologia argumentam que plantas geneticamente modificadas constituem um perigo para o meio ambiente e não estão desenhadas para ajudar os pobres se tiver em conta o seu preço. ***<u>O objectivo do presente estudo e de colher a sua opiniao sobre alguns assuntos que polarizam estes debates bem como judar a perceber melhor o possivel impacto que o algodao transgenico podera ter em Mocambique</u>***.

QAA1. Por favor, poderia descrever sumariamente a sua empresa no que concerne a:

a. Ano de fundação____

b.Que serviços providencia aos camponeses?____________________________________

c. Alguma vez a sua empresa teve que ajustar a sua estrutura para melhor responder as necessidades do campones? Que ajustamentos fez?_______________________________________

QEAA6. De acordo com a sua experiência, quais são as pestes mais problemáticas no algodão em Moçambique e como poderia minimizar o seu efeito?

(Sabendo-se que o efeito das pragas pode variar consoante as condições agro-climáticas, poderia fornecer informação para cada tipo de estação: **Os tipos de estação são: Ano normal, seco e húmido)**

Tabela para Ano normal

Pestes	Período de incedência	Danos causados (max. rendimento perdido)	Condições favoraveis	Locais de alta incidência (distritos)	Pesticidas sao apripria-dos	Quando aplicar pesticidas ?

Tabela para Ano Seco

Pestes	Período de incedência	Danos causados (max. rendimento perdido)	Condi-ções favoráveis	Locais de alta incidência (distritos)	Pesticidas apropriad os	Quando aplicar pesticidas ? (Semana e mês)

Tabela para ano chuvoso

Pestes	Período de incedência	Danos causados (max. rendimento perdido)	Condi-ções favorá-veis	Locais de alta incidência (distritos)	Pesticidas apropriad os	Quando aplicar pesticidas ?

QAA8.Quais são os pesticidas que a sua empresa importa e/ou distribue aos camponeses?

Nome do pesticida	Classe (I, II, III or IV)	Conteudo de ingrediente activo

QAA9. Quais os custos envolvidos na importaçao de agro-químicos?

Custos	**Preço por ton**
Preço FOB em _______________ (U.S. $)	
Frete para o local de importação (U.S. $)	
Desembarque no local de importação (U.S. $)	
Seguros	
Custos de porto local	
Custos de transporte e comercialização ate o mercado grossista	
Custos de transporte e comercializaçao até o mercado retalhista	
Armazenamento	

FALEMOS AGORA SOBRE O ALGODÃO TRANSGÉNICO

QEAA3a. Terá ouvido falar de algodao transgénico?_____________________________________

QEAA3. Quais são as expectativas em relação ao desempenho do algodão transgénico (*"Bt cotton"*) em Moçambique?____

QE4. Tem alguma ideia de variedades que possam estar adaptadas a condições de Moçambique ou similares? (Por favor forneça informação mais detalhada sobre elas na tabela abaixo)

Variedades	Empresa produ-tora	Preço da semente	Nível de resistência a pestes. 0 nenhum 1 baixo, 2 médio 3 alto	Rendi-mento (Kg/ha)	Exigên-cias em pesteci-das (no. de aplica-ções)	Pesticidas mais apropria-dos	desvanta-gens

QE5. O que poderia recomendar para minimizar o efeito de resistência das pestes ao algodão transgénico (*"Bt cotton"*)?

1. Cultura hospedeira
2. Alta dosagem do CryA1 na formulação das variedades
3. Ambas
4. Outra (especifique) ____

Justifique as suas opções:____

QEAAGov10. Em caso de se passar a produzir algodão transgénico em Moçambique, quais seriam as vantagens, desvantagens que dai poderiam surgir, como é que a sua empresa seria afectada e como poderia reagir face ao choque?

	Campo-neses	Empresas algodoeiras	Empresas de Agro-químicos	Pesquisa-dores	Governo (Instituto de Algodão)
Vantagens					
Desvan-tagens					
Soluções					

QAA11. Quais seriam as condições necessárias para a sua empresa adoptar o algodão transgénico?____

QAA12. Se o camponês tivesse que pagar o custo real de cada serviço prestado pela sua empresa, quanto lhe custaria:

a. Pulverizadores ______________
b. Pesticidas_______________
c. Serviços de extensão_____________
d. Crédito____________________
e. Outros____________________

QAA13. Qual destes serviços a sua empresa subsidia ao camponês e qual e o valor subsidiado?

a. Pulverizadores ______________
b. Pesticidas_______________
c. Serviços de extensão_____________
d. Crédito____________________
e. Outros____________________

Q14. Comentários:____

APPENDIX C

Selection bias test

Table C-1 Cotton Yield Regression coefficients in Northern Mozambique, 2003.

Variable	Equation 1[30]			Equation 2[31]		
	Coef.	S. E.	p-value	Coef.	S. E.	p-value
ln (TOTWAE)	0.44	1.289	0.001	0.43	0.129	0.001
ln (HERB)	0.62	0.269	0.024	0.56	0.263	0.036
ln (MAIZE YIELD)	-0.08	0.082	0.333			
VILMTZ1	1.46	0.590	0.015	1.45	0.590	0.015
VILMTZ2	1.53	0.612	0.014	1.52	0.612	0.014
VILMTZ4	1.07	0.612	0.084	1.07	0.612	0.082
VILMTZ5	2.02	0.704	0.005	2.07	0.702	0.004
VILMTZ7	1.23	0.624	0.051	1.28	0.621	0.042
VILMEC2	1.74	0.574	0.003	1.74	0.574	0.003
VILMON1	1.71	0.625	0.007	1.72	0.624	0.007
VILMON4	1.89	0.601	0.002	1.89	0.602	0.002
VILMON5	1.54	0.680	0.025	1.57	0.680	0.023
VILMON6	2.05	0.824	0.015	2.06	0.824	0.014
Constant	4.03	1.18	0.001	3.61	1.09	0.001
Ln (YIELD)= Dep. Var.	N=122, F-value =5.79, p-value=0.000 Adj. R-square = 0.4767			N=122, F-value = 6.02, p-value = 0.000 Adj. R-square =0.4769		

Source: Author's computations based on Strasberg (1997)

From the results presented in the two regressions we observe that maize yield (instrument for selection bias) is not significant although has negative sign. Thus, we decide not to worry much about selection bias.

[30] Variance-Weighted Least Square Regression of Cotton yield excluding maize yield.
[31] Variance-Weighted Least Square Regression of Cotton yield including maize yield.

APPENDIX D

Village Identification

Table D-1 Definition of the village dummy variables

Variable	District	Village Name	Frequence[32]
VILMTZ1	Montepuez	Macarranga	30
VILMTZ2	Montepuez	Nacuaia	12
VILMTZ3	Montepuez	Nacuca	37
VILMTZ4	Montepuez	Nropa/Mondiane	15
VILMTZ5	Montepuez	Nacimoja	5
VILMTZ6	Montepuez	25 de Setembro	4
VILMTZ7	Montepuez	Linde	10
VILMEC1	Meconta	Napipine	17
VILMEC2	Meconta	Varrua	1
VILMEC3	Meconta	Napita	2
VILMON1	Monapo	Mepine	21
VILMON2	Monapo	Natete	13
VILMON3	Monapo	3 de Fevereiro	20
VILMON4	Monapo	Namacopa	18
VILMON5	Monapo	Nacololo	7
VILMON6	Monapo	Picadane	3

Source: Adapted from Strasberg (1997).

[32] Total of 215 cases.

Table D-2 Regression coefficients for village dummy variables in Northern Mozambique, 2003.

