EVALUATING SOYBEAN FARMING PRACTICES IN MATO GROSSO, BRAZIL: ECONOMIC AND ENVIRONMENTAL PERSPECTIVES

By

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To my wonderful parents.

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This study provides an evaluation of the management practices adopted by soybean farmers in northern Mato Grosso, Brazil to promote sustainable agriculture. Since Amaggi Group, the leading soybean operator in Mato Grosso, requires social and environmental responsibility from its pre-financed producers, this study addresses the following research questions: Do management practices differ between pre-financed and not pre-financed farmers with regard to implementation of no-tillage systems, deforestation and pesticide use? Are there differences in yield between farmers pre-financed by the Amaggi Group and those who are not?

Moreover, because farms are located in different biomes such as Cerrado and Amazon Forest, additional questions arise: Do management practices differ among the municipalities of Sinop, Sorriso and Tapurah, with regard to no-tillage systems, deforestation, forested area and pesticide use? Are there differences in soybean yield among the municipalities of Sinop, Sorriso and Tapurah? A case study of two soybean farms in the region of Sinop provides indications of the impacts of uncertainties in the exchange rate and the world soybean price on the farmers' net revenue.

A total of 40 soybean producers chosen randomly were interviewed, from which 20 farmers were pre-financed by Amaggi and 20 farmers were not pre-financed. With regard to their

location, 10 farms were located in Sinop, 20 in Sorriso and 10 in Tapurah. Data collected with regard to land use, soybean farming practices, and soybean yields were statistically analyzed. Soybean pest and diseases, and pesticide use were also considered. For two farms located in Sinop, net revenue analyses and risk analyses were conducted.

Data analyses revealed that the only difference between pre-financed and not pre-financed farms is related to the no-tillage system: 15% of the pre-financed soybean area did not have surface residues from cover crops, compared with 0.5% of not pre-financed farms. Comparisons among the farm locations revealed that an average of 27% of farm area in Sorriso was deforested while farms in Sinop were on average of 37% deforested. The use of desiccant prior to soybean harvest was an exception in pesticide patterns: farms located in Tapurah applied desiccant to 82% of their soybean area while farms located in Sorriso applied it to 50% of their area. Finally farms in Sinop had a higher soybean yield of fifty-two 60kg bags per hectare compared with 56 bags in Sorriso. The case study of two farms in Sinop revealed that the smaller farm is more susceptible to risks and uncertainties in the exchange rate and soybean price. An unfavorable exchange rate and relatively low soybean price increased the risk of the smaller farm losing money.

CHAPTER 1
INTRODUCTION

Soybean Production and Expansion in Mato Grosso, Brazil

According to the United States Department of Agriculture (USDA, 2004), Brazil is the second largest soybean (*Glycine max*) producer in the world, accounting for 24% of world soybean production. Its 2004/2005 harvest produced 50.5 million tons, with an average yield of 2.34 tons/ha in a harvest area of 21.52 million hectares. Although the United States is the leading producer, accounting for 40% of world soybean production, it is estimated that Brazil can surpass its production by the end of this decade.

Brazilian agriculture has benefited from currency devaluations, low production costs, rapid technological advances, and domestic and foreign investment to expand production capacity (USDA, 2006). Soybean production in Brazil is likely to increase as a result of the growing demand in the national and international market for oil producing grains such as soybean, which can be processed into meal for live stock rations, into oil for domestic use, and for biodiesel production. In addition, Brazil has unparalleled arable land reserves, and the technology to efficiently employ them, particularly in the state of Mato Grosso (Agnol, 2006).

The state of Mato Grosso accounts for approximately 29% of the soybeans produced in Brazil (USDA, 2007), and is the country's largest soybean producing state. In 2005, Mato Grosso produced 17.76 million tons, with an average yield of 2.90 tons/ha in an area of 6.1 million hectares (IBGE, 2006). Most of Mato Grosso's production is concentrated in the central and southern region, in the Cerrado ecosystem, a tropical savanna. The state of Mato Grosso has an area of 906,807 km^2. Although the state is part of the Legal Amazon, an administrative area defined by economic purposes to promote the economic development of the region, its natural vegetation is formed by three different ecosystems: Cerrado or savanna biome (38.29%), located primarily in southeastern and center Mato Grosso, tropical forest biome (55%) in the north formed by the Amazon Rainforest and Semi-deciduous seasonal forests, and Pantanal (7.02%), a wetland located in the southwestern region (Schwenk, 2005).

In the 1980s, the state of Mato Grosso experienced a rapid expansion of soybean production in the Cerrado region, due to the availability of abundant and affordable arable land, economies of scale compared to the southern region of Brazil, technology, mechanization, and the lowest operating costs per hectare (Goldsmith and Hirsch, 2006). Currently, 58% of Brazil's total soybean production comes from the Cerrado (Mittermeier et al., 2004). Soybean expansion into the Amazon biome began in 1997 when new soybean varieties were developed that tolerated the humid and hot Amazon climate. Soybean production in the Amazon has increased at a rate of 15% per year since 1999 (WHRC, 2007).

Although the state of Mato Grosso has good potential for soybean production, there are some challenges too. The great distance from the production region to ports in addition to the poor condition of the roadways leads to high transport costs. As a comparison, 74% of Brazilian soybeans still travel by road, 23% are transported by railways, and 3% by waterways; in the U.S., waterways carry 61%, and roadways transport only 16% (Goldsmith and Hirsch, 2006). The soils characteristic of Mato Grosso are relatively poor. They are acid, poor in nutrients and have elevated levels of aluminum, which demand high amounts of fertilizers accounting for 30% or more of soybean production costs. Moreover, environmental concerns exist. The dramatic shifts in land use as native savannas, dryland forests, and even certain rain forest sub-regions become potential areas for soybean cultivation may accelerate land clearing (Goldsmith and Hirsch, 2006).

According to Brazil's National Institute for Space Research (INPE), 30.75% of Mato Grosso's total area (approximately 27,860,110 hectares) had been deforested as of 2003. Higher deforestation rates occurred in northern Mato Grosso in 2003, where the biome is Tropical forest; and there are recently colonized areas such as the municipality of Sinop with 71.05% of its area deforested since 1964 (Moreno, 2005). Deforestation has been reduced dramatically since 2003/2004, however, due to a number of economic and policy variables (Souza, 2006).

According to Fearnside (2001), soybean is much more environmentally damaging than other crops because it requires massive transportation infrastructure. Also, biodiversity loss occurs when natural ecosystems are converted to industrial farming systems. Soybean expansion from the Cerrado toward the Amazon forest certainly contributes to land degradation, fragmentation and biodiversity losses. However, this environmental trade-off is typical of most countries where industrial agriculture has occurred. Furthermore, the degree to which soybean expansion is directly responsible for this loss is uncertain since soybean tends to expand to previously converted land, such as pasture (Brown et al., 2005).

In order to protect the great biodiversity of the Cerrado and Amazon forest and maintain landscape and environmental values, best management practices need to be adopted for the production of any crop. Rather than bring new land under cultivation through the deforestation of tropical forest and Cerrado, degraded soils and ecosystems must be restored and used more effectively. Achieving food security and improving environmental quality through sustainable management of soils is an important tool in avoiding additional deforestation and enhancing landscape values (Lal, 2000).

Being aware of these challenges, most of the industries today have changed from very intensive agriculture, harrowing and ploughing the soil like the site preparation used in the 1970s and 1980s, to minimal cultivation techniques to avoid soil erosion and nutrient losses (Ondro et al., 1995). The soybean farmers in Mato Grosso state claim that they are adopting best management practices to respond to the growing demand for commodities, produced in a manner that minimizes environmental impacts, in other words, sustainable agriculture.

Sustainable Agriculture

The greatest challenge to contemporary agriculture is to realize the goals of sustainable agriculture in practice. Most definitions of sustainable agriculture include the following elements: economic viability, maintenance of an adequate food supply for all people, conservation of nutrients and resources, minimal impact on the environment and natural ecosystems, intergeneration or even indefinite stability and equity (Powers and McSorley, 2000).

The search for a sustainable agricultural model implies the promotion of management practices that are environmentally appropriate, socially beneficial, and economically viable. In the context of soybean farming in the Cerrado region of Brazil, some of these management practices include (1) legal compliance with land protection regulations and (2) good farming practices such as crop rotation, no-tillage planting system, integrated systems, and integrated pest management (Shimada, 2006). They are essential to protect and preserve the range of species and habitats in the countryside, as well as conserve valuable soil and water resources.

Legal Compliance

To manage an agricultural business in Mato Grosso one must take into account legislation pertinent to the development of private rural properties in the Legal Amazon. Critical elements of this legislation originated in Brazil’s 1965 New Forestry Code (Código Florestal, 4.771, 1965) and are related to Permanent Preservation Areas (Áreas de Preservação Permanente, APP) and the Legal Reserve Area (Área de Reserva Legal, RL). These will be discussed in turn.

Permanent preserved areas (APP)

APP is forest and other vegetated area that must be preserved, with the objective of protecting rivers, natural landscape, biodiversity and soil. According to Article 2 of Brazil's 1965 Forestry Code (4.771) and considering the geographic characteristics of Mato Grosso, the most common APPs which must be protected or reforested are situated:

- Along rivers or water courses from their highest level along riparian zones, whose minimal width is shown in Table 1-1;
- Around lakes, ponds or water tanks, natural or artificial;
- In springs, either perennial or ephemeral, with a minimum width of 50 meters; and
- On the edge of steep slopes with a minimum width of 100 meters.

Legal reserve (RL)

According to the 2000 provisionary measure nº 1956-50/00, the legal reserve is defined as a forested area located inside a rural property, excluding the APP, in which biodiversity, flora and fauna are conserved, and ecological processes are rehabilitated. Although land clearing is illegal in the RL, sustainable forest management for multiple goods and services is permitted. In Mato Grosso as in any other state that forms the Legal Amazon, the percentage of the rural property to be maintained as an RL is:

- 80% if located in a tropical forest area;
- 35% if located in the Cerrado; and
- 20% if located in all other regions.

Among the items discussed in provisional measure nº 1956-50/00, is the compensation mechanism for legal reserve. This mechanism offers the rural producers who do not have the minimum legal reserve required in their property, the alternative of compensating the area lacking in another property in the same micro-hydrological basin and ecosystem.

Since Brazil's 1965 New Forestry Code was enacted, it has been modified many times by law and provisionary measures (Table 1-2), serving to demonstrate the legislators' difficulty in reconciling the social and economic interests of the different stakeholders involved (Joels, 2002). The requirement of registering the legal reserve with the landed property registration, forbidding changing its destination and desegregation was introduced by law 7.803, of July 18, 1989 (Art. 16 § 2°).

Good Farming Practices

Crop rotation and cover crops

Crop rotations or continuous crop sequences involve replacing monoculture cropping with other crops over time. The rotation can be with cash crops where markets often determines the crop sequence and more than one cash crop can be grown per year; and cover crops which are not usually marketable, but are typically used to protect the soil from erosion, improve soil structure, enhance soil fertility, and suppress pest and pathogens. Cover crops are lower-value crops usually grown in the dry season which is less favorable for cash crop production. If legumes are used, they are planted in the rainy season, but are left in the field throughout the dry season. Another option is to allow an area to fallow (unintentional rotation), because of erosion or when weeds take over an area (Powers and McSorley, 2000).

In the Brazilian Cerrado regions, some of the most prominent production systems are the continuous cash crop sequences of cotton (*Gossypium* sp) – soybean (*Glycine max*), and cotton (*Gossypium* sp) – soybean (*Glycine max*) – corn (*Zea mays*). The most common cover crops are millet (*Pennisetum glaucum* L. R. Br.), finger millet (*Eleusine indica*) and *Brachiaria ruziziensis* (Figure 1-1). In some regions of Mato Grosso, it is common to have cash crops such as corn, sorghum (*Sorghum bicolor* (L.) Moech.), castor bean (*Ricinus communis* L.), or sunflower

(*Helianthus annuus*) planted after early soybean as a second crop. They serve the same purpose of cover crops and can often be sold (Altmann, 2006).

Soil conservation and management

According to the Food and Agriculture Organization (FAO) and the United Nations (2001), soil erosion, accelerated by wind and water, is responsible for around 40% of land degradation worldwide. Soil conservation practices that provide some cover to the soil surface are the most efficient against soil erosion. The most frequently used soil conservation methods by soybean producers in Mato Grosso are direct seeding with terraces (Shimada, 2006).

In direct seeding (also known as direct drilling, no tillage practice, no till, and zero tillage), the surface residues from cover crops are left undisturbed. These residues maintain the soil covered and thus help to control erosion and conserve moisture. Maintenance of surface residue can reduce soil erosion up to 90% or more (Powers and McSorley, 2000). The seeds are placed in the soil without tilling. Additional advantages of this system are that it reduces the need for tractor power and tillage equipment, it demands less fuel, and increases soil organic matter (Buchholz et al., 1993).

The main disadvantages of direct seeding are that this system relies on herbicide use for weed control and it may delay planting because of greater moisture under heavy residue. Direct seeding involves important trade-offs between the soil conservation benefits and the intensive application of herbicide. Traditional tillage systems involve the mechanical and biological break-down of weed species which, given Mato Grosso's climate, result in significant increases in erosion and consequent nutrient loss. Thus, herbicide use in this system substitutes the need for tilling; it improves crop yield by reducing weed density and competition while direct seeding minimizes soil erosion and nutrient loss (Powers and McSorley, 2000).

Terrace, a raised bank of earth having vertical or sloping sides and a flat top, slow or prevent the rapid surface runoff of irrigation water or rainfall. Being implemented with no tillage, these sustainable agriculture practices provide social, economic and environmental benefits. These practices are recognized by national institutions such as the Brazilian Agricultural Research Corporation (Empresa Brasileira de Pesquisa Agropecuária, EMBRAPA), the Ministry of the Environment (Ministério do Meio Ambiente, MMA) and the National Water Agency (Agencia Nacional de Água, ANA), and by international institutions such as the World Bank and the Food and Agriculture Organization (FAO) (Shimada, 2006).

Integrated production systems

Integrated production systems are farm systems that combine the production of various goods and services. One common variant of this system in Mato Grosso is the agrosilvipastoral system. An agrosilvipastoral system is a type of agroforestry system that includes the production of trees or shrubs, crops, pasture, and animals (World Agroforestry Centre, 2006). In tropical environments, both grazing systems of pasture under commercial tree stands, and growing and managing fodder-producing trees on farmlands are used (Nair, 1990).

The benefits of the agrosilvipastoral system reported by Russo (1996) include: diversification that stabilizes the agricultural system; economic benefits obtained from fuelwood, timber, and posts; soil improvement from leguminous trees and deep nutrient uptake by trees; production of biomass which may be used as forage and/or organic matter; livestock production that provides meat, milk, and nutrient cycling through manure; and added nutritional value to the rural family's diet. One of the few disadvantages is the soil compacting and trampling of crops by animals; however, this can be minimized through careful planning.

In integrated production systems combining crop and livestock production, the pasture is introduced following the soybean harvest. This can reduce pest and disease infestation by breaking the life cycle of specific pest and soybean diseases. The pasture also provides a significant amount of organic residues which enables subsequent direct seeding. The soybean that is planted over the existing pasture typically has a higher productivity and tends to reduce production costs due to no tillage. Additional income is also generated in this system with the addition of cattle grazing (Bortolini, 2006).

With the implementation of crop-livestock systems in regions that produce corn as a cover crop, three harvests in one year can be obtained. In Lucas do Rio Verde, in the north central Mato Grosso, soybean is planted from October to February; corn, a small amount of sorghum, and sunflowers are planted from February to June; and from June to September cattle are allowed to graze on the cover crops where the pasture was planted (Bortolini, 2006).

Integrated pest management (IPM)

According to Powers and McSorley (2000), integrated pest management programs have the objective of reducing pesticide use and environmental impact. It involves integration of multiple tactics for managing a single pest, and integration of the management of multiple kinds of pests. Many techniques such as resistant cultivars, soil amendment, crop rotation, sanitation, biological control and chemical control can be used in IPM (Shimada, 2006).