	Quadratic			Translog			Cobb-Douglas		
Variable	**Coef.**	**S. E**	**p-value**	**Coef.**	**S. E**	**p-value**	**Coef.**	**S. E**	**p-value**
Vilmtz1	-168.7	221.7	0.448	0.19	0.360	0.598	0.41	0.372	0.273
Vilmtz2	-128.0	240.0	0.595	0.21	0.39	0.588	0.62	0.407	0.132
Vilmtz4	-370.1	239.5	0.201	-0.06	0.386	0.886	0.12	0.400	0.757
Vilmtz5	93.4	259.3	0.719	0.79	0.425	0.065	1.05	0.441	0.019
Vilmtz6	-543.7	282.3	0.056	-0.98	0.459	0.034	-0.97	0.479	0.045
Vilmtz7	-160.6	243.9	0.511	0.17	0.407	0.676	0.50	0.421	0.239
Vilmon1	-157.7	225.1	0.484	0.24	0.363	0.499	0.43	0.378	0.253
Vilmon2	-354.1	458.4	0.441	-0.46	0.722	0.524	-0.53	0.754	0.483
Vilmon3	-371.9	221.7	0.095	-0.32	0.355	0.373	-0.18	0.372	0.634
Vilmon4	28.2	226.5	0.901	0.29	0.363	0.428	0.65	0.372	0.081
Vilmon5	-110.2	243.4	0.651	0.36	0.393	0.364	0.59	0.409	0.154
Vilmon6	-179.4	279.3	0.522	0.40	0.452	0.378	0.57	0.472	0.227
Vilmec2	35.7	221.6	0.872	0.53	0.354	0.136	0.68	0.370	0.069
Vilmec3	-301.4	233.8	0.199	-0.24	0.372	0.525	0.01	0.385	0.970
Dependent Variable is Yield in Kg/ha	Adj R^2 = 0.5561 F(31,183) = 12.66 Prob > F = 0.0000			Adj R^2 = 0.5408 F(30,184) = 11.50 Prob > F = 0.0000			Adj R^2 = 0.4925 F(24,190) = 9.60 Prob > F = 0.0000		

Source: Author's computations based on Strasberg (1997).

APPENDIX E

Mackinnon, White and Davidson test (MWD) for Non-nested models

To illustrate the test, assume the following:

Ho: quadratic model: Yield is a function of regressors, the X's

H1 Translog model: lnYield is a function of logs of regressors, the logs of X's

Step 1: We estimated the quadratic model and obtained predicted values, h_0.

Step 2: We estimated the translog model and obtained its predicted values, lnh1

Step 3: we computed $z_1 = lnh_1 - lnh_0$

Step 4: regressed of log Yield on X's and z1 in the translog model. We rejected Ho if the coefficient z1 is statistically different from zero by the usual t-test, then the translog is not the true model.

Step 5: we computed z_2 = (antilog of lnh_1-h_0)

Step 6: regressed the Yield on X's and z_2 on quadratic model. We rejected H1 if the coefficient z_2 is statistically different from zero by the usual t-test, then the quadratic is not the true model. The results are summarized in the table F-1.

In both regressions z_1 and z_2 are statistically significant. Therefore, no one model is the true one. Both cannot be rejected. Then, to select the superior the Adj. R^2 was be used. But because they have different measurement units, the anti log of the predicted yield from translog was correlated to the observed yield and, Woodridge (2000) suggests to calculate the comparable R^2 of translog by taking the square of the correlation coefficient between h1 and yield, resulting in 0.6296 (0.7935^2). Then, the R2 for translog is greater than that of the quadratic model of 0.5777. So, we pick the translog model.

Table E-1 Quadratic and Translog regressions for MWD test

Variable	Quadratic			Translog		
	Coef.	S. E.	p-value	Coef.	S. E.	p-value
TOTWAE				-1.96	0.949	0.041
$TOTWAE^2$				0.32	0.128	0.012
SEEDWEEK				3.46	1.079	0.002
$SEEDWEEK^2$	-15.51	7.612	0.043	-1.14	0.317	0.000
FERTQ	23.64	12.72	0.065			
INSPESTS	-356.11	91.131	0.000	-0.27	0.142	0.062
LANDQUAL	-82.89	38.106	0.031	-0.022	0.098	0.025
BOLLW				-1.24	0.278	0.000
$BOLLW^2$	26.84	10.165	0.009	0.87	0.170	0.000
FERTWSEED	-1.48	0.879	0.095			
HERBQ				0.22	0.060	0.000
VILMTZ5				1.19	0.431	0.007
VILMTZ6	-557.37	306.95	0.071			
VILMON5				0.75	0.400	0.061
VILMEC2				0.86	0.360	0.018
Z_1				0.01	0.000	0.004
Z_2	214.67	109.39	0.051			
Constant				5.13	1.88	0.007
	N=215, F-value = 10.36, p-value = 0.000, Adj. R^2 = 0.5843			N=215, F-value = 10.10, p-value = 0.000, Adj. R^2 = 0.5686		

Source: Author's computation based on Strasberg (1997).

APPENDIX F

Pesticide Endogeneity - Hausman test

Table F-1 Regression coefficients for BOLLW endogeneity test

Variable	**Regression 1**[33]			**Regression 2**[34]		
	Coef.	**S. E.**	**p-value**	**Coef.**	**S. E.**	**p-value**
ln (TOTWAE)				0.42	0.098	0.000
ln (SEEDWEEK)				-0.36	0.163	0.030
ln (FERTQ)				0.10	0.045	0.029
INSPESTS	0.42	0.165	0.011			
ln (LANDQUAL)				-0.41	0.210	0.051
ln (BOLLW)				0.14	0.065	0.033
Residual				1.54	1.53	0.315
ln (SUCKINS)	-0.22	0.09	0.025			
VILMTZ5				1.44	0.592	0.016
VILMTZ6				-1.38	0.62	0.028
VILMON1	0.77	0.420	0.067			
Constant				2.81	1.34	0.038
	N=215, F-value = 1.99, p- value = 0.0060, Adj. R-square = 0.0995, Dep. Var. = ln (BOLLW)			N=215, F-value = 9.30, p-value = 0.000, Adj. R-square = 0.4923, Dep. Var. = ln (YIELD)		

Source: Author's computations based on Strasberg (1997)

The coefficient of the residual is not significant. Therefore, we conclude that insecticide applications to control bollworms are not endogenously decided by the farmers.

[33] Regression with BOLLW as dependent variable as function of all other exogenous variables besides the usual explanatory variables.
[34] The original regression including the predicted BOLLW as an additional explanatory variable.

APPENDIX G

Yield Estimations

According to Verbeek (2000), predicted yield from logY = f(x) is underestimated if set that is equal to exp (log xi') because taking log is a nonlinear transformation. The only way to get around this problem is to make distributional assumptions. Assuming for example that the error term is normally distributed with mean zero and variance s^2; it will imply that the conditional distribution of yi is lognormal. Therefore, to adjust for the nonlinear transformation, the half-variance term is added, assuming that the error term is normally distributed. So, the yields were estimated as described below.

To illustrate how yield values with and without Bt were estimated, consider for instance, seeding week three (SEEDWEEK=3) with no additional insecticide application under low-input use (assumptions: no fertilizer and herbicide use), higher pest infestation (INSPESTS=1), and fertile soils (LANDQUAL=1).

We start by presenting the final Cobb-Douglas model that will be used to predict yields with Bt cotton as:

(1) Conv. Cotton Yield = exp^{4.76 + ∑village*freq[35]/n + 0.43*ln(TOTWAE) - 0.38*ln(SEEDWEEK) - 0.29*INSPESTS + 0.11*ln(FERTQ) + 0.15*ln(BOLLW) + 0.12*ln(HERBQ) - 0.22*ln(LANDQUAL) + 0.12ln(AGE) + 0.04*ln(SUCKI) + s^2*0.5}

where s is sample standard deviation (0.270391) and s^2 is sample variance.

Using this model, the conventional cotton yield under the scenario stated above can be calculated by inserting representative values for major inputs. As we mentioned in section 3.3, the representative values represent the most common values and sample average values in the sample for continuous and integer variables, respectively. For instance, the sample average for TOTWAE is 49 days, for AGE is 35 years, for FERTQ is 21Kg/ha, for HERBQ is 8.3 litres/ha, while the most common values for BOLLW is 3

[35] See Appendix D.

insecticide applications (35% of the sample applied insecticide three times to control bollworms). To assure that three insecticide applications are in fact a representative figure, we appeal to MADER (2000a) in the same study area where we got the same figure. For SUCKI, the representative value is 1 (29% of the sample), and for LANDQUAL is 1(61% of the sample).

(Eq G1) Conv. Cotton Yield = $\exp\{4.76 + 0.36 + 0.43*\ln(49) - 0.38*\ln(3) - 0.29*1 + 0.11*\ln(0+1) + 0.15*\ln(3) + 0.12*\ln(0+1) - 0.22*\ln(1) + 0.12*\ln(35) + 0.04*\ln(0+1) + 0.270391^2*0.5\}$
= exp^(6.725) = 833 Kg/ha

To calculate the conventional cotton yield, we inserted BOLLW=3 in the Eq G1 because under typical practice, farmers apply mostly three times to control bollworms.