Biological control is the management of a pest by another living organism. The strategy involves manipulating predators, parasites, and pathogen presence to maintain pest populations in a field at levels below which they may cause economic injury to the crop (Powers and McSorley, 2000). Application of Baculovirus *Anticarsia Gemmatalis* to control velvetbean caterpillar began in Brazil in the beginning of the 1980s and grew rapidly from 2,000 hectares in 1982/1983 to more than 500,000 hectares in the 1987/1988 harvest period. The use of Baculovirus reduces the use of chemical insecticide and has environmental benefits. In addition, it does not interfere with other organisms that may help control other pests. For better results in controlling insect pests, management decisions should be supported by regular monitoring of the crop and life stage, damage levels, insect lifecycle, and the size of the outbreak (Shimada, 2006).

According to EMBRAPA (2004), the foliar blight disease (*Rhizoctonia solani*) is efficiently controlled when IPM methods are adopted. Since there are no cultivars resistant to this disease, control methods include direct seeding, crop rotations with non-host plants, reduction of soybean plant density, balanced plant nutrition especially with potassium (K), sulfur (S), zinc (Zn), copper (Cu) and Manganese (Mn), weed control and chemical control.

Pesticide use and technology

Pesticide purchase and application represent one of the greatest costs in agribusiness. Pesticides are also responsible for major negative environmental impacts and work-related accidents. To minimize environmental impacts and protect workers, a variety of variables need to be considered before application such as weather conditions (moisture, temperature, wind and rain), the product features, and the target pest (Shimada, 2006).

There are a number of stages in the production process in which farmers in Mato Grosso commonly apply pesticides. First, herbicides are applied to the field before soybean planting to eliminate weeds. Second, agrochemicals are used in treating seeds to kill fungal diseases and improve seed germination. Then, during the growth cycle, post-emergent herbicides, insecticides and fungicides are applied to the crop to reduce potential damage from weeds, insects and fungus. Finally, non-selective herbicides (also desiccants) are applied to facilitate soybean harvest. To avoid pesticide residues in the harvested soybean grain, desiccants should be applied seven days before the soybean harvest (EMBRAPA, 2004).

According to Bickel and Dros (2003), five to ten liters of pesticide, depending on the level of technology used, are applied per hectare of soybean in Mato Grosso. This translates into 4.3 million kilograms of empty pesticide packages collected each year, rendering Mato Grosso the third largest producer of this type of waste. Therefore, compulsory collecting and triple washing of empty pesticide packages are very important components of pest management, reducing the risk of groundwater contamination.

Amaggi Group

Amaggi Group, a privately held company, is the leading soybean operator in Mato Grosso. In Amaggi Group's farms, there is a total 122 thousand hectares of soybean, 23 thousand hectares of corn (secondary crop), and 16 thousand hectares of cotton planted. In the municipality of Sapezal, there are two farms: Tucunaré with an area of 57,833 hectares and the Agro-Sam farm with an area of 20,371 hectares. The 47,212 hectare Itamarati farm is located in Campo Novo dos Parecis. The first farms acquired by the Group are in southern Mato Grosso and have a total area of 16,989 hectares. Tanguro farm, 72,600 hectares in size, is located in northern Mato Grosso (Grupo Amaggi, 2007).

Amaggi Group has been solidifying its position in the agribusiness, through vertical integration in the production, processing and exportation of soybean and sub-products such as oil and meal. One of its divisions, Amaggi Export and Import, operates in the states of Mato Grosso, Rondônia, and Amazonas. Its business is to commercialize, store, process, transport, and promote soybean production in Mato Grosso by pre-financing farmers. Amaggi Export and Import has silos in the region of the BR-163 such as in Sorriso and Sinop with a capacity of 60,000 tons each, and in Tapurah with a capacity of 18,000 tons.

Amaggi Group silos receive both genetically modified soybeans (GM) and non-genetically modified soybeans (non-GM). The GM soybeans are segregated from the non-GM soybeans. The producers, besides paying royalties to the company which sells the patented seed, receive different prices for GM soybeans and non-GM soybeans due to export logistics. The non-GM soybeans are exported through ports in the town of Itacoatiara (Amazonas state), where the

Amaggi Group has a private port, and in the city of Santos (São Paulo state). The GM soybeans are exported through the port in the city of Paranaguá (Paraná state). Countries that are willing to pay more for non-GM soybeans pay a premium for this product, compared with GM soybean. This premium is not transferred to the producers, however, since it covers the soybean segregation costs. The countries that usually pay premiums to Amaggi are Norway, Ireland, Denmark and Japan (L. M. Ribeiro, personal communication, June 6, 2007).

One of Amaggi Group's objectives is to combine the preservation of the environment with excellent results in terms of production and profitability. In working towards this objective, Amaggi Group has developed and disseminates a set of good farming practices for soybean producers in Mato Grosso, to induce a gradual improvement in the levels of legal compliance and the standards of environmental performance. In addition, Amaggi Group requires social-environmental responsibility from its pre-financed producers (Grupo Amaggi, 2007).

Since 2004, Amaggi Group's credit policy has had the objective of promoting an ongoing improvement of the environmental indicators of its pre-financed producers. Based on data collected on the properties of pre-financed farmers, recommendations for improvement are developed. With regard to legal compliance, Amaggi Group requires legalization of legal reserves, recuperation of riparian areas and no illegal deforestation for the duration of the contract. With regard to good farming practices, adoption or increase in the area where the no-tillage system is applied, and implementation of integrated pest management are recommended (Grupo Amaggi, 2006).

Study Objectives, Research Questions and Hypotheses

This project provides a comprehensive evaluation of the management practices adopted by soybean farmers in northern Mato Grosso, Brazil where the agricultural frontier is pushing into the Amazon. The first objective is to evaluate differences in farming practices adopted by soybean farmers in the region of BR-163. In order to accomplish this task, farmers that are pre-financed by Amaggi Group which are required to demonstrate environmental responsibility, were randomly selected to be compared with farmers who are not pre-financed by Amaggi Group. The second objective is to evaluate differences in farming practices between regions, namely the municipalities of Sinop, Sorriso, and Tapurah due to the fact that they are located in different biomes.

Semi-structured interviews with soybean farmers pre-financed by Amaggi Group and those not pre-financed by Amaggi Group in the municipalities of Sinop, Sorriso, and Tapurah, where Amaggi Group operates, were carried out in June and July 2006 to address the following research questions:

- Do management practices differ between pre-financed and not pre-financed farmers with regard to implementation of no-tillage systems, deforestation and pesticide use?
- Are there differences in yield between farmers pre-financed by the Amaggi Group and those who are not?
- Are there differences in management practices among the municipalities of Sinop, Sorriso and Tapurah, with regard to no-tillage system, deforestation, forested area and pesticide use?
- Are there differences in soybean yield among the municipalities of Sinop, Sorriso and Tapurah?
- What are the impacts of uncertainties in exchange rate and world soybean prices on the net revenue of soybean farmers in the region of Sinop?

Given Amaggi Group's credit policy with their pre-financed producers, and the environmental concerns in northern Mato Grosso, the following hypotheses are tested in Chapter 2 and 3:

- The pre-financed farmers are more likely to preserve forested area;
- The pre-financed farmers have a greater percentage of soybean area in a no tillage system;
- The pre-financed farmers have greater cover crop diversity;

- The pre-financed farmers use fewer types of pesticide than those who are not;
- The pre-financed farmers have greater yields than those who are not.

Moreover, based on the assumption that farms that are located closer to the Amazon forest would have more forested area on farm and, therefore, would need less pesticide use, and that soybean productivity in areas that are newly deforested is lower than in areas that have been cultivated for longer periods of time, additional hypotheses tested in Chapter 2 and 3 are:

- The producers located in Sorriso are less likely to preserve forested areas than those located in Sinop and Tapurah;
- The producers located in Sorriso are more likely to plant corn as a second crop than those located in Sinop and Tapurah;
- The producers located in Sinop use less fungicide and apply it fewer times than the producers located in Sorriso and Tapurah;
- The producers located in Sinop have lower yields than those located in Sorriso and Tapurah.

This study is divided into four parts. Chapter 2 compares land use and soybean farming practices adopted by farmers in the study region. Chapter 3 complements Chapter 2, examining the pesticide use strategies implemented by farmers. Chapter 4 compares yields between groups, and provides a case study of two farms in Sinop. Risk analyses are conducted to evaluate farmer susceptibility to uncertainties in the soybean price and the exchange rate. Chapter 5 summarizes the findings and provides conclusions and recommendations.

Methods

Description of Study Sites

The study was undertaken in the municipalities of Sinop, Sorriso, and Tapurah situated in northern Mato Grosso (Figure 1-2). Benefits such as accessible lands offered by the federal and regional governments as part of the regional development programs, and infrastructure development enabled large areas to be purchased by the private sector and colonized. From the middle of the 1970s until the end of the 1980s, entrepreneurs from the southern and southeastern regions of Brazil attained vast extensions of public or private lands to invest in colonization programs, agriculture and cattle ranching (Moreno, 2005).

Characteristic of this frontier region are large-scale cattle ranching operations and mechanized monoculture farming due to the arable lands and flat topography. Soybean production in 2004 and 2005 for Sorriso, Sinop, and Tapurah are displayed in Table 1-3. The municipalities are located in the region of highway BR–163; however, only Sorriso and Sinop are actually on the highway.

The BR-163 site

The BR-163 is one of the main federal highways. It was opened during the 1970s through the National Integration Program (PIN) with the objective of integrating the Amazon region with the national economy. The highway is 1,780 kilometers long and extends from Cuiabá, capital of Mato Grosso, to Santarém on the Amazon river in Pará state. Paving BR-163 is not yet completed, with 953 kilometers remaining between Matupá (MT) to Santarém (ISA, 2005).

Due to the fact that the BR-163 passes through remote regions of the country that are of both environmental and cultural interest, the pavement of the BR-163 has been debated since the 1990s. However, it was not until 2003 that it was decided that paving the BR-163 would go ahead as a component of Mato Grosso and Pará's sustainable development programs. In 2004 the federal government created the BR-163 Sustainable Regional Development Plan for the highway's areas of influence (Figure 1-3), which seeks to resolve stakeholders' demands in a participatory manner (ISA, 2005).

Municipality of Sinop

In 1972, the Real Estate Society of North Paraná (SINOP), a colonizing enterprise, bought an area of approximately 200 thousand hectares in the municipality of Chapada dos Guimarães;

successive acquisitions resulted in an area of more than 600 thousand hectares. In the BR-163's area of influence, the projects of Vera, Sinop, Santa Carmem and Cláudia were implemented (Moreno, 2005). The city of Sinop was officially founded September 14, 1974, and after 5 years the municipality of Sinop was created with an area of 3,207 Km^2. The city of Sinop is located 500 kilometers north of Cuiabá and 80 kilometers south of the city of Sorriso (Assessoria de Comunicação da Prefeitura de Sinop [ASSECOM], 2006).

One of the main economic activities in Sinop is timber production. Sinop began to diversify its economy after 1995 by implementing sustainable forest management, conducting research in reforestation, cattle ranching and agriculture (Pichinin, no date). The settlers of Sinop came from the south of Brazil. Today, migrant people are coming from other regions of Mato Grosso. According to IBGE, there were 74,831 inhabitants in the year 2000. In 2004, there were an estimated 94,724 inhabitants, an increase of 26.58% (ASSECOM, 2006).

The topography in Sinop is generally flat with some slightly undulating areas, which is favorable for agriculture and cattle ranching. Most of its soil is clay with some sandy soils and there are some areas that are susceptible to erosion. Before the occupation and deforestation of its natural vegetation, Sinop was covered by Rainforest. The typical climate is hot and humid with an average annual temperature of 28°C. The equatorial rain pattern is characterized by a dry season from June to August, and a rainy season with the heaviest rains from January to March (ASSECOM, 2006).

Municipality of Sorriso

In 1977, a private colonization project was implemented along the BR-163 and resulted in the city Sorriso (Moreno, 2005). The majority of the migrant people came from southern regions of Brazil, especially from the states of Rio Grande do Sul, Paraná and Santa Catarina. In May 13, 1986, the district of Sorriso was desegregated from the municipalities of Nobres, Sinop, and

Diamantino and it was denominated the municipality of Sorriso with an area of 10,480 Km^2. The municipality of Sorriso is located 412 kilometers north of Cuiabá. According to IBGE, Sorriso has 48,325 inhabitants, however a more recent estimate is 65 thousand people (Sorriso City Hall, 2005).

Sorriso's soil has excellent water infiltration capacity and medium susceptibility to erosion. In inadequate use conditions or under heavy precipitation, irreversible soil degradation can occur. The climate is tropical humid with a defined dry season. The difference in average temperature is 15°C from the hottest to the coldest month. The average annual temperature is 30°C. The average annual precipitation is around 2,000mm and it is concentrated in the months between October and March. Relative humidity is on average 80%, but it is 22% from June to the end of August (Sorriso City Hall, 2005).

The main economic activities are mechanized agriculture, producing cash crops such as rice, soybean, corn, and cotton. Logging and wood processing is also an important activity. Sorriso is considered the second largest grain producer in Brazil. In the 2004/2005 harvest period, the planted area was 613,957 hectares with approximately 2,485,000 tons of grain harvested. According to research by IBGE (2005), the municipality of Sorriso is the fourth largest corn producer, and the largest soybean producer in Brazil. Cattle ranching is increasing annually and currently there are 40,000 head of cattle on 30,000 hectares of pasture (Sorriso City Hall, 2005).

Municipality of Tapurah

The private enterprise Eldorado was responsible for colonization in Tapurah, the name referencing an Indian chief of the region. The first family settlement in Tapurah occurred in 1969. In 1981 the district of Tapurah was created, and on July 4, 1988 the municipality of Tapurah with an area of 11,600 Km^2 was disaggregated from the municipality of Diamantino

(Tapurah City Hall, 2006). In 2002, two new municipalities Itanhangá and Ipiranga do Norte were disaggregated from the municipality of Tapurah resulting in an area of 4,489.60 Km^2. The city of Tapurah is seated 414 kilometers from Cuiabá and 100 kilometers northwest of Lucas do Rio Verde, which is also located along the BR-163 south of Sorriso.

The population of Tapurah has significantly increased; according to IGBE, there were 8,816 people in 1996 and in 2004 there were 13,295 people. The average annual growth rate was 6.87% between 1996 and 2000. Today, Tapurah has 13,735 inhabitants, from which 7,300 inhabitants live in the rural areas (Tapurah City Hall, 2006).

Since its colonization, large areas were deforested for agriculture, cattle ranching, timber harvesting and settlements. The total deforested area is 219,900 hectares, from which 150,700 hectares are used for agriculture and 43,000 hectares for cattle ranching; there are 228,969 hectares of forest remaining. In 2005/2006, there were 109,500 hectares planted with soybean, 19,000 hectares with corn as a secondary crop, 5,000 hectares with cotton, and 2,000 hectares with rice (Tapurah City Hall, 2006).

The agricultural areas are excellent for mechanized agriculture due to their regular soils, although the smallholder agriculture also exists. In its remaining forested area, selective timber harvesting is practiced. The climate is tropical with two well defined seasons (Tapurah City Hall, 2006).

Field Methods

A total of 40 soybean producer interviews and surveys were conducted during June and July of 2006. Amaggi Group staff presented the researcher to Amaggi's branch managers in the municipalities of Sinop, Sorriso, and Tapurah. The managers assisted the researcher in getting in contact with soybean producers in these regions. The first municipality visited was Sinop, then Sorriso, and finally Tapurah. A decisive factor for farm selection was that farmers should grow soybeans. A second criterion was that half of the producers in each region should be pre-financed by Amaggi Group and the other half not. Thirdly, the number of farms chosen in each municipality was proportional to the number of soybean farms in that municipality. Farm size was not a criterion, since most farms in the study region are medium to large scale. According to Brazil's Institute of Colonization and Agrarian Reform (INCRA), medium farms are from 500 hectares up to 2,000 hectares and large farms are from 2,000 hectares up to 10,000 hectares. The size distribution of the studied farms is displayed in Table 1-4.

From the total of 40 farmers interviewed, 10 interviews occurred in Sinop, where 5 farmers were pre-financed by Amaggi Group and 5 farmers were not; 20 interviews occurred in Sorriso where 10 farmers were pre-financed by Amaggi Group and 10 farmers were not; and finally 10 interviews in Tapurah, where 5 farmers were pre-financed by Amaggi group and 5 farmers were not. Fewer interviews occurred in the municipalities of Sinop and Tapurah because there are fewer farmers in these municipalities compared with Sorriso.

The pre-financed farmers were randomly selected from 18 farmers that were pre-financed by Amaggi Group in the region of Sinop, from 51 pre-financed farmers in Sorriso, and from 25 pre-financed farms in Tapurah, all of them pre-financed in the year of 2006. João Shimada (Amaggi Group's Environmental Coordinator) facilitated access to Amaggi's Branch Managers in each municipality. Shimada accompanied the researcher in the field from the beginning of the field work in June 7, 2006 until the beginning of July. His assistance and support was extremely important familiarizing the researcher with the study area and providing background on the soybean production process in the region. The researcher contacted the selected farmers, and depending on their interest and availability, the interviews were scheduled. Due to time constraints, distance to the farms, and farmers' convenience, some interviews could not be conducted on the actual farm sites. Therefore, some farmers were also interviewed in homes, offices, and in Amaggi's offices.

The farmers that were not pre-financed by Amaggi Group were suggested by Amaggi's branch managers, since they knew most of the farmers in the study region, by staff of the Mato Grosso Agriculture and Cattle Ranching Foundation (Fundação Mato Grosso), especially in Sorriso where the foundation headquarters are located; and by the researcher and João Shimada's contacts in Sinop, Sorriso, and Tapurah. The researcher contacted the farmers, and again according to the farmers' interest and time availability, the interviews were scheduled in their farms, houses or offices.

The researcher encountered some challenges during field research. The trip to the study region could not begin before June because soybean farmers were on strike in Brazil. Farmers in Mato Grosso set up blockages of main roads, including the BR-163, demanding better soybean prices and government aid. During this time, soybean prices were depressed, exchange rates were unfavorable for exports, and in some regions there were lower soybean yields due to poor weather during that harvest season. In addition, access to farmers was sometimes made difficult due to tight schedules and Brazil's soccer team's participation in the World Cup.

Interviews

The same semi-structured interviews were applied to all farmers. Interview content included questions concerning land cover and land use distribution, soybean agricultural practices, soybean diseases, pesticide use, and yields (see semi-structured interview in Appendix).

More specifically, farmers were asked about the size of their properties, if it was leased or owned, the hectares planted with soybeans and other annual crops, hectares with pasture, forested area and reforested area. They were also asked whether or not they were currently adopting a no tillage system in their soybean area and for how long they had practiced this system, how many hectares of soybean area were being covered by different cover crops, and planted with GM soybeans and nematode resistant cultivars.

With regard to soybean diseases and pesticide use, farmers were asked what kind of soybean disease they consider the most problematic, what kinds of insect infestation, pathogenic disease, and nematodes they had in the 2006 soybean harvest season, and which chemical pesticide was used for each stage of soybean production. Data on the number of fungicide applications and the area applied with desiccant prior to soybean harvest were also collected.

With regard to soybean productivity, farmers were asked about their soybean yields for the 2005/2006 harvest. Since soybean production costs are often kept confidential, these costs were only obtained for two farms in Sinop and serve as the basis for the case study presented in Chapter 4. These data were obtained for Sinop since the farmers in this municipality appeared to be more receptive.

Table 1-1. Required widths for Permanent Preservation Areas (APP) according to width of the watercourse. Source: Brazil's 1965 New Forestry Code (4.771).

Water courses width	APP width
Up to 10 meters	30 meters*
Between 10 and 50 meters	50 meters
Between 50 and 200 meters	100 meters
Between 200 and 600 meters	200 meters
Larger than 600 meters width	500 meters

*In Mato Grosso the required APP width is 50 meters.

Table 1-2. Legal Reserve (RL) modifications since Brazil's 1965 New Forestry Code implementation. Biome: Forest (F), Cerrado (C), Ecotone (E). Source: Shimada, 2007.

Date – legislation	Main topics established		RL for regions*
1934 – Decree 23.793		F	25%
	Reserve of ¼ on forested lands; rural properties located close to forests are exempted.	C	0%
Sep 15, 1965 – New Forestry Code law 4.771		F	20% S; 50% N
	Reserve of 20% for area with shrubs and 50% for north region.	C	0%
Jul 18, 1989 – Law 7.803		F	20% S; 50% N
	RL definition and registration requirement; Cerrado region is included.	C	20%
Jan 17, 91 – Law 8.171		F	20% S; 50% N
	Reforestation requirement for RL of 1/30 for each year.	C	20%
1995 – Mato Grosso Complementary law 038-MT		F	20% S; 50% N
	RL of 50% in transition areas, which depends on regulation.	C	20%
		E	50% in MT
Aug 22, 1996 – MP 1.551		F	20% S; 50% N; 80% E
	Changes in RL percentages for northern regions and northern MT	C	20% S; 50% N
Dec 11, 1997 – MP 1.605		F	20% S; 50% N; 80% E
	Exceptions of the 80% RL for INCRA settlements, areas under than 100 ha and used for family agriculture.	C	20% S; 50% N
Dec 14, 1998 – MP 1.736		F	20% S; 50% N; 80% E
	Reforestation requirement abolished; RL modified for Cerrado's region.	C	20%
Jul 18, 1999 – MP 1.885		F	20% S; 50% N; 80% E
	Indigenous area is considered APP. APP can be calculated as RL.	C	20%
Jan 06, 2000 – MP 1.956		F	20% S; 50% N; 80% E
	Compensation of RL permitted in other areas within the same micro-hydrological basin.	C	20%
May 26, 2000 – MP 1.956-50		F	80% LA; 20% others
	Deforested areas after 12/14/98 cannot be compensated. Agrarian reform projects are forbidden in forested areas. Changes in the % RL.	C	35% LA; 20% others
Jun 26, 2000 – MP 1.956-51		F	80% LA; 20% others
	Cerrado area for Legal Amazon: 20% RL and 15% compensation area. Small properties planted with fructiferous, ornamental and exotics species can count towards RL requirement.	C	35% LA; 20% others
Jul 26, 2000 – MP 1.9956-52		F	80% LA; 20% others
	APP can count for RL if APP + RL > 50%; and 80% for Legal Amazon region	C	35% LA; 20% others
Aug 23, 2000 – MP 1956-53		F	80% LA; 20% others
	The owner is exempted for paying taxes for 30 years if he/she donates the RL for forest reserve	C	35% LA; 20% others
Sep 21,2000 – MP 1.956-54		F	80% LA; 20% others
	Reforestation requirement for RL - 1/10th of area every 3 years.	C	35% LA; 20% others
Mar 22, 2001 – MP 2.090-61		F	80% LA; 20% others
	Forest management in indigenous areas is allowed.	C	35% LA; 20% others
Aug 22, 2001 – MP 2.166-67		F	80% LA; 20% others
	Currently in effect	C	35% LA; 20% others

*S = South; N = North; E = Ecotone; LA = Legal Amazon states.

Table 1-3. Soybean production, planted and harvested area for Brazil, Mato Grosso, and the municipalities of Sinop, Sorriso and Tapurah for year 2004 and 2005. Source IBGE – Municipal Agricultural Production.

	Production (tons)		Planted area (hectares)		Harvest area (hectares)	
	2004	2005	2004	2005	2004	2005
Brazil	49,549,941	51,182,074	21,601,340	23,426,756	21,538,990	22,948,874
Mato Grosso	14,517,912	17,761,444	5,279,928	6,121,724	5,263,428	6,106,654
Sinop	243,395	375,417	84,495	130,326	84,495	130,326
Sorriso	1,688,120	1,804,669	547,867	582,356	540,867	578,356
Tapurah	719,808	332,640	260,800	109,500	260,800	108,706

Table 1-4. Selected farm size distribution according to INCRA in Sinop, Sorriso and Tapurah.

Farm size	Hectares	# of selected farms	Percentage
Very small	< 50	0	0
Small	50 – 499	4	10
Medium	500 – 1,999	19	48
Large	2,000 – 9,999	14	35
Very large	≥ 10,000	3	8

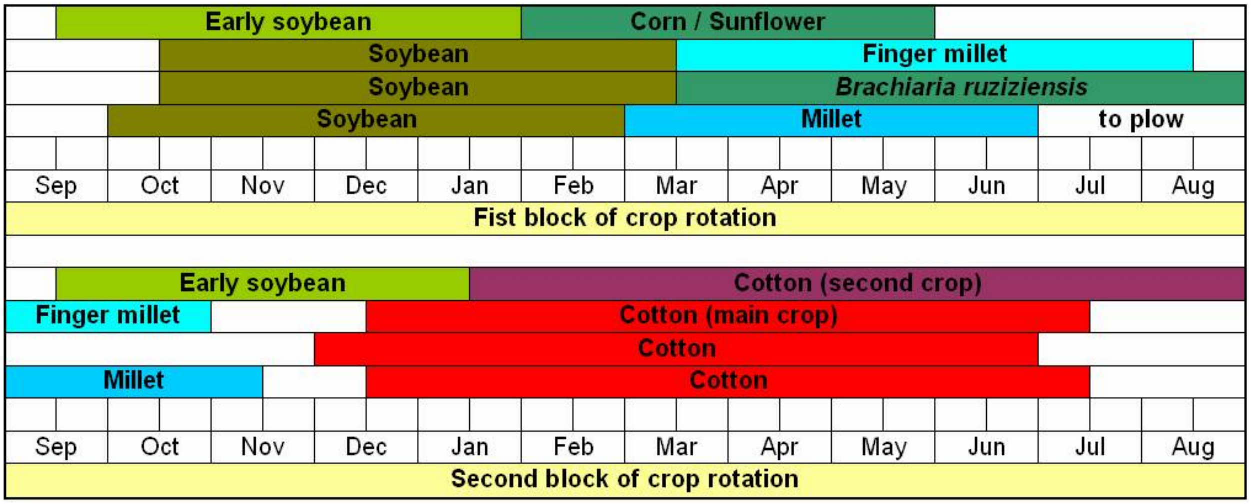


Figure 1-1. Some cover crop options for the Cotton – Soybean rotation system. [Source: Altmann, N. 2006. Rotação, sucessão e consorcio de espécies para agricultura sustentável. Boletim de Pesquisa de Soja 2006 (Page 237, Figure 2). Fundação Mato Grosso, Rondonópolis, Mato Grosso.]

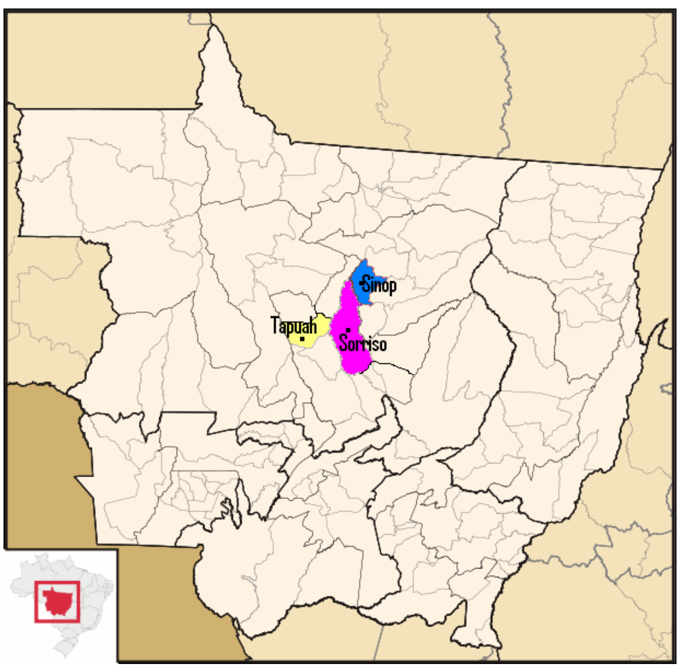


Figure 1-2. Map of the study region. Municipalities of Sorriso, Sinop and Tapurah located northern Mato Grosso. [Source: Wikipedia, 2007. Available at: http://pt.wikipedia.org/wiki/Sinop. Modified by the author.]

Figure 1-3. Highway BR-163 and its area of influence. [Source: Ministério do Meio Ambiente, 2005. Plano de Desenvolvimento Regional Sustentável para a Área de Influência da Rodovia BR-163 Cuiabá – Santarém.]

CHAPTER 2
SOYBEAN MANAGEMENT PRACTICES

Introduction

The purpose of this chapter is to analyze the agricultural management practices adopted by soybean farmers in Sinop, Sorriso, and Tapurah, located in northern Mato Grosso, Brazil. Since the Amaggi Group requires social-environmental responsibility from its pre-financed producers, the management practices adopted by farmers who were pre-financed by Amaggi Group in the study region in the year of 2006 will be compared to those who were not pre-financed. Amaggi Group requires legalization of legal reserves, recuperation of riparian areas, and no illegal deforestation for the duration of the contract. With regard to good farming practices, adoption or increase in the area farmed as a no-tillage system and the implementation of integrated pest management are recommended, although not required.

Because the study farms are located in different biomes, for example, farms located in Sinop are in the Amazon forest and farms in Sorriso are in the Cerrado region, it is expected that farms would differ in their percentage of forest cover. Moreover, the municipality of Sorriso is known for its important contribution to the grain producing industry, which leads to the expectation that producers in Sorriso designate a higher farm area to plant soybeans, as well as corn as a secondary cash crop. Therefore, the agricultural practices of farms will also be compared according to their respective municipalities. The following hypotheses will be tested:

- **Hypothesis 1:** Farms pre-financed are more likely to preserve forested area than those that were not pre-financed;
- **Hypothesis 2:** Farms in Sorriso are less likely to preserve forested areas than the farms located in Sinop and Tapurah;
- **Hypothesis 3:** Farms pre-financed have a greater percentage of soybean area in a no tillage system;
- **Hypothesis 4:** Farms pre-financed have greater cover crop diversity; and

- **Hypothesis 5:** The producers located in Sorriso are more likely to plant corn as a second crop than those farmers located in Sinop and Tapurah.

To accomplish this task, this chapter is structured as follow: First, the methods section describes the data analysis and how the descriptive and statistical analyses, linear regression models and weighted means were conducted. Later, the results of land use, soybean planting practices and soybean pests (the latter included in this Chapter as an introduction to Chapter 3), are displayed; finally the discussion section comments on the hypotheses.

Methods

Data Analyses

Data on agricultural practices collected in June and July 2006 from 40 interviewed soybean farmers were organized according to land use and soybean planting practices. Land use describes the physical and productive characteristics of the properties. The variables included in land use are: farm size, years since land purchase and the most recent deforestation, distance from municipal seat, number of head of cattle, percentage of farm area covered by the most recent deforestation, and percentages of farm area in natural forest, reforestation, soybean cultivation, other annual crops and pasture. Leased land is not considered here due to a lack of data.

It is important to note that the variable percentage of natural forest on farm is part of the legal reserve, but many farmers have additional area off-site as compensation areas. However, it is not the objective of this study to verify if this percentage is in compliance with the law. Therefore, what is reported here is natural forest preserved on farm.

Soybean planting practices describe the management practices adopted in areas cultivated with soybeans, in this case leased land is included because it is directly under the farmer's management. The variables reported are: area planted with soybeans; percentage of soybean area that is planted with genetically modified (GM) soybeans and resistant cultivars; years between land purchase and first implement action of a no tillage system; and percentages of soybean area with different cover crops: corn, millet, other cover crops, and area left in fallow.