Predicted Bt cotton yield was estimated the same way, but BOLLW=6, to simulate cotton yield with six insecticide applications to control bollworms for complete bollworm control, which is the principal characteristic of Bt cotton:

(Eq G2) Conv. Cotton Yield = $\exp\hat{}\{4.76 + 0.36 + 0.43*\ln(49) - 0.38*\ln(3) - 0.29*1 + 0.11*\ln(0+1) + 0.15*\ln(\mathbf{6}) + 0.12*\ln(0+1) - 0.22*\ln(1) + 0.12*35 + 0.270391^2*0.5\}$
= 926 Kg/ha

Then, we reduced the Bt cotton yield by an amount equivalent to the effect of one insecticide application to control sucking insects. This adjustment accounts for the fact that the current Bt cotton varieties appear to be less resistant to sucking-insects than the local conventional cotton varieties. The cotton yield effect of one insecticide application for sucking-insect control was estimated as the difference between conventional cotton yields with and without one insecticide application:

(Eq G3) SUCKI Yield effect = Conv. Cotton Yield (Eq G1) - Conv. Cotton Yield with one SUCKI

Where,

Conv. Cotton Yield with one SUCKI = exp^{4.76 + ∑village*freq/n + 0.43*ln(TOTWAE) - 0.38*ln(SEEDWEEK) - 0.29*INSPESTS + 0.11*ln(FERTQ) + 0.15*ln(BOLLW) + 0.12*ln(HERBQ) - 0.22*ln(LANDQUAL) + 0.12ln(AGE) + s^2*0.5 + 0.04*ln(**2**)}

One could ask why 0.004*ln(2) instead of 0.004*ln(1). This is simply because the log(1)=0 and this results that Yield of conventional cotton in Eq G1 becomes equal to conventional yield with one SUCKI, resulting that the SUCKI Yield effect in Eq G3 is equal to zero (since ln(1) = 0, then the effect of SUCKI in the yield estimation disappears). So, to handle this methodological problem, ln(2), was used to reflect the idea that if conventional cotton still use SUCKI=1, the effect of one addition SUCKI will result in some positive yield difference over the conventional cotton yield with SUCKI=1.

Conv. Cotton Yield with one SUCKI= exp^{4.76 + 0.36+ 0.43*ln(49) - 0.42*ln(3) - 0.29*1 + 0.11*ln(0+1) + 0.15*ln(3) + 0.12*ln(0+1) - 0.22*ln(1) + 0.12*35 + 0.270391^2*0.5 + 0.04*ln(2)} = 858 Kg/ha. Using the equation (3) the SUCKI Yield effect is given by 858 – 833 = 25Kg/ha.

Based on the -25 Kg/ha predicted yield effect of current Bt cotton varieties' greater susceptibility to sucking insect damage, the likely Bt cotton is calculated as:

(Eq G4) Bt Cotton Yield = (Eq G2)-(Eq G3) = 926 – 25 = 901 Kg/ha.

The percentage Bt cotton yield gain over conventional cotton is calculated as:

(Eq G5) Bt cotton yield gain = 100*[(Eq G4)-(Eq G1)]/(Eq G1), or simply 100*(901-

833)/833 = 8.2%.

For other scenarios, the yields were estimated the same way, and table 4-5 reports values obtained in the steps described in Equations (G1), (G4), and (G5).

APPENDIX H

Financial Partial Budget

Table H-1 Financial Bt cotton Partial Budget

Level of input use		Items	Bt Cotton Returns by seeding week (Bt - Conventional cotton)					
			3	4	5	6	7	8
LOW - INPUT USE	No additional pesticide application	seed cotton yield (Kg/ha)	23	21	19	18	16	15
		seed cotton price($/ha)	0.11	0.11	0.11	0.11	0.11	0.11
		Gross revenue ($/ha)	2.52	2.28	2.10	1.93	1.72	1.67
		insecticide	-9.94	-9.94	-9.94	-9.94	-9.94	-9.94
		seed cotton	16.60	16.60	16.60	16.60	16.60	16.60
		Spraying labor ($/ha)	-4.05	-4.05	-4.05	-4.05	-4.05	-4.05
		family ae labor days	57.00	57.00	57.00	57.00	57.00	57.00
		Net returns to land ($/ha)	-0.09	-0.33	-0.52	-0.68	-0.89	-0.94
		Net returns to fam. labor ($/ae)	0.00	-0.01	-0.01	-0.01	-0.02	-0.02
	One additional pesticide application	seed cotton yield (Kg/ha)	6	4	4	5	4	4
		seed cotton price($/ha)	0.11	0.11	0.11	0.11	0.11	0.11
		Gross revenue ($/ha)	0.65	0.42	0.46	0.52	0.42	0.38
		insecticide	-10.10	-10.10	-10.10	-10.10	-10.10	-10.10
		seed cotton	16.60	16.60	16.60	16.60	16.60	16.60
		Spraying labor ($/ha)	-4.05	-4.05	-4.05	-4.05	-4.05	-4.05
		family ae labor days	57.00	57.00	57.00	57.00	57.00	57.00
		Net returns to land ($/ha)	-1.80	-2.03	-1.98	-1.92	-2.03	-2.06
		Net returns to fam. labor ($/ae)	-0.03	-0.04	-0.03	-0.03	-0.04	-0.04
	Two additional pesticide applications	seed cotton yield (Kg/ha)	-8	-7	-6	-6	-6	-5
		seed cotton price($/ha)	0.11	0.11	0.11	0.11	0.11	0.11
		Gross revenue ($/ha)	-0.88	-0.78	-0.62	-0.65	-0.64	-0.57
		insecticide	-10.27	-10.27	-10.27	-10.27	-10.27	-10.27
		seed cotton	16.60	16.60	16.60	16.60	16.60	16.60
		family ae labor days	57.00	57.00	57.00	57.00	57.00	57.00
		Spraying labor ($/ha)	-4.05	-4.05	-4.05	-4.05	-4.05	-4.05
		Net returns to land ($/ha)	-3.16	-3.06	-2.90	-2.93	-2.92	-2.85
		Net returns to fam. labor ($/ae)	-0.06	-0.05	-0.05	-0.05	-0.05	-0.05
	Three additional pesticide applications	seed cotton yield (Kg/ha)	-17	-15	-14	-13	-12	-11
		seed cotton price($/ha)	0.11	0.11	0.11	0.11	0.11	0.11
		Gross revenue ($/ha)	-1.85	-1.63	-1.57	-1.39	-1.37	-1.18
		insecticide	-10.44	-10.44	-10.44	-10.44	-10.44	-10.44
		seed cotton	16.60	16.60	16.60	16.60	16.60	16.60
		family ae labor days	57.00	57.00	57.00	57.00	57.00	57.00
		Spraying labor ($/ha)	-4.05	-4.05	-4.05	-4.05	-4.05	-4.05
		Net returns to land ($/ha)	-3.97	-3.74	-3.68	-3.50	-3.48	-3.30
		Net returns to fam. labor ($/ae)	-0.07	-0.07	-0.06	-0.06	-0.06	-0.06

Table H-1 (Cont'd).