With regard to soybean diseases, the study variables are: the percent of farmers reporting insect pests, pathogenic diseases and plant parasitic nematodes. These variables, although not statistically analyzed, provide a snapshot of the soybean diseases and insect pests that occurred in the 2006 crop.

Descriptive Analyses

Descriptive analyses with regard to land use, soybean planting practices, cover crops and soybean diseases were conducted between farms pre-financed and not pre-financed by Amaggi Group named as “financial groups,” and among farms located in the municipalities of Sinop, Sorriso and Tapurah named as “municipal groups.”

Statistical Analyses

Comparisons of independent sample means were conducted to test for differences in land use and soybean planting practices at a 95% confidential interval between financial groups and among municipal groups. The statistical analysis was conducted as follows: first, a pre-test concerning two-population variances (F-test) was conducted to verify if the variances between groups were equal (Ott and Longnecker, 2004). If the variances were equal, a two-tailed t-test for equal variances was conducted; if unequal, a two-tailed t-test for unequal variances was conducted. Both types of tests (equal or unequal variances) were carried out at the 95% confidence intervals.

Regression Analysis

Two simple linear regression models were formulated to explain the percentage of natural forest on farms and another simple linear regression model was formulated to explain percentage of deforested area in the most recent deforestation. The explanatory variables for each simple linear regression respectively are: farm size, year of land purchase and year of most recent deforestation. Then, each model was formulated into financial group and municipal group to test the significance of each linear regression.

A multiple regression model was developed to test if the variables (1) years on farm, (2) kilometers from municipal seat, (3) farms located in Sinop and Sorriso and (4) farms pre-financed by Amaggi Group affect the percentage of natural forest left on farm. Dummy variables were assigned for farm location and if the farms were pre-financed or not by Amaggi Group. The dummy-coded variable 1 was given to farms pre-financed by Amaggi Group and 0 to the farms not pre-financed by Amaggi Group. The dummy-coded variable 1 was given to farms located in Sinop and 0 to the other farms, in another column the same procedure was done to farms located in Sorriso.

Weighted Means

The weighted means for area in each cover crop were calculated to analyze the importance of different cover crops. The total hectares of each cover crop were summed and divided by the total soybean plantation area (on both owned and leased land) and displayed in pie charts. The least common cover crops reported by farmers were summed together for better visualization in the pie chart, named as "other cover crops." This procedure was performed separately for financial groups and municipal groups.

Results

Land Use

Comparisons between financial groups

There is a great heterogeneity among farms in each group as well as within groups in land use (Table 2-1). Both groups have a greater percentage of farm area planted to soybeans rather than pasture, other annual crops, natural forest and reforestation. For the pre-financed farms, 60% is in soybeans, 33% is natural forest, 1.6% is other annual crops, 1% is pasture, and 0.09% is reforestation. For the not pre-financed farms, 62% is in soybeans, 32% is natural forest, 2.1% is pasture, 1% is other annual crops and 0.13% is reforestation. Comparisons of means between financial groups do not reveal any statistically significant differences.

Other means related to land use show that the pre-financed farms have occupied the same land for an average of 16 years and are located an average of 53 kilometers from the municipal seat, while the non pre-financed farms have occupied the area for an average of 11 years and are located an average of 32 kilometers from municipal seat; these differences are statistically significant ($P<0.1$). On average, pre-financed farms have 66 head of cattle while the not pre-financed farms have 270 head of cattle. Six years has elapsed since the most recent deforestation for both groups: the pre-financed farms deforested 19% of the area in the last deforestation and the not pre-financed farms deforested 21% of the area. The differences in head of cattle per farm and percentage area of the most recent deforestation are not statistically significant.

Comparisons among municipal groups

Comparisons among municipal groups reveal some similarities and differences in land use (Table 2-2). More than half of the average farm area is used to plant soybeans in all municipal groups. For farms in Sinop, 56% is in soybeans, 37% is natural forest, 2.3% is other annual crops, 1.7% is pasture and 0.12% is reforestation. For farms in Sorriso, 68% is in soybeans, 27% is natural forest, 0.6% is pasture, 0.35% is other annual crops and 0.09% is reforestation. For farms in Tapurah (most remote municipality), 52% is in soybeans, 40% is natural forest, 3.6% is pasture, 2.3% is other annual crops and 0.23 % is reforestation. Statistical comparisons of means reveal that the percentage of area of soybean cultivation and of natural forest are significantly different ($P<0.05$) between Sorriso and Sinop and between Sorriso and Tapurah.

Other means related to land use show that farms in Sinop have been occupying the same land for an average of 11 years and they are an average of 35 kilometers from the city of Sinop. Farms in Sorriso have an average of 13 years occupying the same land and are an average of 56 kilometers from the city of Sorriso. Farms in Tapurah have an average of 17 years occupying the same land and they are an average of 22 kilometers from the city of Tapurah. Comparisons of means show that there is a statistically significant difference ($P<0.05$) in distance from municipal seat between farms located in Sorriso and Tapurah.

On average, there are 37 head of cattle per farm in Sinop, 137 in Sorriso and 338 in Tapurah. On farms in Sinop, it has been an average of 5 years since the most recent deforestation, which deforested 18% of farm area. On farms in Sorriso, it has been an average of 6 years since the most recent deforestation, which deforested 22% of farm area. Finally, on farms in Tapurah, it has been an average of 8 years since the most recent deforestation, which deforested 22% of farm area. Despite these differences in means, they are not statistically significant.

Linear regression models

A linear regression shows that there is a positive and significant ($P<0.05$) relationship between the percentage of natural forest and farm area (Figure 2-1). However, separate regressions for financial groups (Figure 2-2) reveal that this relationship is statistically significant only for the not pre-financed farms ($P<0.05$); considering the municipal groups (Figure 2-3), the regression is significant only for the farms located in Sorriso ($P<0.05$).

There is a slight positive relationship between the percentage of natural forest and the year of land purchase (Figure 2-4), that is, the more recently the land purchase, the higher the percentage of natural forest. However, this is not a statistically significant relationship. Separate regression for financial groups (Figure 2-5) does not show a significant relationship; however, considering the municipal groups (Figure 2-6), there is a statistically significant relationship for the farms in Sinop and Sorriso (P<0.05).

There is a positive though not statistically significant relationship between the size area of the most recent deforestation and the year of occurrence (Figure 2-7). This appears to be mostly related to the financial groups (Figure 2-8) and in Tapurah (Figure 2-9).

A multiple regression model was developed to describe the percentage of farm area with natural forest. The model is specified as follows:

$$NF = \beta_0 + \beta_1 \cdot FS + \beta_2 \cdot YP + \beta_3 \cdot KM + \beta_4 \cdot PF + \beta_5 \cdot SI + \beta_6 \cdot SO \qquad (2\text{-}1)$$

Where:

NF = Percentage area of natural forest

FS = Farm size in hectares

YP = Number of years since farm purchase

KM = Distance from municipal seat in kilometers

PF = 1 if the farm is pre-financed

SI = 1 if the farm is in Sinop

SO = 1 if the farm is in Sorriso

The model is statistically significant (P<0.05) and shows that 45.6% of the variance in percentage of natural forest can be predicted from the independent variables FS, YP, KM, PF, SI and SO (Table 2-3). The variables FS, KM and SI have a positive effect on the dependent variable. An increase in one of these variables, while holding the other variables constant, results in an increase in the percentage of natural forest. However, only the variable FS is statistically significant (P<0.05). The other variables (YP, PF and SO) have a negative effect on the percentage of natural forest. Therefore, an increase in one of these variables, while holding the other variables constant, reduces the percentage of natural forest. Only the variable SO is statistically significant ($P<0.1$).

Soybean Planting Practices

Comparisons between financial groups

Comparisons between financial groups present some similarity and differences in soybean planting practices (Table 2-4). The total soybean area planted on both owned and leased land for the pre-financed farms averages 1865 hectares, of which 8% is planted with genetically modified (GM) soybeans and 6% with nematode resistant soybean cultivars. Not pre-financed farms average 1707 hectares of soybeans, of which 2% is planted with GM soybeans and 6% is planted with resistant cultivars. However, there are no statistically significant differences between the financial groups.

Regarding to no-tillage system for soybeans, this practice was implemented by pre-financed farmers an average of 6 years after land purchase, while not pre-financed farmers implemented it an average of 8 years since land was purchased. However, this difference is not statistically significant.

The cover crops for the no-till system adopted by financial groups are as follows: the pre-financed farms planted 33% of their soybean area with corn, 44% with millet, 8% with other cover crops and 15% of soybeans were left in fallow; the not pre-financed farms planted 31% of their soybean area with corn, 64% with millet, 5% with other cover crops and 0.5% of soybeans were left in fallow. Comparisons of means reveals that percentage of soybean area with millet cover crop and percentage of soybean area left in fallow are statistically different ($P<0.05$) between the financial groups.

Figure 2-10 shows the percentage of farmers adopting each type of cover crop for the no-tillage system. More than 80% of pre-financed farmers reported using corn and millet as their cover crops, while up to 10% reported using sorghum, *Brachiaria ruziziensis*, sunflower, rice, cotton and finger millet as cover crops. More than 75% of not pre-financed farmers also reported using corn and millet as their favorite choices of cover crops, while up to 20% of them reported using only sorghum and rice as cover crops.

Weighted means is another technique used to analyze the cover crops adopted by the financial groups. This method (Figure 2-11) reveals that for the pre-financed group, 41% of total soybean area is planted with millet, 31% with corn, 11% with other cover crops, and 17% left in fallow. Cover crop data for the not pre-financed group reveal that 60% of total soybean area is planted with millet, 32% with corn, 8% with other cover crops and no land left in fallow.

Comparison among municipal groups

Table 2-5 shows soybean planting practices (including owned and leased land) among the municipal groups. Farms in Sinop average 1690 hectares of soybeans in which 1% is planted with GM soybeans and 6% with resistant cultivars. Farms in Sorriso average 2112 hectares of soybeans in which 9% is planted with GM soybeans and 4% with resistant cultivars. In the case of Tapurah, farms average 1232 hectares of soybeans in which 2% are planted with GM soybeans and 10% with resistant cultivars. Comparison of means reveals that soybean plantation area is statistically different ($P<0.1$) between farms in Sorriso and Tapurah.

Farmers in Sinop implemented a no-tillage system for soybean plantations an average of 6 years after land purchase; farmers in Sorriso implemented it an average of 5 years after farm purchase; and farms in Tapurah implemented a no-till practice an average of 12 years since the land was purchased. Comparisons of means reveals that there is a statistically significant difference ($P<0.05$) between farms in Sorriso and Tapurah.

Farms in Sinop planted 26% of their soybean area with corn, 53% with millet, 1% with other cover crops and 19% of the soybean area was left in fallow; farms in Sorriso planted 37%

with corn, 50% with millet, 9% with other cover crops and 4% was left in fallow; and farms in Tapurah planted 28% of soybean area with corn, 62% with millet, 7% with other cover crops and 4% of soybean area was left in fallow. However, none of these differences are statistically significant between the municipal groups.

Figure 2-12 shows the percentage of soybean farmers adopting a variety of cover crops for the no-tillage system. More than 60% of the farmers in all municipal groups reported using corn and millet as cover crops, while up to 10% of farmers in Sinop reported using sorghum, rice and finger millet as cover crops; up to 10% of farmers in Sorriso reported using sorghum, rice and cotton; and up to 20% of farmers in Tapurah reported using sorghum, *Brachiaria ruziziensis*, and sunflower as cover crops.

Analysis of the weighted means in the municipal groups (Figure 2-13) reveals that, in Sinop, 38% of total soybean area is planted with millet, 28% with corn 5% with other cover crops and 29% left in fallow. In Sorriso, cover crops are 52% millet, 33% corn, 12% other cover crops and 3% of total soybean area was left in fallow. In Tapurah, cover crops are 59% millet, 31% corn, 8% other cover crops and 2% of total soybean area was left in fallow.

Soybean Pests

Comparisons between financial groups

Most of the soybean farmers consider that soybean pathogenic diseases such as Asian soybean rust (*Phakopsora pachyrhizi*) or anthracnose (*Colletotrichum truncatum*) are more problematic than insect infestation such as whitefly (*Bemisia* spp.) or stinkbugs and plant-parasitic nematodes (Figure 2-14).

With regard to pathogenic diseases (Figure 2-15), all farmers reported having Asian soybean rust in their soybean crops, 50% of pre-financed farmers reported having anthracnose disease and 20% reported foliar blight (*Rhizoctonia solani / Thanatephorus cucumeris*); 45% of not pre-financed farmers reported having anthracnose disease and 35% foliar blight.

With regard to insect infestation (Figure 2-16), 85% of the soybean farmers had problems with whitefly. While 80% of the not pre-financed farmers had problems with stinkbug and caterpillar (*Anticarsia gemmatalis*) infestation, only 60% and 55% of the pre-financed farmers had stinkbugs and caterpillar infestation respectively. Almost half of the farmers in both financial groups reported having nematodes in their soybean crops (Figure 2-17).

Comparisons among municipal groups

Most of the soybean farmers consider that soybean pathogenic disease is more problematic than insect infestation and plant-parasite nematodes (Figure 2-14). With regard to pathogenic diseases (Figure 2-15), all farmers reported having Asian soybean rust in their soybean crops. Farmers in Sinop did not report any foliar blight disease and 30% reported anthracnose. In Sorriso, 35% of the farmers had anthracnose and 35% had foliar blight disease, while in Tapurah 90% of the farmers had anthracnose and 40% had foliar blight disease.

With regard to insect infestation (Figure 2-16) in Sinop, 80% of the farmers had whitefly and stinkbug and 70% had caterpillar in their soybean crops. In Sorriso, 95% of the farmers had whitefly, 55% had caterpillar, and 50% had stinkbug. All farmers in Tapurah had stinkbug, 90% had caterpillar, and 70% had whitefly infestations.

Although a minority of farmers reported having problems with other insect pests such as soybean looper (*Pseudoplusia includens*) and lesser cornstalk borer (*Elasmopalpus lignosellus*), farmers in Sinop did not report them. While 63% of the farmers located in Sorriso reported having nematodes in their soybean crops, approximately 30% of the farmers located in Sinop and Tapurah reported having them (Figure 2-17).

Discussion

Land Use

The preceding analyses demonstrate that there were no significant differences in land use when comparing farms pre-financed and not pre-financed by Amaggi Group. However, when comparing municipal groups, some differences can be noticed.

Comparison between financial groups

Farms pre-financed farms by Amaggi Group did not conserve more forest than the not pre-financed farms, therefore, rejecting the first hypothesis. Since Amaggi Group requires that their pre-financed farms have their Legal Reserve legalized and they do not allow illegal deforestation, it was expected that these standards would have a positive effect on natural forest left on pre-financed farms. However, statistical analysis revealed that the mean percentage of natural forest on pre-financed farms is not significantly different from the not pre-financed farms. Multiple regression analysis lends support to the result that whether or not a farm is pre-financed does not have a significant effect on percentage of natural forest on farm. This result may be explained by the fact that companies other than Amaggi Group also provide pre-financing policies such as legal reserve officially recognized.

Although the average years since the land purchase and distance from municipal seat were statistically different between pre-financed and not pre-financed farms, these variables did not have a significant effect on forested area. Having specific percentages of natural forest preserved on the farms is a landowner obligation according to federal law, however it is unknown if the areas comply with current legislation.

In Mato Grosso, the calculation of the legal reserve requirement for each farm is based on the map of forest typology from the project RADAM, which was created in the 1970s (J. Y. Shimada, personal communication, May 21, 2007). According to types of vegetation inside the property, the required percentage of legal reserve is calculated for each fraction of farm area and the area is summed. The percentage of legal reserve that is applied also depends on the date that the property was registered, since legislation and forest typology has changed since the 1965 New Forestry Code. In Mato Grosso, before adopting the RADAM project, the legal reserve requirement was based on the map of economic-ecological zoning map. Therefore, a farm's percentage of legal reserve rarely matches with the current legislation, given potential diversity of vegetation types on the farm and the date the property was registered.

Comparisons among municipal groups

The producers located in Sorriso have preserved less forested areas than those in Sinop and Tapurah, as asserted in the second hypothesis. The municipality of Sorriso is located to the south of Sinop and less deeply embedded in the Amazon forest. The environmental law says that 80% of the property should be protected natural forest if situated in the forest region and 35% of the property should be protected natural forest if located in the Cerrado. Therefore, it was expected that farms in Sorriso would have less forested area on farm than the farms located in Sinop, since Sinop is located in the Amazon forest biome.

Multiple regression analysis also confirmed that if the farm was located in Sorriso, it had a negative and significant effect on the percentage of natural forest on farm. Therefore, farmers in Sorriso are less likely to preserve natural forest. Even though farms located in Tapurah are closer to the municipal seat than the farms in Sorriso, the municipality of Tapurah is not situated along the BR-163. This could have contributed to a greater percentage of natural forest on farms in this region compared to those located in Sorriso.

The municipality of Sorriso is considered the largest soybean producer in Brazil. This is reflected in the data that show the mean percentage of soybean area in the studied farms is statistically greater in Sorriso than in Tapurah and Sinop. One particular detail noticed by the researcher is that there are also a much larger number of soybean farmers in the municipality of Sorriso than in Sinop and Tapurah. Another possibility is that, since farms in Sorriso are less likely to preserve natural forest on farm than the others municipalities as statistically tested, farmers use this deforested land for planting soybeans.

Soybean Planting Practices

The analyses demonstrated that there are few significant differences in no-tillage systems and cover crops adopted by soybean farmers when comparing these practices between financial groups, and no difference are revealed among municipal groups.

Comparison between financial groups

The pre-financed farms do not have a greater percentage of soybean area in a no-tillage system, therefore rejecting the third hypothesis. Even though Amaggi Group recommends that their pre-financed farms adopt the no-tillage system as a good farming practice, results revealed that pre-financed farms had more soybean area with no cover crop (left in fallow) than the not pre-financed farms. That is, pre-financed farms have less area with cover crop residues left unincorporated on soil surface (to plant soybean on) than the not pre-financed farms.

Another reason for pre-financed farmers having less soybean area planted with cover crops might be problems with soil erosion; four pre-financed farmers and one not pre-financed farmer reported having soil erosion. Where erosion is problematic, these areas are typically left to fallow for a number of years.

Although there is no statistically significant difference in the other cover crops planted (besides millet) between the financial groups, survey data demonstrates that pre-financed farmers are adopting a greater variety of cover crops. Growing different cover crops results in diversification of production, improved yields of subsequent crops, and reductions in pest infestation as the lifecycle of pests and pathogens is interrupted. The pre-financed farmers reported using four more types of cover crops than the not pre-financed farmers, although this was not statistically tested due to a small sample size. For this reason, it was not possible to test the fourth hypothesis that the pre-financed farmers have greater cover crop diversity.

However, this survey data might demonstrate that some soybean farmers are interested in diversifying their production. Even though the number of farmers adopting these different cover crops is small, it may suggest that soybean farmers are starting to search for a more sustainable agricultural system as demonstrated by the integration of crops and livestock with the adoption of *Brachiaria ruziziensis*.

With regard to GM soybeans, even though Amaggi Group silos receive them, the area planted with GM soybeans by pre-financed farmers is low and not statistically different from the not pre-financed farmers. This may be explained by the fact that pre-financed farmers are receiving better prices for non-GM soybean, since Amaggi export them through a private port, which reduces transportation costs.

Comparisons among municipal groups

Although the municipality of Sorriso is considered the fourth largest corn producer in Brazil, the farmers located in Sorriso do not plant more corn as a cover crop than those located in Sinop and Tapurah. Results showed that there is no statistically significant difference between the municipal groups with regard to corn as cover crop. Therefore, the fifth hypothesis that farmers in Sorriso are more likely to plant corn as a cover crop than those farmers located in Sinop and Tapurah is rejected.

According to Piccoli, the president of the Sorriso rural workers union (A Gazeta, 2007), crop production of corn as a secondary crop can be delayed by the weather; too much rainfall can delay the harvest of soybeans and consequently delay the corn planting, which has a specific period to be planted. As reported by many farmers, especially in Sinop, too much rainfall in 2006 prevented farmers from harvesting the whole soybean plantation and planting corn at the appropriate time. The weather might be the reason why fewer farmers in Sinop, reported planting corn as a cover crop for that year.

The variety of cover crops reported by the municipal groups reveals that at least three different cover crops besides corn and millet are being adopted by farmers in each municipality. Although the number of farmers adopting these other cover crops is small and not statistically tested, it might demonstrate that the search for a sustainable agriculture is not concentrated only in one region.

With regard to GM soybean, results suggest that although GM soybeans are legally permitted to be planted in Mato Grosso (approved two years ago by the Brazilian government (USDA, 2007)), farmers in the study region are currently not readily adopting them since the percentage of area planted with GM soybeans was low. According to Fundação Mato Grosso (2006), the production costs for a non-GM soybean crop is very similar to a GM soybean crop, because the high price of RR seeds (genetically modified herbicide-resistant Roundup Ready soybeans) and the payments of royalties cancel any positive effects with the savings gained with the use of only one post-emergent herbicide such as Roundup.

Soybean Pests

Although there are no hypotheses related to soybean diseases, it is important to compare the pathogenic diseases, insect infestation and plant parasitic nematodes between financial groups and among municipal groups in order to better understand Chapter 3, which will discuss pesticide use.

Comparisons between financial groups

The results showed that there are no major differences between financial groups with regard to pathogenic diseases; for example, all farmers reported having Asian rust disease in their soybean crop. According to Yorinoni et al. (2004), the first report of Asian soybean rust in Brazil was at the end of the 2001 harvest season in the state of Paraná in southern Brazil. Since then, this disease has spread over the soybean producer states. Transported by wind, and when favorable weather conditions exist, such as high air moisture and with temperatures between 18°C and 26°C, this rust can cause substantial losses in productivity (Fundação Mato Grosso, 2006).

The foliar blight (*Rhizoctonia solani*) disease which had disappeared from soybean crops in the northern region of Mato Grosso, reappeared in the 2005/2006 harvest period especially where the area was not covered with cereal cover crops (Folha do Estado, 2006). Some farmers from both groups reported having foliar blight in their soybean crop. All the pathogenic diseases reported by farmers depend on high moisture to proliferate, and according to the farmers interviewed, rainfall was greater than average in 2006.

Regarding insect infestation, more not pre-financed farmers reported having stinkbugs and caterpillar in their soybean crop. Stinkbugs have been more prevalent since 2001, the most common species of which are *Nezara viridula*, *Piezodorus guildinii*, *Dichelops melacanthus*, *Dichelops furcatus*, *Euschistus heros* and *Thyanta perditor* (Gassen, 2002). Damage is caused by the nymphs and adults sucking sap from the bean pods, resulting in reduced soybean quality and "foliar retention" at the end of the soybean cycle, which can complicate mechanized harvest. Together with defoliator caterpillars, they represent the principal insects that are controlled through pest management (Degrand and Vivan, 2006).

About 85% of farmers in both groups reported having whiteflies in their crop. Direct crop damage occurs when whiteflies feed in plant phloem, remove plant sap and reduce plant vigor. Whiteflies also excrete honeydew, which promotes sooty mold that interferes with photosynthesis and may lower harvest quality (Fasulo, 2006). Infestation of whiteflies has become common in soybean cultivars in the last few years. The whitefly species *Bemisia tabaci* and *Bemisia argentifolii* are worrying the soybean producers in Mato Grosso due to the difficulty in controlling them in an economically feasible manner (Degrand and Vivan, 2006).

Almost 50% of farmers from both groups reported having nematodes in their soybean crop and half of these farmers reported having cyst nematodes (*Heterodera glycines*). When an area is infested with nematodes, nothing can be done in the actual harvest period, rather, precautions need to be focused on the next crop on that specific site (Dias at al., 2006). For a sustainable production system where there are occurrences of cyst nematodes on site, crop rotation with a non-host cultivar is the best strategy to manage nematodes.

Corn can be an option as a cover crop in regions with occurrence of soybean cyst nematode (Altmann, 2006). Crop rotations with corn break the nematode’s reproductive cycle by providing an unfavorable host. Though this strategy does not completely eliminate nematodes, it does reduce their population on site; the objective is to lower numbers enough so that the next susceptible crop is successful. Leaving land fallow is also a possible solution, since it starves nematodes if the area is 100% free of weeds. Other problems may result, however, particularly soil erosion and surface runoff (Powers and McSorley, 2000).

Comparison among municipal groups

High levels of precipitation in December 2005 in northern Mato Grosso contributed to the appearance of Asian rust and foliar blight in various soybean producing municipalities (Folha do Estado, 2006). Anthracnose is one of the principal soybean diseases in the Cerrado region (EMBRAPA, 2004) and some farmers in all the study municipalities reported having this disease in their crops.

Many more than half of the farmers in all municipalities reported having whitefly infestation. According to Degrande and Vivan (2006), the municipalities of Sinop, Sorriso, Tapurah, and other regions in mid-north Mato Grosso had huge outbreaks of this pest in the last few years. In places where precipitation is less intense, whiteflies pose less risk to soybean cultivation.

The farmers in Sinop reported having root-knot nematodes (*Meloidogyne* spp.) in their soybean crop. To manage this species of nematode, the most efficient and cost effective strategy is for farmers to plant resistant cultivars. In the statistical analyses, results showed that a small percentage of soybean area was planted with resistant cultivars in all three study regions. Currently many soybean cultivars are resistant to *Meloidogyne* spp. in Brazil (Dias at al., 2006). More farmers in Sorriso reported having *Heterodera glycines* than *Meloidogyne* spp., and farmers in Tapurah reported having only *Heterodera glycines*.

As mentioned before, when nematodes are found in the soybean crop, it is important to identify the nematode species in order to design an effective management program. For example, one farmer from the municipality of Sorriso detected *Heterodera glycines* nematode in his crop. To combat this pest, the farmer reported that he was going to plant 200 hectares of his soybean area with a resistant cultivar in the following planting season.

Conclusion

This chapter shows that although soybean farmers in Sinop, Sorriso, and Tapurah located in northern Mato Grosso adopted similar soil conservation practices, such as the no-tillage system and the maintenance of forest cover, there are some differences in the percentage of farm area where these techniques are practiced. With regard to financial groups, the main difference is that pre-financed farms have a higher percentage of soybean area left in fallow than the farms that were not pre-financed. With regard to municipal groups, the main difference is that farmers in Sorriso are less likely to preserve forest cover than farmers in Sinop and Tapurah.

Table 2-1. Descriptive statistics and comparison of means of land use between financial groups: farms that were pre-financed (PRE) and farms that were not. Table shows number of farms (N); minimum, maximum, mean, and standard deviation of values reported; and t-test statistics for comparisons.

		N	Min.	Max.	Mean	Std. Dev.	t-value	P
Farm size (ha)	PRE	20	325	14000	3349	3543	0.414	0.682
	NOT	20	121	13300	2891	3460		
Years since land purchase	PRE	19	0	30	11	10	-1.792	0.081*
	NOT	20	3	28	16	9		
% Natural forest (% of farm area)	PRE	20	15%	67%	33%	14%	0.377	0.708
	NOT	20	14%	75%	32%	15%		
Years since the most recent deforestation	PRE	12	2	14	6	4	0.140	0.890
	NOT	18	2	17	6	4		
Area of the most recent deforestation (% of farm area)	PRE	12	4%	58%	19%	19%	-0.298	0.768
	NOT	18	4%	83%	21%	21%		
Reforestation (% of farm area)	PRE	20	0%	1.4%	0.09%	0.31%	-0.344	0.733
	NOT	20	0%	1.7%	0.13%	0.40%		
Soybean cultivation (% of farm area)	PRE	20	27%	84%	60%	17%	-0.273	0.787
	NOT	20	18%	83%	62%	17%		
Other annual crops (% of farm area)	PRE	20	0%	11%	1.6%	3.4%	0.528	0.601
	NOT	20	0%	11%	1.0%	3.0%		
Pasture (% of farm area)	PRE	20	0%	9%	1.1%	2.1%	-0.904	0.372
	NOT	20	0%	20%	2.1%	4.7%		
Head of cattle (per farm)	PRE	11	5	300	66	82	-1.580	0.140
	NOT	12	0	1100	270	438		
Distance from municipal seat (Km)	PRE	13	3	150	53	40	1.809	0.089*
	NOT	14	8	60	32	17		

*indicates t-value significant at P<0.1.

Table 2-2. Descriptive statistics and comparison of means of land use among municipal groups: farms located in the municipalities of Sinop (SIN), Sorriso (SOR) and Tapurah (TAP). Table shows number of farms (N); minimum, maximum, mean, and standard deviation of values reported; and t-test statistics for comparisons.

	Municipality*	N	Min.	Max.	Mean	Std. Dev	t-value		P
Farm size (ha)	1 SIN	10	121	14000	2960	4161	1-2	-.256	0.800
	2 SOR	20	558	13300	3332	3546	2-3	0.367	0.716
	3 TAP	10	230	10000	2858	2818	1-3	0.064	0.950
Years since land purchase	1 SIN	10	0	29	11	10	1-2	-0.480	0.635
	2 SOR	19	3	25	13	9	2-3	-1.061	0.298
	3 TAP	10	2	30	17	11	1-3	-1.197	0.247
Natural forest (% of farm area)	1 SIN	10	19%	52%	37%	10%	1-2	2.560	0.016**
	2 SOR	20	14%	50%	27%	11%	2-3	-2.471	0.020**
	3 TAP	10	19%	75%	40%	19%	1-3	-0.413	0.685
Years since the most recent deforestation	1 SIN	7	2	13	5	4	1-2	-0.192	0.850
	2 SOR	14	2	17	6	4	2-3	-1.114	0.278
	3 TAP	9	2	14	8	5	1-3	-1.113	0.284
Area of most recent deforestation (% of farm area)	1 SIN	7	4%	59%	18%	19%	1-2	-0.484	0.634
	2 SOR	14	4%	83%	22%	22%	2-3	0.448	0.659
	3 TAP	9	4%	58%	18%	19%	1-3	-0.077	0.939
Reforestation (% of farm area)	1 SIN	10	0%	0.4%	0.05%	0.12%	1-2	-0.382	0.706
	2 SOR	20	0%	1.4%	0.09%	0.31%	2-3	-0.889	0.382
	3 TAP	10	0%	1.7%	0.23%	0.55%	1-3	-1.006	0.338
Soybean cultivation (% of farm area)	1 SIN	10	40%	80%	56%	12%	1-2	-2.306	0.029**
	2 SOR	20	27%	84%	68%	15%	2-3	2.612	0.014**
	3 TAP	10	18%	80%	52%	20%	1-3	0.561	0.581
Other annual crops (% of farm area)	1 SIN	10	0%	11%	2.3%	4.0%	1-2	1.459	0.174
	2 SOR	20	0%	7%	0.35%	1.6%	2-3	-1.367	0.201
	3 TAP	10	0%	11%	2.3%	4.3%	1-3	-0.001	0.999
Pasture (% of farm area)	1 SIN	10	0%	9%	1.7%	2.8%	1-2	1.583	0.125
	2 SOR	20	0%	3%	0.6%	0.91%	2-3	-1.449	0.181
	3 TAP	10	0%	20%	3.6%	6.4%	1-3	-0.853	0.410
Head of cattle (per farm)	1 SIN	6	0	90	37	33	1-2	-0.707	0.491
	2 SOR	10	0	1100	137	340	2-3	-1.092	0.292
	3 TAP	7	20	1000	338	420	1-3	-1.889	0.107
Distance from municipal seat (Km)	1 SIN	8	8	100	35	32	1-2	-1.401	0.177
	2 SOR	13	27	150	56	33	2-3	2.306	0.034**
	3 TAP	6	3	40	22	16	1-3	0.887	0.392

**indicates t-value significant at P<0.05.

Table 2-3. Multiple regression model for natural forest (% of farm area).