HIGH-INPUT USE	No additional pesticide application	seed cotton yield (Kg/ha)	42	38	34	32	30	29
		seed cotton price($/ha)	0.11	0.11	0.11	0.11	0.11	0.11
		Gross revenue ($/ha)	4.66	4.20	3.78	3.53	3.28	3.17
		Insecticide	-9.94	-9.94	-9.94	-9.94	-9.94	-9.94
		seed cotton	16.60	16.60	16.60	16.60	16.60	16.60
		family ae labor days	57.00	57.00	57.00	57.00	57.00	57.00
		Spraying labor ($/ha)	-4.05	-4.05	-4.05	-4.05	-4.05	-4.05
		Net returns to land ($/ha)	2.05	1.59	1.17	0.92	0.67	0.56
		Net returns to fam. labor ($/ae)	0.04	0.03	0.02	0.02	0.01	0.01
	One additional pesticide application	seed cotton yield (Kg/ha)	9	9	8	8	6	7
		seed cotton price($/ha)	0.11	0.11	0.11	0.11	0.11	0.11
		Gross revenue ($/ha)	1.04	0.94	0.86	0.84	0.70	0.72
		Insecticide	-10.10	-10.10	-10.10	-10.10	-10.10	-10.10
		seed cotton	16.60	16.60	16.60	16.60	16.60	16.60
		Spraying labor ($/ha)	-4.05	-4.05	-4.05	-4.05	-4.05	-4.05
		family ae labor days	57.00	57.00	57.00	57.00	57.00	57.00
		Net returns to land ($/ha)	-1.41	-1.51	-1.59	-1.61	-1.74	-1.73
		Net returns to fam. labor ($/ae)	-0.02	-0.03	-0.03	-0.03	-0.03	-0.03
	Two additional pesticide applications	seed cotton yield (Kg/ha)	-14	-12	-12	-11	-10	-9
		seed cotton price($/ha)	0.11	0.11	0.11	0.11	0.11	0.11
		Gross revenue ($/ha)	-1.57	-1.33	-1.28	-1.18	-1.08	-0.96
		Insecticide	-10.27	-10.27	-10.27	-10.27	-10.27	-10.27
		seed cotton	16.60	16.60	16.60	16.60	16.60	16.60
		family ae labor days	57.00	57.00	57.00	57.00	57.00	57.00
		Spraying labor ($/ha)	-4.05	-4.05	-4.05	-4.05	-4.05	-4.05
		Net returns to land ($/ha)	-3.85	-3.61	-3.56	-3.46	-3.36	-3.24
		Net returns to fam. labor ($/ae)	-0.07	-0.06	-0.06	-0.06	-0.06	-0.06
	Three additional pesticide applications	seed cotton yield (Kg/ha)	-31	-32	-25	-24	-22	-22
		seed cotton price($/ha)	0.11	0.11	0.11	0.11	0.11	0.11
		Gross revenue ($/ha)	-3.39	-3.55	-2.74	-2.63	-2.42	-2.39
		Insecticide	-10.44	-10.44	-10.44	-10.44	-10.44	-10.44
		seed cotton	16.60	16.60	16.60	16.60	16.60	16.60
		family ae labor days	57.00	57.00	57.00	57.00	57.00	57.00
		Spraying labor ($/ha)	-4.05	-4.05	-4.05	-4.05	-4.05	-4.05
		Net returns to land ($/ha)	-5.51	-5.66	-4.85	-4.74	-4.53	-4.51
		Net returns to fam. labor ($/ae)	-0.10	-0.10	-0.09	-0.08	-0.08	-0.08

Source: Author's computations based on Strasberg (1997), MADER (2000), and MADER (2001a).

APPENDIX I

Economic Partial Budget

Table I-1 Foreign exchange premium calculation, Northern Mozambique, 2003.

Year	1998	1999	2000	2001	2002
Exports of goods and services (% of GDP)	10.49	10.12	12.87	21.75	23.51
GDP (current US$)	3.87E+09	3.98E+09	3.68E+09	3.44E+09	3.60E+09
Imports of goods and services (% of GDP)	27.89	37.77	38.9	35.45	38.23
Exports (US $)	4.06E+08	4.03E+08	4.74E+08	7.48E+08	8.46E+08
Imports (US $)	1.08E+09	1.50E+09	1.43E+09	1.22E+09	1.38E+09
OER	11853.42	12673.25	15113.08	20679.59	23746.51
CPI	100.28	103.42	116.58	127.13	1.48E+02
EXPORTS REAL (MT)	3.42E+04	3.07E+04	2.69E+04	2.85E+04	2.40E+04
IMPORTS REAL (MT)	9.08E+04	1.15E+05	8.12E+04	4.64E+04	3.90E+04
Exports duty rate (%)[36]	0.33	0.33	0.33	0.33	0.33
Imports duty rate (%)[37]	0.4	0.4	0.4	0.4	0.4
Foreign premium	1.20	1.25	1.22	1.12	1.12
Average					1.18

Source: Author's computations based on IFS (2004), WBI, (2003), NTIS, (2003), and MADER (2003a).

[36] Average duty rate for exploitation and exportation of natural resource, cashew nut, fish, and prawns.

[37] Duties on imported goods range from zero to 30%. A duty of 30% is levied on consumer goods; and a value-added tax of 17% is assessed at point of sale. Mozambique does not use import quotas.

Table I-2 Economic Seed Cotton Export Parity Price, Northern Mozambique, 2003.

Items	Data	Economic in U.S. $ Lint	Seed	in Meticais '000 Lint	Seed
CIF ($/ton)		0	0		
Freight, insurance, handling ($)		0	0		
FOB Port Nacala or Maputo ($/ton)		1059.7	75.8		
FOB in '000 Mt/ton converted at 23,963 Mt/U.S.$	23,963			25,394	1,817
Border Price, Port Nacala or Maputo		1059.7	75.8	25,394	1,817
Adjusted for (1+ foreign exchange premium)	1.18	1250.4	89.5	29,964	2,144
Minus export duty [not deducted in economic analysis]					
Minus port handling in Nacala a/					
Minus transport from ginner to Port of Nacala a/					
= Export Parity price, gin/project site		1250.4	89.5	29,964	2,144
Convert to seed cotton:		0.35	0.65	0.35	0.65
= Seed cotton equivalent		437.7	58.2	10,488	1,394
Combined lint + seed price			495.8		11,881
Company cost factor[38]	55%		55%		55%
= Export Parity price of seed cotton, farm gate, per ton			272.7		6534.6
= Export Parity price of seed cotton, farm gate, per kg			**0.2727**		**6.535**
Implied OER					23,963
Implied costs for port handling, transport, ginning/baling/storage, collection/internal transport:					5,530

Source: Author's computations based on MADER (2001b), IAM (2003).

38 Reliable data on costs forced us to use a rule of thumb that cotton companies in Mozambique, in that to cover costs and earn a "reasonable" profit; they can pay farmers not more than 55% of the FOB price. This rule is used to propose farm price to IAM in the process of cotton price definition (See Appendix A).

Table I-3 Financial Seed Cotton Export Parity Price, Northern Mozambique, 2003

		Financial			
		in U.S. $		in Meticais '000	
Items	**Data**	**Lint**	**Seed**	**Lint**	**Seed**
CIF ($/ton)		0	0		
Freight, insurance, handling ($)		0	0		
FOB Port Nacala or Maputo ($/ton)		1059.7	75.8		
FOB in '000 Mt/ton converted at 23,963 Mt/U.S.$	23,963			25,394	1,817
Border Price, Port Nacala or Maputo		1059.7	75.8	25,394	1,817
Minus export duty	2.5%	26.5	1.9	634.8	45.4
Minus port handling in Nacala					
Minus transport from ginner to Port of Nacala					
= Export Parity price, Gin/project site		1033.2	73.9	24758.8	1771.5
Convert to seed cotton:		0.35	0.65	0.35	0.65
= Seed cotton equivalent		361.6	48.1	8,666	1,151
Combined lint + seed price			409.7		9,817
Company cost factor	55%		55%		55%
= Export Parity price of seed cotton, farm gate, per ton			225.3		5399.4
= Export Parity price of seed cotton, farm gate, per kg			**0.2253**		**5.399**
Implied OER					23,963
Implied costs for port handling, transport, ginning/baling/storage, collection/internal transport:					4,601

Source: Author's computations based on MADER (2001a), IAM (2003).

Comparing the financial export parity price ($0.23/Kg) to the official cotton price ($0.11/Kg), one can see that the farm gate price is almost 50% less than what farmers would get if they were incurring all the costs from farm to port. In this situation, farmers would be better off.

Table I-4 Economic Bt Cotton Seed import parity price, Northern Mozambique, 2003.

Items	Data	Economic cost in U.S. $	Economic cost in Meticais '000
CIF ($/ton)		664.00	
Added to Importation cost except duties ($) (freight, insurance, handling)[39]	5.2 %		
FOB in '000 Mt/ton converted at 23,963 Mt/U.S.$			
Adjusted for (1+foreign exchange premium)	1.18		
= Border price, port of Nacala per ton		698.31	19,603
Added to the wholesale margin	23%		
= Import parity price in Nampula per ton		1,006.20	24,112
Added to transportation cost within Nampula districts per ton[40]		139.00	3,331
= Import Parity Price of Bt seed, farm gate, per ton		1,1451.20	27,443
= Import Parity Price of Bt seed, farm gate per Kg		**1.15**	**27.44**
Implied OER			23,863

Source: Author's computations based on MADER/MSU/FSP (2003), Ismail et al. (2001).