Dependent variable	Predictor	B	t-value	P	R^2
Natural forest (% of farm area)	Intercept	35.906	4.586	0.000	0.456**
	Farm size (FS)	0.001	2.209	0.039**	
	Years on farm (YP)	-0.400	-1.368	0.186	
	Km from municipal seat (KM)	0.136	1.587	0.128	
	Farms in Sinop (SI)	0.582	0.086	0.932	
	Farms in Sorriso (SO)	-12.036	-1.837	0.081*	
	Pre-financed farms (PF)	-6.169	-1.211	0.240	

*indicates t-value significant at P<0.1.
**indicates t-value significant at P<0.05.

Table 2-4. Descriptive statistics and comparison of means of soybean planting practices (including both owned and leased land) between financial groups: farms that were pre-financed (PRE) and farms that were not. Table shows number of farms (N); minimum, maximum, mean, and standard deviation of values reported; and t-test statistics for comparisons.

		N	Min.	Max.	Mean	Std. Dev.	t-value	P
Soybean area (ha)	PRE	20	170	6000	1865	1753	0.279	0.781
	NOT	20	146	7300	1707	1841		
% planted with GM soybeans	PRE	16	0%	65%	8%	20%	1.130	0.274
	NOT	18	0%	17%	2%	5%		
% planted with nematode resistant cultivar	PRE	20	0%	36%	6%	11%	0.148	0.883
	NOT	19	0%	40%	6%	11%		
Time between land purchase and no-till system (yr)	PRE	18	0	25	6	8	-1.106	0.276
	NOT	20	0	22	8	7		
% of soybean area with corn cover crop	PRE	20	0%	86%	33%	25%	0.309	0.759
	NOT	20	0%	64%	31%	22%		
% of soybean area with millet cover crop	PRE	20	0%	100%	44%	33%	-2.105	0.042**
	NOT	20	23%	100%	64%	26%		
% of soybean area with other cover crops	PRE	20	0%	60%	8%	17%	0.598	0.554
	NOT	20	0%	38%	5%	11%		
% of soybean area with no cover crop (left fallow)	PRE	20	0%	100%	15%	27%	2.423	0.025**
	NOT	20	0%	10%	0.5%	2.2%		

**indicates t-value significant at P<0.05.

Table 2-5. Descriptive statistics and comparison of means of soybean planting practices (including both owned and leased land) among municipal groups: farms located in the municipalities of Sinop (SIN), Sorriso (SOR) and Tapurah (TAP). Table shows number of farms (N); minimum, maximum, mean, and standard deviation of values reported; and t-test statistics for comparisons.

	Municipality	N	Min.	Max.	Mean	Std. Dev.	t-value		P
Soybean area (ha)	1 SIN	10	146	6000	1690	2064	1-2	-0.536	0.596
	2 SOR	20	400	7300	2112	2016	2-3	1.843	0.078*
	3 TAP	10	600	2000	1232	499	1-3	0.682	0.511
% planted with GM	1 SIN	7	0%	7%	1%	3%	1-2	-0.970	0.343
soybeans	2 SOR	17	0%	65%	9%	19%	2-3	1.079	0.291
	3 TAP	10	0%	17%	2%	5%	1-3	-0.189	0.853
% planted with nema-	1 SIN	9	0%	19%	6%	9%	1-2	0.481	0.635
tode resistant	2 SOR	20	0%	36%	4%	11%	2-3	-1.449	0.159
cultivar	3 TAP	10	0%	40%	10%	13%	1-3	-0.878	0.392
Time between land	1 SIN	10	0	25	6	9	1-2	0.436	0.666
purchase and no-	2 SOR	19	0	16	5	5	2-3	-2.440	0.02**
till system (yr)	3 TAP	9	2	23	12	8	1-3	-1.311	0.207
% of soybean area	1 SIN	10	0%	85%	26%	29%	1-2	-1.110	0.277
with corn cover	2 SOR	20	0%	86%	37%	21%	2-3	1.147	0.261
crop	3 TAP	10	0%	50%	28%	20%	1-3	-0.105	0.918
% of soybean area	1 SIN	10	0%	100%	53%	39%	1-2	0.224	0.825
with millet cover	2 SOR	20	0%	100%	50%	28%	2-3	-1.084	0.288
crop	3 TAP	10	25%	100%	62%	27%	1-3	-0.587	0.564
% of soybean area	1 SIN	10	0%	10%	1%	3%	1-2	-1.663	0.111
with other cover	2 SOR	20	0%	60%	9%	19%	2-3	0.279	0.782
crops	3 TAP	10	0%	28%	7%	11%	1-3	-1.493	0.165
% of soybean area	1 SIN	10	0%	100%	19%	34%	1-2	1.319	0.215
with no cover crop	2 SOR	20	0%	45%	4%	13%	2-3	0.184	0.831
(left fallow)	3 TAP	10	0%	25%	4%	8%	1-3	1.409	0.189

*indicates t-value significant at P<0.1.
**indicates t-value significant at P<0.05.

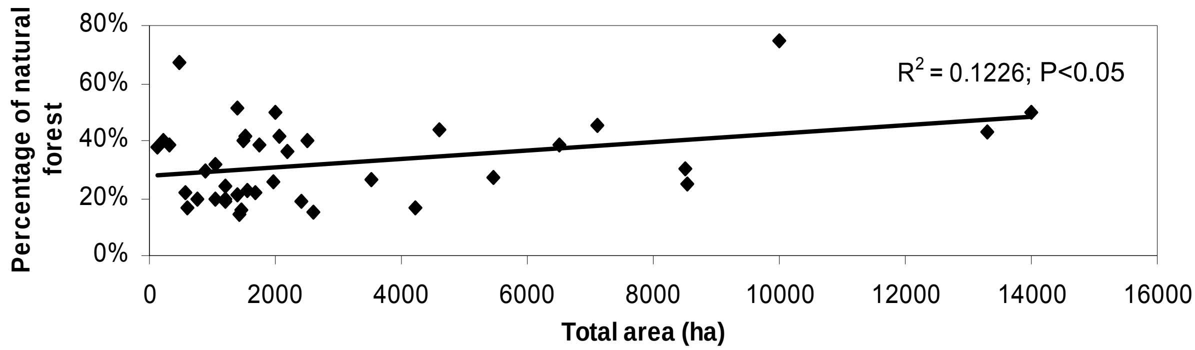


Figure 2-1. Relationship between farm size and percentage of natural forest on all sites (N=40).

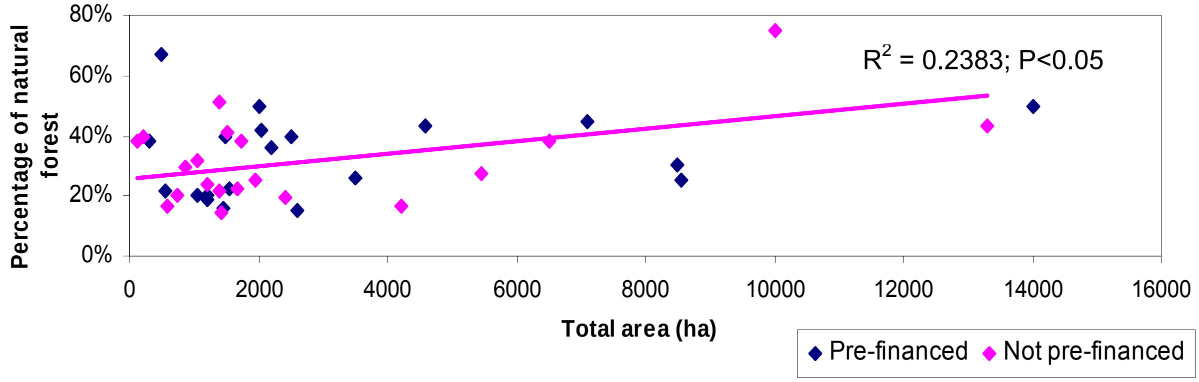


Figure 2-2. Relationship between farm size and percentage of natural forest on farms that were pre-financed by Amaggi Group (N=20; R^2=0.0417 NS) and farms that were not (N=20).

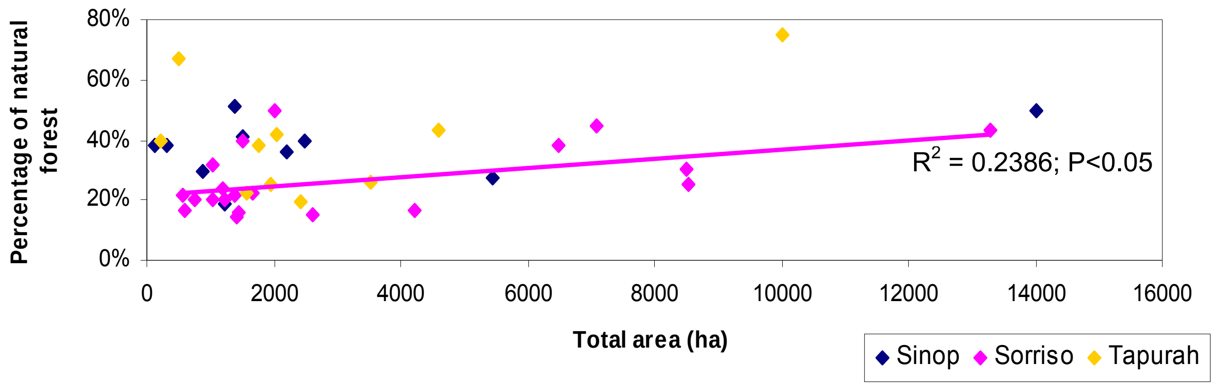


Figure 2-3. Relationship between farm size and percentage of natural forest in Sinop (N=10; R^2=0.1232 NS), Sorriso (N=20), and Tapurah (N=10; R^2=0.2313 NS).

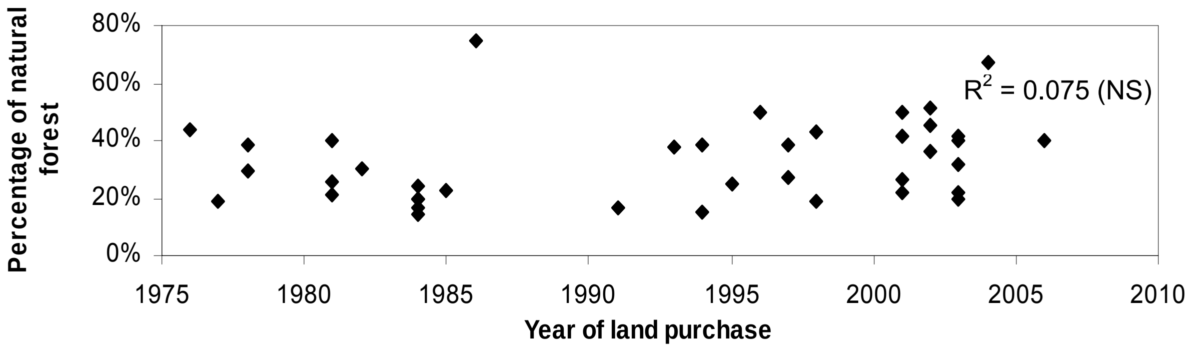


Figure 2-4. Relationship between year of land purchase and the percentage of natural forest on all sites (N=39).

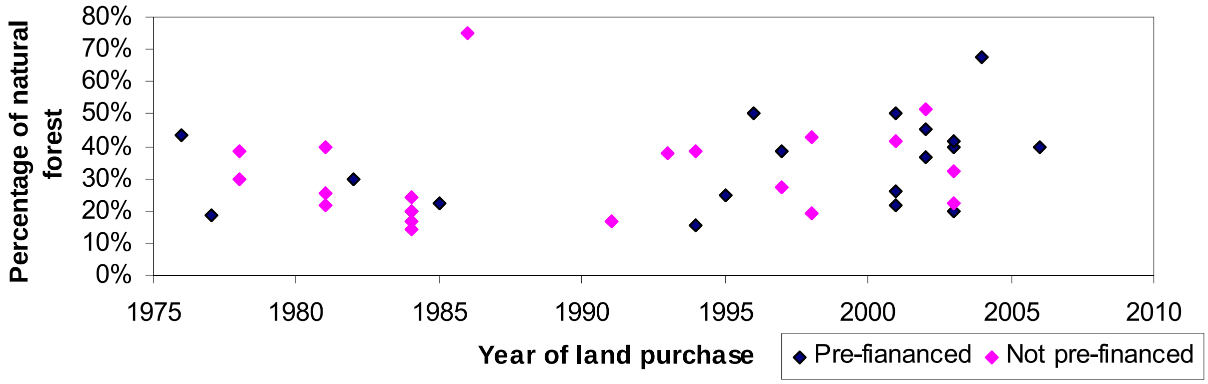


Figure 2-5. Relationship between year of land purchase and percentage of natural forest on farms that were pre-financed by Amaggi Group (N=19; R^2=0.1379 NS) and farms that were not (N=20; R^2=0.0229 NS).

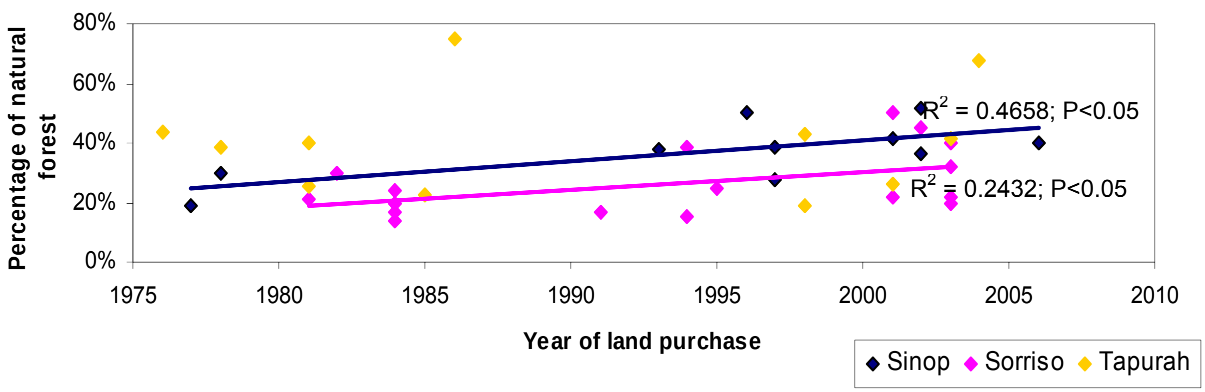


Figure 2-6. Relationship between year of land purchase and percentage of natural forest in Sinop (N=10), Sorriso (N=19) and Tapurah (N=10; R^2=0.007 NS).