[39] Aggregate cost with importation except import duties. Assumed nontraded.
[40] Assumed nontraded and 10Km at $13.9/ton/Km.

Table I-5 Partial Budgets to the Economy as whole (Economic Analysis), Northern Mozambique, 2003.

Level of input use		Items	Bt cotton returns by seeding week (Bt – Conventional cotton) 3	4	5	6	7	8
LOW - INPUT USE	No additional pesticide application	Cotton yield (Kg/ha)	22.95	20.70	19.05	17.55	15.65	15.20
		Gross revenue ($/ha)	6.26	5.64	5.19	4.79	4.27	4.14
		Insecticide	-28.03	-28.03	-28.03	-28.03	-28.03	-28.03
		Bt seed	25.00	25.00	25.00	25.00	25.00	25.00
		Spraying labor	-5.08	-5.08	-5.08	-5.08	-5.08	-5.08
		Opportunity cost of farmer's capital	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78
		Incr. Net return to land ($/ha)	15.15	14.54	14.09	13.68	13.16	13.04
	One additional pesticide application	Cotton yield (Kg/ha)	5.90	3.80	4.20	4.75	3.80	3.50
		Gross revenue ($/ha)	1.61	1.04	1.15	1.30	1.04	0.95
		Insecticide	-28.50	-28.50	-28.50	-28.50	-28.50	-28.50
		Bt seed	25.00	25.00	25.00	25.00	25.00	25.00
		Spraying labor	-5.08	-5.08	-5.08	-5.08	-5.08	-5.08
		Opportunity cost of farmer's capital	-0.78	-0.78	-0.78	-0.78	-0.78	-0.78
		Incr. Net return to land ($/ha)	10.97	9.61	9.72	9.87	9.61	9.53
	Two additional pesticide applications	Cotton yield (Kg/ha)	-8.00	-7.05	-5.60	-5.95	-5.85	-5.15
		Gross revenue ($/ha)	-2.18	-1.92	-1.53	-1.62	-1.60	-1.40
		Insecticide	-28.97	-28.97	-28.97	-28.97	-28.97	-28.97
		Bt Seed	25.00	25.00	25.00	25.00	25.00	25.00
		Spraying labor	-5.08	-5.08	-5.08	-5.08	-5.08	-5.08
		Opportunity cost of farmer's capital	-0.41	-0.41	-0.41	-0.41	-0.41	-0.41
		Incr. Net return to land ($/ha)	7.27	7.53	7.92	7.83	7.85	8.04
	Three additional pesticide applications	Cotton yield (Kg/ha)	-16.85	-14.80	-14.25	-12.60	-12.45	-10.75
		Gross revenue ($/ha)	-4.59	-4.04	-3.89	-3.44	-3.40	-2.93
		Insecticide	-29.43	-29.43	-29.43	-29.43	-29.43	-29.43
		Bt seed	25.00	25.00	25.00	25.00	25.00	25.00
		Spraying labor	-5.08	-5.08	-5.08	-5.08	-5.08	-5.08
		Opportunity cost of farmer's capital	-0.41	-0.41	-0.41	-0.41	-0.41	-0.41
		Incr. Net return to land ($/ha)	5.32	5.88	6.03	6.48	6.52	6.98

Table I-5 (Cont'd).

HIGH-INPUT USE	No additional pesticide application	Cotton yield (Kg/ha)	42.40	38.20	34.40	32.10	29.80	28.85
		Gross revenue ($/ha)	11.56	10.42	9.38	8.75	8.13	7.87
		Insecticide	-28.03	-28.03	-28.03	-28.03	-28.03	-28.03
		Bt seed	25.00	25.00	25.00	25.00	25.00	25.00
		Spraying labor	-5.08	-5.08	-5.08	-5.08	-5.08	-5.08
		Opportunity cost of farmer's capital	-0.41	-0.41	-0.41	-0.41	-0.41	-0.41
		Incr. Net return to land ($/ha)	20.08	18.93	17.89	17.27	16.64	16.38
	One additional pesticide application	seed cotton yield (Kg/ha)	9.45	8.50	7.80	7.60	6.40	6.50
		Gross revenue ($/ha)	2.58	2.32	2.13	2.07	1.75	1.77
		Insecticide	-28.50	-28.50	-28.50	-28.50	-28.50	-28.50
		Bt seed	25.00	25.00	25.00	25.00	25.00	25.00
		Spraying labor	-5.08	-5.08	-5.08	-5.08	-5.08	-5.08
		Opportunity cost of farmer's capital	-0.41	-0.41	-0.41	-0.41	-0.41	-0.41
		Incr. Net return to land ($/ha)	11.56	11.30	11.11	11.05	10.73	10.75
	Two additional pesticide applications	seed cotton yield (Kg/ha)	-14.25	-12.05	-11.60	-10.70	-9.85	-8.70
		Gross revenue ($/ha)	-3.89	-3.29	-3.16	-2.92	-2.69	-2.37
		Insecticide	-28.97	-28.97	-28.97	-28.97	-28.97	-28.97
		Bt seed	25.00	25.00	25.00	25.00	25.00	25.00
		Spraying labor	-5.08	-5.08	-5.08	-5.08	-5.08	-5.08
		Opportunity cost of farmer's capital	-0.41	-0.41	-0.41	-0.41	-0.41	-0.41
		Incr. Net return to land ($/ha)	5.56	6.16	6.28	6.53	6.76	7.08
	Three additional pesticide applications	seed cotton yield (Kg/ha)	-30.85	-32.25	-24.90	-23.90	-22.00	-21.75
		Gross revenue ($/ha)	-8.41	-8.79	-6.79	-6.52	-6.00	-5.93
		Insecticide	-29.43	-29.43	-29.43	-29.43	-29.43	-29.43
		Bt seed	25.00	25.00	25.00	25.00	25.00	25.00
		Spraying labor	-5.08	-5.08	-5.08	-5.08	-5.08	-5.08
		Opportunity cost of farmer's capital	-0.40	-0.40	-0.40	-0.40	-0.40	-0.40
		Incr. Net return to land ($/ha)	1.50	1.12	3.13	3.40	3.92	3.98

Source: Author's computations based on Strasberg (1997), MADER (2000), and MADER (2001a).

APPENDIX J

Financial and Economic Enterprise Budgets

Table J-1 Bt cotton Financial Enterprise Budgets.

Level of input use	Items	Conventional cotton on seeding week						Bt cotton on seeding week					
		3	4	5	6	7	8	3	4	5	6	7	8
	seed cotton yield (Kg/ha)	833	745	683	637	618	570	856	766	702	655	634	585
	seed cotton price($/ha)	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
	Gross revenue ($/ha)	91.63	81.95	75.13	70.07	67.98	62.70	94.15	84.23	77.23	72.00	69.70	64.37
	Insecticide	9.94	9.94	9.94	9.94	9.94	9.94	0.00	0.00	0.00	0.00	0.00	0.00
	Fertilizer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LOW-INPUT USE	seed cotton	0.00	0.00	0.00	0.00	0.00	0.00	16.60	16.60	16.60	16.60	16.60	16.60
	Fertilizer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Herbicide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	sprayer batteries	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
No additional insecticide application	hoes and machetes	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88
	hired labor (for all activities)	27.30	27.30	27.30	27.30	27.30	27.30	23.25	23.25	23.25	23.25	23.25	23.25
	family ae labor days	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00
	Net returns to land ($/ha)	51.99	42.31	35.49	30.43	28.34	23.06	51.90	41.98	34.98	29.75	27.45	22.12
	Incr. Net return to land ($/ha)							-0.09	-0.33	-0.52	-0.68	-0.89	-0.94
	Net returns to fam. labor ($/ae)	0.91	0.74	0.62	0.53	0.50	0.40	0.91	0.74	0.61	0.52	0.48	0.39
	Incr.Net Return to fam. labor ($/ae)							0.00	-0.01	-0.01	-0.01	-0.02	-0.02

Table J-1 (Cont'd).

	seed cotton yield (Kg/ha)	870	779	714	665	627	595	876	783	718	670	631	599
	seed cotton price($/ha)	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
LOW-INPUT USE	Gross revenue ($/ha)	95.70	85.69	78.54	73.15	68.97	65.45	96.35	86.11	79.00	73.67	69.39	65.84
	Insecticide	13.25	13.25	13.25	13.25	13.25	13.25	3.15	3.15	3.15	3.15	3.15	3.15
	seed cotton	0.00	0.00	0.00	0.00	0.00	0.00	16.60	16.60	16.60	16.60	16.60	16.60
	sprayer batteries	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
One additional insecticide applications	hoes and machetes	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88
	hired labor (for all activities)	28.65	28.65	28.65	28.65	28.65	28.65	24.60	24.60	24.60	24.60	24.60	24.60
	family ae labor days	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00
	Net returns to land ($/ha)	51.40	41.39	34.24	28.85	24.67	21.15	49.60	39.36	32.25	26.93	22.64	19.09
	Incr. Net return to land ($/ha)							-1.80	-2.03	-1.98	-1.92	-2.03	-2.06
	Net returns to fam. labor ($/ae)	0.90	0.73	0.60	0.51	0.43	0.37	0.87	0.69	0.57	0.47	0.40	0.33
	Incr. Net return to fam. labor ($/ae)							-0.03	-0.04	-0.03	-0.03	-0.04	-0.04
	seed cotton yield (Kg/ha)	901	806	739	689	649	616	893	799	733	683	643	611
	seed cotton price($/ha)	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
LOW-INPUT USE	Gross revenue ($/ha)	99.11	88.66	81.29	75.79	71.39	67.76	98.23	87.88	80.67	75.14	70.75	67.19
	Insecticide	16.57	16.57	16.57	16.57	16.57	16.57	6.29	6.29	6.29	6.29	6.29	6.29
	seed cotton	0.00	0.00	0.00	0.00	0.00	0.00	16.60	16.60	16.60	16.60	16.60	16.60
	sprayer batteries	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
Two additional insecticide applications	hoes and machetes	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88
	hired labor (for all activities)	30.00	30.00	30.00	30.00	30.00	30.00	25.95	25.95	25.95	25.95	25.95	25.95
	family ae labor days	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00
	Net returns to land ($/ha)	50.15	39.70	32.33	26.83	22.43	18.80	46.99	36.64	29.43	23.89	19.50	15.95
	Incr. Net return to land ($/ha)							-3.16	-3.06	-2.90	-2.93	-2.92	-2.85
	Net returns to fam. labor ($/ae)	0.88	0.70	0.57	0.47	0.39	0.33	0.82	0.64	0.52	0.42	0.34	0.28
	Incr. Net return to fam. labor ($/ae)							-0.06	-0.05	-0.05	-0.05	-0.05	-0.05

Table J-1 (Cont'd).

	seed cotton yield (Kg/ha)	1546	1383	1269	1182	1114	1057	1588	1421	1303	1214	1144	1086
	seed cotton price($/ha)	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
	Gross revenue ($/ha)	170.06	152.13	139.59	130.02	122.54	116.27	174.72	156.33	143.37	133.55	125.82	119.44
	Insecticide	9.94	9.94	9.94	9.94	9.94	9.94	0.00	0.00	0.00	0.00	0.00	0.00
HIGH-INPUT USE	Fertilizer	7.98	7.98	7.98	7.98	7.98	7.98	7.98	7.98	7.98	7.98	7.98	7.98
	seed cotton	0.00	0.00	0.00	0.00	0.00	0.00	16.60	16.60	16.60	16.60	16.60	16.60
	Herbicide	14.49	14.49	14.49	14.49	14.49	14.49	14.49	14.49	14.49	14.49	14.49	14.49
	sprayer batteries	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
No additional insecticide application	hoes and machetes	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88
	hired labor	27.30	27.30	27.30	27.30	27.30	27.30	23.25	23.25	23.25	23.25	23.25	23.25
	family ae labor days	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00
	Net returns to land ($/ha)	107.95	90.02	77.48	67.91	60.43	54.16	110.00	91.61	78.65	68.83	61.10	54.72
	Incr. Net return to land ($/ha)							2.05	1.59	1.17	0.92	0.67	0.56
	Net returns to fam. labor ($/ae)	1.89	1.58	1.36	1.19	1.06	0.95	1.93	1.61	1.38	1.21	1.07	0.96
	Incr. Net return to fam. labor ($/ae)							0.04	0.03	0.02	0.02	0.01	0.01
	seed cotton yield (Kg/ha)	1616	1445	1326	1235	1164	1105	1625	1454	1334	1243	1170	1112
	seed cotton price($/ha)	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
	Gross revenue ($/ha)	177.76	158.95	145.86	135.85	128.04	121.55	178.80	159.89	146.72	136.69	128.74	122.27
	Insecticide	13.25	13.25	13.25	13.25	13.25	13.25	3.15	3.15	3.15	3.15	3.15	3.15
HIGH-INPUT USE	Fertilizer	7.98	7.98	7.98	7.98	7.98	7.98	7.98	7.98	7.98	7.98	7.98	7.98
	seed cotton	0.00	0.00	0.00	0.00	0.00	0.00	16.60	16.60	16.60	16.60	16.60	16.60
	Herbicide	14.49	14.49	14.49	14.49	14.49	14.49	14.49	14.49	14.49	14.49	14.49	14.49
	sprayer batteries	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
One additional insecticide application	hoes and machetes	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88
	hired labor	28.65	28.65	28.65	28.65	28.65	28.65	24.60	24.60	24.60	24.60	24.60	24.60
	family ae labor days	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00
	Net returns to land ($/ha)	110.99	92.18	79.09	69.08	61.27	54.78	109.58	90.67	77.50	67.47	59.53	53.05
	Incr. Net return to land ($/ha)							-1.41	-1.51	-1.59	-1.61	-1.74	-1.73
	Net returns to fam. labor ($/ae)	1.95	1.62	1.39	1.21	1.07	0.96	1.92	1.59	1.36	1.18	1.04	0.93
	Incr. Net return to fam. labor							-0.02	-0.03	-0.03	-0.03	-0.03	-0.03

Table J-1 (Cont'd).

	seed cotton yield (Kg/ha)	1672	1495	1372	1278	1204	1143	1658	1483	1360	1267	1194	1134
	seed cotton price($/ha)	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
	Gross revenue ($/ha)	183.92	164.45	150.92	140.58	132.44	125.73	182.35	163.12	149.64	139.40	131.36	124.77
	Insecticide	16.57	16.57	16.57	16.57	16.57	16.57	6.29	6.29	6.29	6.29	6.29	6.29
HIGH-INPUT USE	Fertilizer	7.98	7.98	7.98	7.98	7.98	7.98	7.98	7.98	7.98	7.98	7.98	7.98
	seed cotton	0.00	0.00	0.00	0.00	0.00	0.00	16.60	16.60	16.60	16.60	16.60	16.60
	Herbicide	14.49	14.49	14.49	14.49	14.49	14.49	14.49	14.49	14.49	14.49	14.49	14.49
	sprayer batteries	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
Two additional insecticide applications	hoes and machetes	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88
	hired labor	30.00	30.00	30.00	30.00	30.00	30.00	25.95	25.95	25.95	25.95	25.95	25.95
	family ae labor days	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00
	Net returns to land ($/ha)	112.49	93.02	79.49	69.15	61.01	54.30	108.64	89.41	75.93	65.69	57.64	51.06
	Incr. Net return to land ($/ha)							-3.85	-3.61	-3.56	-3.46	-3.36	-3.24
	Net returns to fam.labor ($/ae)	1.97	1.63	1.39	1.21	1.07	0.95	1.91	1.57	1.33	1.15	1.01	0.90
	Incr. Net return to fam .labor ($/ae)							-0.07	-0.06	-0.06	-0.06	-0.06	-0.06

Table J-1 (Cont'd).