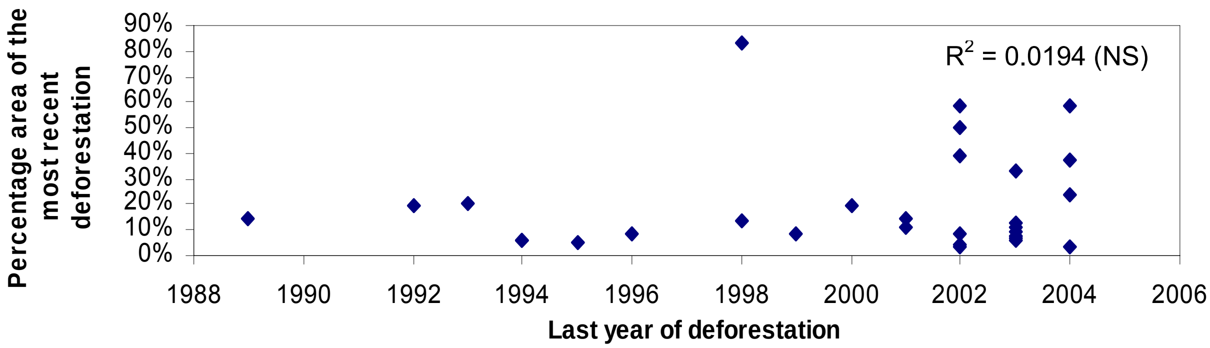


Figure 2-7. Relationship between percentage area of the most recent deforestation and last year of deforestation on all sites (N=30)

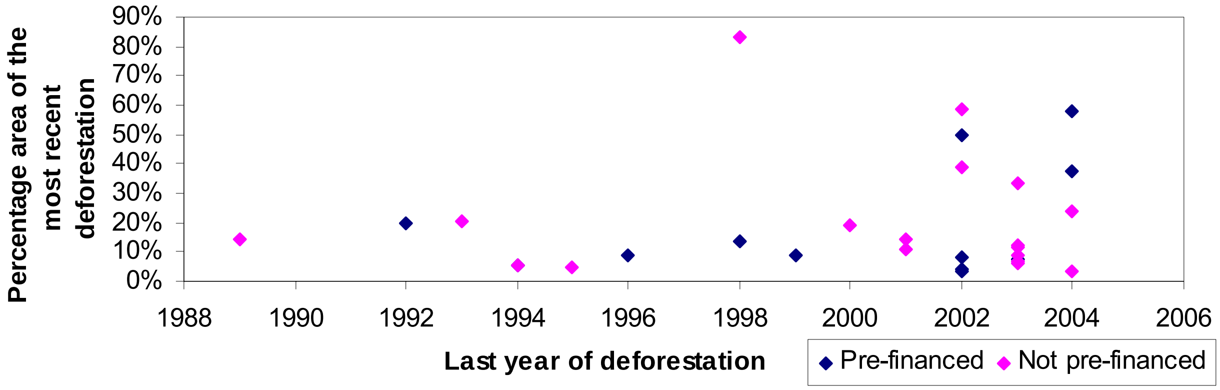


Figure 2-8. Relationship between percentage area of the most recent deforestation and last year of deforestation on farms that were pre-financed by Amaggi Group (N=12; R^2=0.139 NS) and farms that were not (N=18; R^2=0.0002 NS).

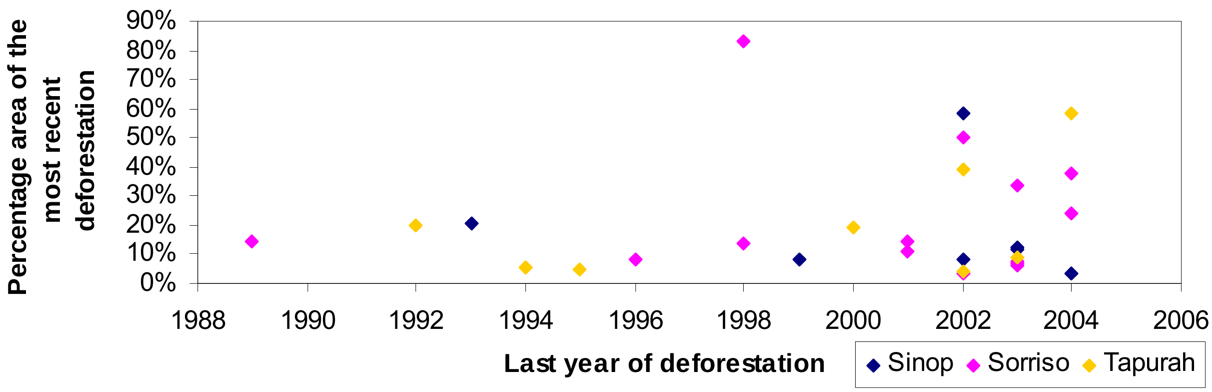


Figure 2-9. Relationship between percentage area of the most recent deforestation and last year of deforestation in Sinop (N=7; R^2=0.0082 NS), Sorriso (N=14; R^2=3E-06 NS) and Tapurah (N=9; R^2=0.2567 NS).

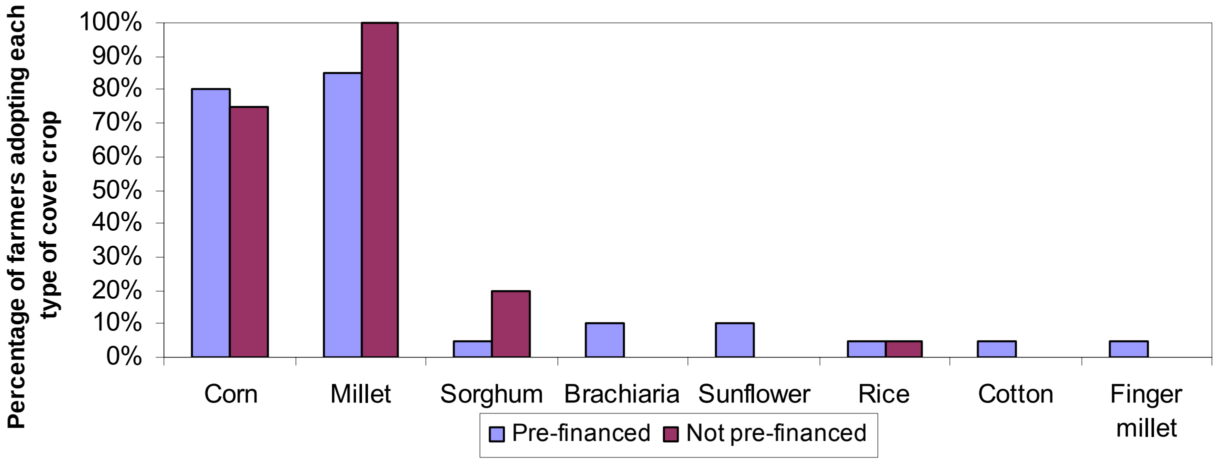


Figure 2-10. Adoption of cover crops for financial groups in 2006.

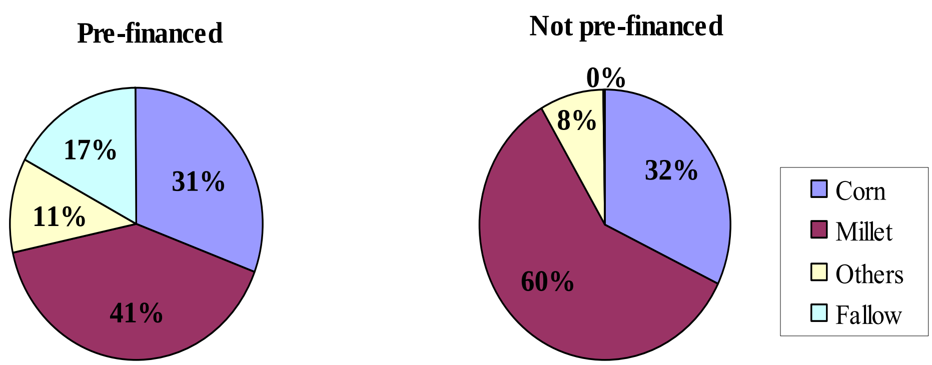


Figure 2-11. Weighted mean of cover crops for no-tillage system for financial groups in 2006.

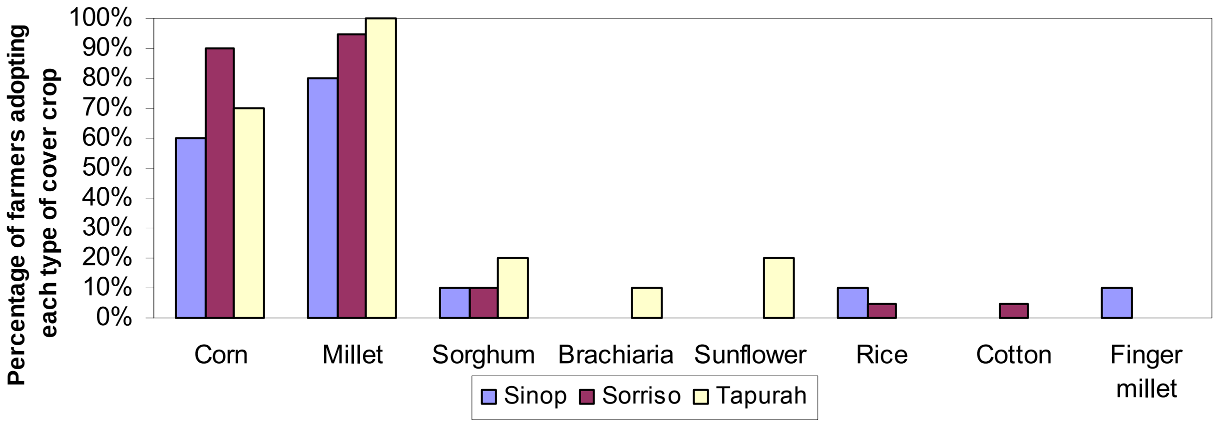


Figure 2-12. Adoption of cover crops for municipal groups in 2006.

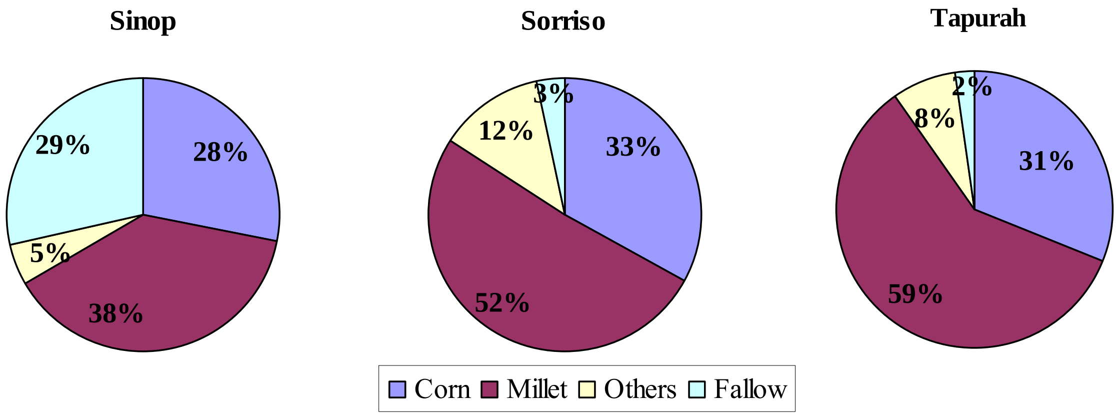


Figure 2-13. Weighted mean of cover crops for no tillage system for municipal groups in 2006

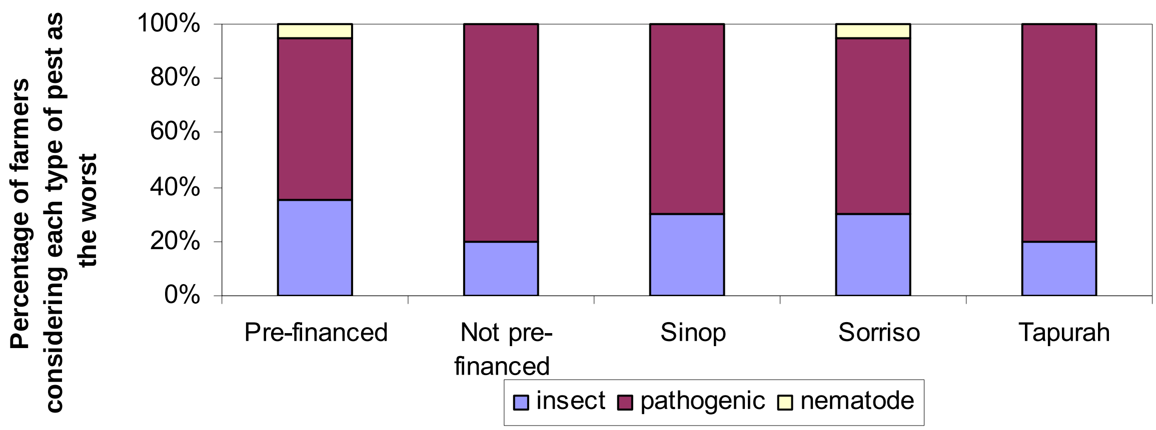


Figure 2-14. Farmer's perspective about the worst soybean pest in 2006. Comparisons between financial groups and among municipal groups.

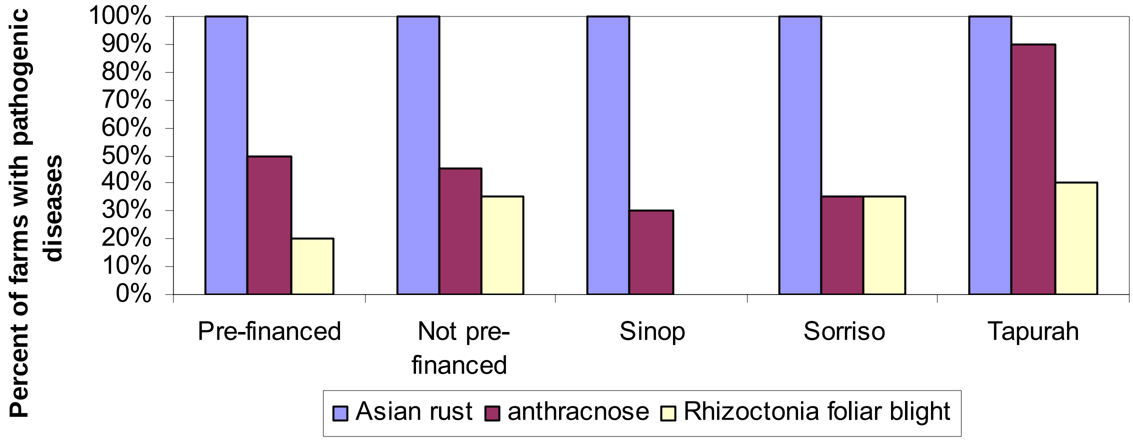


Figure 2-15. Farmers reporting pathogenic disease in their soybean crops in 2006. Comparisons between financial groups and among municipal groups.

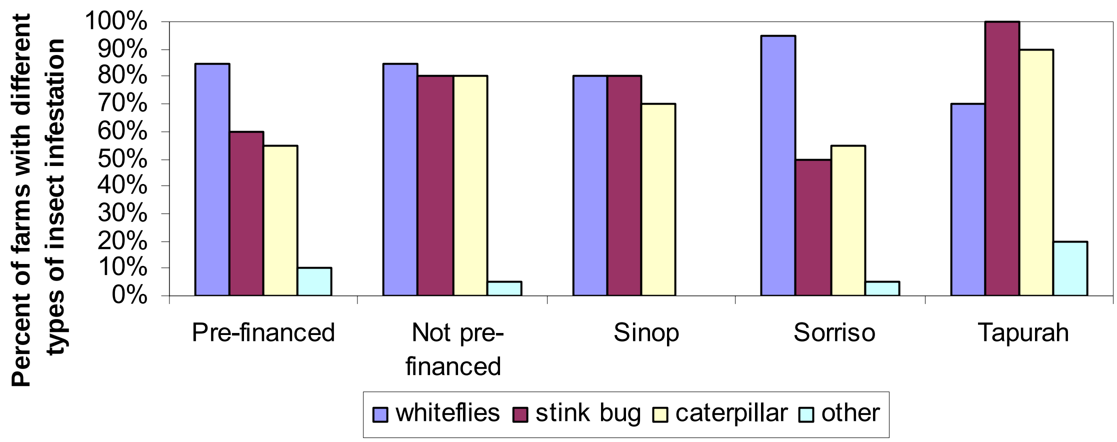


Figure 2-16. Farmers reporting insect infestation in their soybean crop in 2006. Comparisons between financial groups and among municipal groups.