	seed cotton yield (Kg/ha)	1719	1538	1410	1314	1238	1176	1688	1506	1385	1290	1216	1154
	seed cotton price($/ha)	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
	Gross revenue ($/ha)	189.09	169.18	155.10	144.54	136.18	129.36	185.70	165.63	152.36	141.91	133.76	126.97
	Insecticide	19.88	19.88	19.88	19.88	19.88	19.88	9.44	9.44	9.44	9.44	9.44	9.44
HIGH-INPUT USE	Fertilizer	7.98	7.98	7.98	7.98	7.98	7.98	7.98	7.98	7.98	7.98	7.98	7.98
	seed cotton	0.00	0.00	0.00	0.00	0.00	0.00	16.60	16.60	16.60	16.60	16.60	16.60
	Herbicide	14.49	14.49	14.49	14.49	14.49	14.49	14.49	14.49	14.49	14.49	14.49	14.49
	sprayer batteries	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
Three additional insecticide applications	hoes and machetes	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88	1.88
	hired labor	31.35	31.35	31.35	31.35	31.35	31.35	27.30	27.30	27.30	27.30	27.30	27.30
	family ae labor days	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00	57.00
	Net returns to land ($/ha)	112.99	93.08	79.00	68.44	60.08	53.26	107.48	87.42	74.15	63.70	55.55	48.76
	Incr. Net return to land ($/ha)							-5.51	-5.66	-4.85	-4.74	-4.53	-4.51
	Net returns to fam. labor ($/ae)	1.98	1.63	1.39	1.20	1.05	0.93	1.89	1.53	1.30	1.12	0.97	0.86
	Incr. Net return to fam. labor ($/ae)							-0.10	-0.10	-0.09	-0.08	-0.08	-0.08

Source: Author's computations based on Strasberg (1997), MADER (2000), and MADER (2001a).

Table J-2 Bt cotton Economic Enterprise Budgets

Level of input use	Items	Conventional cotton by seeding week						Bt cotton by seeding week					
		3	4	5	6	7	8	3	4	5	6	7	8
LOW-INPUT USE No additional insecticide application	cotton yield (Kg/ha)	833	745	683	637	618	570	856	766	702	655	634	585
	cotton price($/ha)	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
	Gross revenue ($/ha)	227.16	203.16	186.25	173.71	168.53	155.44	233.41	208.80	191.45	178.49	172.79	159.58
	Insecticide	28.03	28.03	28.03	28.03	28.03	28.03	0.00	0.00	0.00	0.00	0.00	0.00
	seed cotton	3.78	3.78	3.78	3.78	3.78	3.78	28.78	28.78	28.78	28.78	28.78	28.78
	Sprayer batteries	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47
	Hoes and machetes	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59
	Hired labor (for all activities)	27.30	27.30	27.30	27.30	27.30	27.30	23.25	23.25	23.25	23.25	23.25	23.25
	Family labor	17.10	17.10	17.10	17.10	17.10	17.10	16.07	16.07	16.07	16.07	16.07	16.07
	Transport of inputs to farm	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03
	Extension services	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72
	Sacks	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43
	Insecticide Sprayers	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
	Total Variable costs ($/ha)	94.86	94.86	94.86	94.86	94.86	94.86	86.76	86.76	86.76	86.76	86.76	86.76
	Opport. Cost of equity capital	4.97	4.97	4.97	4.97	4.97	4.97	4.19	4.19	4.19	4.19	4.19	4.19
	Net returns to land ($/ha)	127.32	103.32	86.41	73.87	68.69	55.60	142.47	117.86	100.50	87.55	81.85	68.64
	Incr. Net return to land ($/ha)							15.15	14.54	14.09	13.68	13.16	13.04
LOW-INPUT USE One additional insecticide application	seed cotton yield (Kg/ha)	870	779	714	665	627	595	876	783	718	670	631	599
	seed cotton price($/ha)	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
	Gross revenue ($/ha)	237.25	212.43	194.70	181.34	170.98	162.25	238.85	213.47	195.85	182.64	172.02	163.21
	Insecticide	37.38	37.38	37.38	37.38	37.38	37.38	8.88	8.88	8.88	8.88	8.88	8.88
	seed cotton	3.78	3.78	3.78	3.78	3.78	3.78	28.78	28.78	28.78	28.78	28.78	28.78
	sprayer batteries	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47
	hoes and machetes	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59
	hired labor (for all activities)	28.65	28.65	28.65	28.65	28.65	28.65	24.60	24.60	24.60	24.60	24.60	24.60
	family labor	17.44	17.44	17.44	17.44	17.44	17.44	16.42	16.42	16.42	16.42	16.42	16.42
	Transport of inputs to farm	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03
	Extension services	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72
	Sacks	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43
	Insecticide Sprayers	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
	Total Variable costs ($/ha)	105.90	105.90	105.90	105.90	105.90	105.90	97.32	97.32	97.32	97.32	97.32	97.32
	Opport. Cost of equity capital	5.11	5.11	5.11	5.11	5.11	5.11	4.33	4.33	4.33	4.33	4.33	4.33
	Net returns to land ($/ha)	126.24	106.53	88.80	75.44	65.08	56.35	137.20	116.14	98.53	85.31	74.69	65.88
	Incr. Net return to land ($/ha)							10.97	9.61	9.72	9.87	9.61	9.53

Table J-2 (Cont'd).

	seed cotton yield (Kg/ha)	901	806	739	689	649	616	893	799	733	683	643	611
	seed cotton price($/ha)	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
	Gross revenue ($/ha)	245.70	219.79	201.52	187.89	176.98	167.98	243.52	217.87	199.99	186.26	175.38	166.58
	Insecticide	46.72	46.72	46.72	46.72	46.72	46.72	17.75	17.75	17.75	17.75	17.75	17.75
	Fertilizer	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LOW-	seed cotton	3.78	3.78	3.78	3.78	3.78	3.78	28.78	28.78	28.78	28.78	28.78	28.78
INPUT	sprayer batteries	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47
USE	hoes and machetes	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59
	hired labor (for all activities)	30.00	30.00	30.00	30.00	30.00	30.00	25.95	25.95	25.95	25.95	25.95	25.95
Two	family labor	17.78	17.78	17.78	17.78	17.78	17.78	16.76	16.76	16.76	16.76	16.76	16.76
additional	Transport of inputs to farm	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03
insecticide	Extension services	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72
application	Sacks	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43
s	Insecticide Sprayers	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
	Total Variable costs ($/ha)	116.94	116.94	116.94	116.94	116.94	116.94	107.89	107.89	107.89	107.89	107.89	107.89
	Opport. Cost of equity capital	4.87	4.87	4.87	4.87	4.87	4.87	4.46	4.46	4.46	4.46	4.46	4.46
	Net returns to land ($/ha)	123.90	97.99	79.72	66.09	55.18	46.18	131.16	105.52	87.64	73.91	63.03	54.22
	Incr. Net return to land ($/ha)							7.27	7.53	7.92	7.83	7.85	8.04
	seed cotton yield (Kg/ha)	926	828	760	708	667	633	909	813	746	695	655	622
	seed cotton price($/ha)	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
	Gross revenue ($/ha)	252.52	225.79	207.25	193.07	181.89	172.62	247.92	221.76	203.36	189.63	178.49	169.68
	Insecticide	56.07	56.07	56.07	56.07	56.07	56.07	26.63	26.63	26.63	26.63	26.63	26.63
	seed cotton	3.78	3.78	3.78	3.78	3.78	3.78	28.78	28.78	28.78	28.78	28.78	28.78
	sprayer batteries	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47
LOW-	hoes and machetes	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59
INPUT	hired labor (for all activities)	31.35	31.35	31.35	31.35	31.35	31.35	27.30	27.30	27.30	27.30	27.30	27.30
USE	family labor	18.13	18.13	18.13	18.13	18.13	18.13	17.10	17.10	17.10	17.10	17.10	17.10
	Transport of inputs to farm	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03
Three	Extension services	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72
additional	Sacks	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43
insecticide	Insecticide Sprayers	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
application	Sacks	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43
	Insecticide Sprayers	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
	Total Variable costs ($/ha)	129.82	129.82	129.82	129.82	129.82	129.82	120.31	120.31	120.31	120.31	120.31	120.31
	Opport. Cost of equity capital	5.19	5.19	5.19	5.19	5.19	5.19	4.78	4.78	4.78	4.78	4.78	4.78
	Net returns to land ($/ha)	117.51	90.79	72.24	58.06	46.88	37.61	122.83	96.66	78.27	64.54	53.40	44.59
	Incr. Net return to land ($/ha)							5.32	5.88	6.03	6.48	6.52	6.98

Table J-2 (Cont'd).

	seed cotton yield (Kg/ha)	1546	1383	1269	1182	1114	1057	1588	1421	1303	1214	1144	1086
	seed cotton price($/ha)	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
	Gross revenue ($/ha)	421.59	377.14	346.05	322.33	303.78	288.24	433.15	387.55	355.43	331.08	311.91	296.11
	Insecticide	28.03	28.03	28.03	28.03	28.03	28.03	0.00	0.00	0.00	0.00	0.00	0.00
	Fertilizer	22.51	22.51	22.51	22.51	22.51	22.51	22.51	22.51	22.51	22.51	22.51	22.51
HIGH-INPUT USE	seed cotton	3.78	3.78	3.78	3.78	3.78	3.78	28.78	28.78	28.78	28.78	28.78	28.78
	Herbicide	40.88	40.88	40.88	40.88	40.88	40.88	40.88	40.88	40.88	40.88	40.88	40.88
	sprayer batteries	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47
	hoes and machetes	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59
No additional insecticide application	hired labor (for all activities)	31.35	31.35	31.35	31.35	31.35	31.35	27.30	27.30	27.30	27.30	27.30	27.30
	family labor	17.10	17.10	17.10	17.10	17.10	17.10	16.07	16.07	16.07	16.07	16.07	16.07
	Transport of inputs to farm	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03
	Extension services	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72
	Sacks	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43
	Insecticide Sprayers	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
	Total Variable costs ($/ha)	162.30	162.30	162.30	162.30	162.30	162.30	154.19	154.19	154.19	154.19	154.19	154.19
	Opport. Cost of equity capital	5.00	5.00	5.00	5.00	5.00	5.00	4.60	4.60	4.60	4.60	4.60	4.60
	Net returns to land ($/ha)	254.29	209.84	178.75	155.02	136.48	120.94	274.36	228.77	196.64	172.29	153.12	137.32
	Incr. Net return to land ($/ha)							20.08	18.93	17.89	17.27	16.64	16.38
	seed cotton yield (Kg/ha)	1616	1445	1326	1235	1164	1105	1625	1454	1334	1243	1170	1112
	seed cotton price($/ha)	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
	Gross revenue ($/ha)	440.68	394.05	361.59	336.78	317.42	301.33	443.25	396.36	363.72	338.85	319.16	303.10
	Insecticide	37.38	37.38	37.38	37.38	37.38	37.38	8.88	8.88	8.88	8.88	8.88	8.88
	Fertilizer	22.51	22.51	22.51	22.51	22.51	22.51	22.51	22.51	22.51	22.51	22.51	22.51
HIGH-INPUT USE	seed cotton	3.78	3.78	3.78	3.78	3.78	3.78	28.78	28.78	28.78	28.78	28.78	28.78
	Herbicide	40.88	40.88	40.88	40.88	40.88	40.88	40.88	40.88	40.88	40.88	40.88	40.88
	sprayer batteries	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47
	hoes and machetes	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59
One additional insecticide application	hired labor (for all activities)	31.35	31.35	31.35	31.35	31.35	31.35	27.30	27.30	27.30	27.30	27.30	27.30
	family labor	17.44	17.44	17.44	17.44	17.44	17.44	16.42	16.42	16.42	16.42	16.42	16.42
	Transport of inputs to farm	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03
	Extension services	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72
	Sacks	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43
	Insecticide Sprayers	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
	Total Variable costs ($/ha)	171.99	171.99	171.99	171.99	171.99	171.99	163.41	163.41	163.41	163.41	163.41	163.41
	Opport. Cost of equity capital	5.00	5.00	5.00	5.00	5.00	5.00	4.60	4.60	4.60	4.60	4.60	4.60
	Net returns to land ($/ha)	263.69	217.06	184.61	159.79	140.43	124.34	275.25	228.36	195.71	170.84	151.16	135.09
	Incr. Net return to land ($/ha)							11.56	11.30	11.11	11.05	10.73	10.75

Table J-2 (Cont'd).

	seed cotton yield (Kg/ha)	1672	1495	1372	1278	1204	1143	1658	1483	1360	1267	1194	1134
	seed cotton price($/ha)	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
	Gross revenue ($/ha)	455.95	407.68	374.14	348.50	328.33	311.69	452.06	404.39	370.97	345.59	325.64	309.32
	Insecticide	46.72	46.72	46.72	46.72	46.72	46.72	17.75	17.75	17.75	17.75	17.75	17.75
	Fertilizer	22.51	22.51	22.51	22.51	22.51	22.51	22.51	22.51	22.51	22.51	22.51	22.51
	seed cotton	3.78	3.78	3.78	3.78	3.78	3.78	28.78	28.78	28.78	28.78	28.78	28.78
HIGH-	Herbicide	40.88	40.88	40.88	40.88	40.88	40.88	40.88	40.88	40.88	40.88	40.88	40.88
INPUT	sprayer batteries	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47
USE	hoes and machetes	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59
	hired labor (for all activities)	31.35	31.35	31.35	31.35	31.35	31.35	27.30	27.30	27.30	27.30	27.30	27.30
Two	family labor	17.78	17.78	17.78	17.78	17.78	17.78	16.76	16.76	16.76	16.76	16.76	16.76
additional	Transport of inputs to farm	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03
insecticide	Extension services	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72
application	Sacks	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43
	Insecticide Sprayers	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
	Total Variable costs ($/ha)	181.67	181.67	181.67	181.67	181.67	181.67	172.63	172.63	172.63	172.63	172.63	172.63
	Opport. Cost of equity capital	5.00	5.00	5.00	5.00	5.00	5.00	4.60	4.60	4.60	4.60	4.60	4.60
	Net returns to land ($/ha)	269.27	221.01	187.46	161.83	141.65	125.02	274.83	227.17	193.75	168.36	148.41	132.09
	Incr. Net return to land ($/ha)							5.56	6.16	6.28	6.53	6.76	7.08
	Incr. Net return to land ($/ha)							1.50	1.12	3.13	3.40	3.92	3.98

Table J-2 (Cont'd).

	seed cotton yield (Kg/ha)	1719	1538	1410	1314	1238	1176	1688	1506	1385	1290	1216	1154
	seed cotton price($/ha)	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27	0.27
	Gross revenue ($/ha)	468.76	419.41	384.50	358.32	337.60	320.69	460.35	410.61	377.71	351.80	331.60	314.76
	Insecticide	56.07	56.07	56.07	56.07	56.07	56.07	26.63	26.63	26.63	26.63	26.63	26.63
	Fertilizer	22.51	22.51	22.51	22.51	22.51	22.51	22.51	22.51	22.51	22.51	22.51	22.51
HIGH-INPUT USE	seed cotton	3.78	3.78	3.78	3.78	3.78	3.78	28.78	28.78	28.78	28.78	28.78	28.78
	Herbicide	40.88	40.88	40.88	40.88	40.88	40.88	40.88	40.88	40.88	40.88	40.88	40.88
	sprayer batteries	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47
	hoes and machetes	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59
Three additional insecticide application	hired labor (for all activities)	31.35	31.35	31.35	31.35	31.35	31.35	27.30	27.30	27.30	27.30	27.30	27.30
	family labor	18.13	18.13	18.13	18.13	18.13	18.13	17.10	17.10	17.10	17.10	17.10	17.10
	Transport of inputs to farm	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03	6.03
	Extension services	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72	7.72
	Sacks	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43
	Insecticide Sprayers	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
	Total Variable costs ($/ha)	191.36	191.36	191.36	191.36	191.36	191.36	181.85	181.85	181.85	181.85	181.85	181.85
	Opport. Cost of equity capital	5.00	5.00	5.00	5.00	5.00	5.00	4.60	4.60	4.60	4.60	4.60	4.60
	Net returns to land ($/ha)	272.40	223.05	188.14	161.96	141.24	124.33	273.91	224.17	191.27	165.36	145.15	128.31
	Incr. Net return to land ($/ha)							1.50	1.12	3.13	3.40	3.92	3.98

Source: Author's computations based on Strasberg (1997), MADER (2000), and MADER (2001a).

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