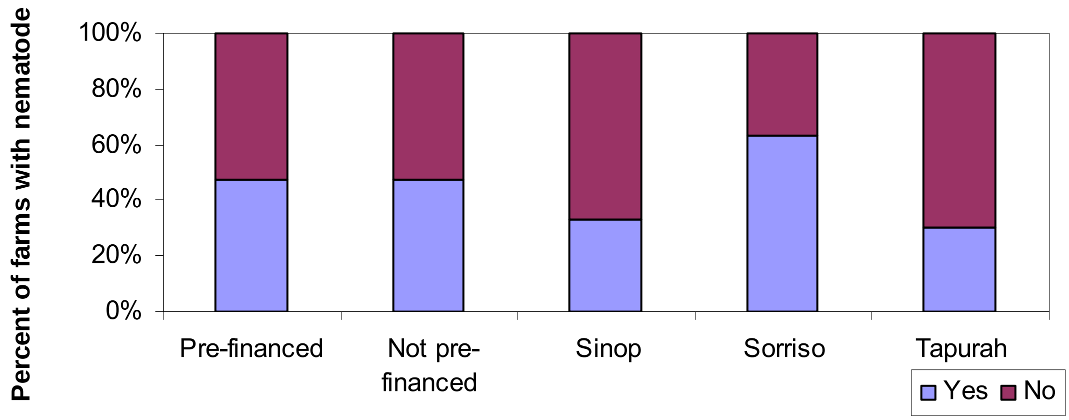


Figure 2-17. Farmers reporting nematodes in their soybean crops in 2006. Comparisons between financial groups and among municipal groups.

CHAPTER 3
PESTICIDES AND THE ENVIRONMENT

Introduction

The purpose of this chapter is to examine pesticide use from seed treatment to soybean harvest among soybean producers in Sinop, Sorriso, and Tapurah, all located in northern Mato Grosso. Consistent with the purpose of this chapter, and based on the Amaggi Group's recommendations to their pre-financed farmers regarding pesticide use, the hypothesis that pre-financed farmers use fewer types of pesticide than those who are not will be tested. Some of Amaggi Group's recommendations are: producers should seek specialized technical support, use inoculations in seed treatment, buy agrochemicals according to the agronomist's prescription and follow the technical advice, implement integrated pest management, adopt biological control or insect growth regulator insecticides when possible, and vary the use of pesticides to avoid insect and weed resistance to the active chemicals in particular pesticides (Grupo Amaggi, 2006).

While conducting field work, it was observed that farmers whose property was surrounded by natural forest or in close proximity to forest were reporting that fewer types of pesticides were used. Therefore, based on the expectation that farms closer to the Amazon forest require fewer pesticide applications, it is hypothesized that the producers located in Sinop, in the Amazon forest biome, use fewer types of pesticides than the producers located in Sorriso and Tapurah. For each stage of soybean pesticide application, it is expected that fewer Sinop farmers use the corresponding pesticide than farmers in the other municipalities. For fungicide use specifically, it is expected that Sinop farmers apply fungicide fewer number of times. Therefore, the hypothesis that farms with a higher percentage of forest cover use fewer types of pesticide will also be tested.

To accomplish this task, background information on pesticide use and reasons for application will be discussed; specific chemical pesticides used by the 40 interviewed farmers in Sinop, Sorriso, and Tapurah regions will also be summarized. Then, descriptive analyses of the percentage of farmers using specific active ingredients of pesticide products will be presented, as well as statistical analyses of fungicide application and desiccants applied to soybeans. Both descriptions and statistical analyses were compared between the studied farms with regard to their financial status, location, and percentage of natural forest on farm.

Pesticide Use

Soybean pests identified in Chapter 2 are responsible for disease and consequent economic losses; therefore, the use of pesticides is often essential to maintain soybean productivity in medium- to large-scale monoculture plantations. The soybean pesticides used for seed treatment, and the herbicides, insecticides, and fungicides used during cultivation are presented below.

Seed Treatment

Most of the pathogenic diseases are disseminated by infected seeds, including anthracnose (*Colletotrichum dematium* var. *truncata*), *Phomopsis* spp., purple seed stain (*Cercospora kikuchii*), *Cercospora sojina*, brown spot (*Septoria glycines*) and *Diaporthe phaseolorum* f.sp. *meridionalis*. The use of fungicides on seeds, besides avoiding the spread of pathogenic diseases, protects the seeds from fungi present in the soil, which can cause damage to seedlings (EMBRAPA, 2004).

The seed treatment with insecticides can be done together with fungicides. The insecticides protect the seed in the soil until its germination, from pests that are detrimental to plant health (Fundação Mato Grosso, 2006). The fungicides and insecticides used for seed treatment by the interviewed farmers are displayed in Table 3-1.

During the process of applying seed treatments, applications of micro-nutrients such as molybdenum and cobalt, or the addition of inoculants to enhance nodulation, may be included as well. For the latter purpose, seeds may be either sprayed with inoculants or mixed with a peat-based material containing *Bradyrhizobium*, which enhances the plant's ability to fix nitrogen. To optimize effectiveness, fungicides and insecticides are applied before the micro-nutrients, while seed inoculation is conducted last (Fundação Mato Grosso, 2006).

Herbicide Use

Weeds can interfere in different ways during soybean production. They can cause a serious decrease in soybean yield, reduce the quality of the soybean grain, cause difficulty during harvest, and can harbor diseases or pests that may spread to adjacent crops (Gazziero, 2006). Weeds are a pervasive challenge in soybean plantations and require high levels of herbicide application, especially when these areas are managed under a zero tillage regime as mentioned in Chapter 1.

Herbicides can be soil-applied or foliage-applied, and are applied pre-planting, pre-emergence, and post-emergence to manage weeds. Nonselective herbicides or desiccants are applied before planting soybean to kill cover crops and any weeds present. Desiccants are also applied prior to soybean harvest to kill and dry the crop and weeds, to improve efficiency during mechanical harvest (Powers and McSorley, 2000). The herbicides used by the producers interviewed are displayed in Table 3-2.

Insecticide and Fungicide Use

It is estimated that up to 15% of the world's food production is lost to insect pests each year (Fundação Mato Grosso, 2006). Therefore, in soybean plantations as with most other intensive crop cultivation, chemical and biological methods are extensively used to manage insects. Biological insecticides are an alternative to the use of chemical insecticides; however, chemical insecticides provide the most rapid method for responding to an emergency situation.

It is also estimated that up to 25% of the world's agricultural production is lost due to fungi, viruses, and bacteria (Fundação Mato Grosso, 2006). Fungicides are used to prevent the development of plant disease under favorable environmental conditions, rather than to cure or reduce active epidemics (Powers and McSorley, 2000). Therefore, some fungicides may be used on a routine preventive basis for this purpose. Insecticides may be used to manage the insect vectors that carry plant viruses. The insecticides and fungicides used by the interviewed soybean farmers are shown in Tables 3-3 and 3-4, respectively.

Methods

Data Analyses

Specific information on pesticide use obtained from 40 grower interviews and surveys conducted during June and July 2006 in northern Mato Grosso were compared in four different ways. The group comparisons and the number of farms in each sub-group are structured as follows:

- **Financial groups:** between 20 farms pre-financed, and 20 farms not pre-financed by Amaggi Group;
- **Municipal groups:** among 10 farms located in Sinop, 20 farms in Sorriso, and 10 farms in Tapurah;
- **Forest-1 groups:** between 20 farms with less than 30% of natural forest on farm, and 20 farms with greater than or equal to 30% of natural forest on farm; and
- **Forest-2 groups:** between 10 farms with less than or equal to 20% of natural forest, and 10 farms with more than 40% of natural forest, excluding the 20 farms that follow in the middle.

In order to test the hypothesis that farms surrounded by natural forest or in close proximity to forest use fewer types of pesticides, forest-1 groups and forest-2 groups were added to the analyses. Although no data were collected regarding neighboring natural forests for these farms, the percentage of natural forest on farm reported by the farmers was used as a proxy.

Descriptive Analyses

Descriptive analyses of the percent of farmers using herbicides, insecticides, and fungicides were conducted within the four group comparisons previously defined. Group comparisons for pesticide use (by common pesticide name) are displayed in Figures 1 to 14 for each stage of pesticide application: seed treatment; herbicide use as pre-planting and pre-harvesting desiccants, and post-emergence; and post-planting insecticide and fungicide use. As shown in Tables 1 to 4, farmers use a variety of pesticides; therefore more than one pesticide common name can by used by a farm.

Some pesticide uses were grouped according to their class or group in the charts. The fungicides were displayed in the figures by chemical groups. The fomosafen and lactofen (common names) post-emergent herbicides for broadleaf weeds are from the same nitrophenyl ether herbicide group. The haloxyfop and fluazifop-p-butyl post-emergent herbicides for narrow-leaf weeds are from the same aryloxyphenoxypropionic herbicide class; although the name of the chemical haloxyfop was kept in the graphs for better visualization. The insecticides diflubenzuron, triflumuron, and novaluron are insect growth regulators, and were grouped as chitin synthesis inhibitors. The cypermethrin, lambda-cyhalothrin, and permethrin insecticides are pyrethroid ester insecticides and were grouped as pyrethroids.

Statistical Analyses

Comparisons of independent sample means were conducted to test for differences in timing of fungicide applications and percentage of soybean area defoliated at a 95% confidential interval between financial groups, municipal groups, forest-1 groups, or forest-2 groups. The statistical analysis was conducted as follows: first, a pre-test (F-test) concerning two-population variances at the 5% level of significance was carried out to test for equality of variances between groups (Ott and Longnecker, 2004). If the variances were equal, a two-tailed t-test for comparison of means from samples with equal variances was conducted; if the F-test revealed inequality between variances, a two-tailed t-test for unequal variances was conducted. Both types of tests (equal or unequal variances) were carried out at 95% confidence intervals.

Results

Seed Treatment

Data on financial groups reveal that 75% of pre-financed farmers use insecticides for seed treatment, 95% use fungicide, 80% inoculate seeds, and 5% use micronutrients for seed treatment. On the other hand, 50% of farmers not pre-financed use insecticide, 95% use fungicides, and 55% of farmers inoculate seeds. Data for the same variables between municipal groups demonstrate that in Sinop, 60% of the farmers use insecticide and 90% use fungicide and inoculate seeds. In Sorriso, 50% of farmers use insecticide and inoculate seeds, 95% use fungicide, and 5% use micronutrients for seed treatment. All farmers in Tapurah use fungicide, 90% use insecticide, and 80% inoculate seeds (Figure 3-1).

Data on forest-1 groups reveal that 95% of farmers from both groups reported using fungicide for seed treatment. For farmers with less than 30% of natural forest on farm, 65% use insecticides, 65% inoculate seeds, and 5% use micronutrients for seed treatment. Among farmers with greater than or equal to 30% of natural forest on farm, 60% use insecticide, and 70% inoculate seeds. Data for forest-2 groups reveal that for farmers with less than or equal to 20% of natural forest on farm, 50% use insecticide, 90% use fungicide, 10% use micronutrients for seed treatment, and 60% inoculate seeds. For farmers with more than 40% of natural forest on farm, all of them use fungicide, and 70% use insecticide and inoculate seeds (Figure 3-2).

Fungicide use for seed treatment

Although not all farmers reported which fungicide they used, data for financial groups reveal that 40% of pre-financed farmers use the combination carboxin + thiram, 15% use carbendazim + thiram, 25% use fludioxonil + metalaxyl-M, and 5% do not use fungicide for seed treatment. Some 45% of farmers not pre-financed use the combinations carboxin + thiram and carbendazim + thiram, 10% use fludioxonil + metalaxyl-M, and 5% do not use fungicide for seed treatment (Figure 3-3).

Data based on municipal groups reveal that in Sinop, 70% of the farmers use the combination carboxin + thiram, 10% use fludioxonil + metalaxyl-M, and 10% do not use fungicide for seed treatment. In Sorriso, 35% of farmers use the mixture carboxin + thiram, 40% use carbendazim + thiram, 25% use fludioxonil + metalaxyl-M, and 5% do not use fungicide for seed treatment. Finally, in Tapurah, 30% of farmers use the combination carboxin + thiram, 40% use carbendazim + thiram, and 10% use fludioxonil + metalaxyl-M for seed treatment.

Data from forest-1 groups show that for farmers with less than 30% of natural forest on farm, 45% use the combination carboxin + thiram, 35% use carbendazim + thiram, 15% use fludioxonil + metalaxyl-M, and 10% do not use fungicide for seed treatment. For farmers with greater than or equal to 30% of natural forest on farm, 40% use carboxin + thiram, 25% use carbendazim + thiram, and 20% use fludioxonil + metalaxyl-M for seed treatment (Figure 3-4).

Data from forest-2 groups reveal that for farmers with less than or equal to 20% of natural forest on farm, 20% use the combination carboxin + thiram, 20% use fludioxonil + metalaxyl-M, 50% use carbendazim + thiram, and 10% do not use fungicide for seed treatment. For farmers with more than 40% of natural forest on farm, 30% use carboxin + thiram, 30% use fludioxonil + metalaxyl-M, and 20% use carbendazim + thiram for seed treatment.

Herbicide Use

Desiccants before soybean planting

All farmers use the chemical glyphosate before soybean planting. Data for financial groups demonstrate that 25% of farmers from both groups mix the chemical 2,4-D with glyphosate. Data based on municipal groups reveal that 40% of farmers in Tapurah, 30% of farmers in Sinop, and 15% of farmers in Sorriso mix glyphosate with 2,4-D (Figure 3-5).

Data for forest-1 and forest-2 groups show that 20% of farmers with less than 30% of natural forest on farm and that 10% of farmers with less than or equal to 20% of natural forest on farm mix 2,4-D with glyphosate, and 30% of farmers with greater than or equal to 30% of natural forest on farm, and another 30% of farmers with more than 40% of natural forest on farm use 2,4-D with glyphosate before soybean planting (Figure 3-6).

Post-emergent herbicides

Data based on financial groups demonstrate that 55% of pre-financed farmers use the chemical imazethapir, 75% use chlorimuron ethyl, 85% use nitrophenyl ether, 85% use haloxyfop, 35% use other post-emergent chemicals, and 5% reported that they do not use post-emergent herbicides. While 74% of not pre-financed farmers use imazethapir, 79% use chlorimuron ethyl, 79% use haloxyfop, 68% use nitrophenyl ether and 21% use other post-emergent herbicides (Figure 3-7).

According to data based on municipal groups, 50% of farmers in Sinop use the chemical imazethapir, 90% use chlorimuron ethyl, 90% use nitrophenyl ether, 80% use haloxyfop, and 30% use others post-emergent herbicides. In Sorriso, 58% of farmers use imazethapir, 63% use chlorimuron ethyl, 68% use nitrophenyl ether, 79% use haloxyfop, 26% use other chemicals and 5% do not use post-emergent herbicides. In Tapurah, 90% use imazethapir, chlorimuron ethyl and haloxyfop, 80% use nitrophenyl ether and 30% use other post-emergent herbicides.

Data from forest-1 groups indicate that for farmers with less than 30% of natural forest on farm, 74% use imazethapir, chlorimuron ethyl and haloxyfop; 68% use nitrophenyl ether; and 32% use other post-emergent herbicides. For farmers with greater than or equal to 30% of natural forest on farm, 55% use imazethapir, 80% use chlorimuron ethyl, 85% use haloxyfop, 90% use nitrophenyl ether, 25% use other chemicals, and 5% of farmers do not use post-emergent herbicides (Figure 3-8).

Data for forest-2 groups show that for farmers with less than or equal to 20% of natural forest on farm, 67% use imazetaphir, 56% use chlorimuron ethyl and nitrophenyl ether, and 44% use haloxyfop and other post-emergent herbicides. For farmers with more than 40% of natural forest on farm, 70% use imazethapir, 80% use chlorimuron ethyl, 90% use nitrophenyl ether and haloxyfop, 20% use other chemicals, and 10% of farmers do not use post-emergent herbicides.

Desiccants prior to soybean harvest

Data from the two financial groups reveal that 80% of pre-financed farmers use diquat before soybean harvest, 50% use paraquat, and 10% use glyphosate. In comparison, 85% of not pre-financed farmers use diquat, 35% use paraquat, 5% glyphosate, and 10% do not use desiccants before soybean harvest. Data separated among municipal groups indicate that 70% of farmers from Sinop use diquat, 60% use paraquat, 10% use glyphosate, and 10% do not use desiccants before soybean harvest. In Sorriso, 85% of farmers use diquat, 30% use paraquat, 10% use glyphosate, and 5% do not use desiccants before soybean harvest. In Tapurah, 90% of farmers use diquat and 50% use paraquat before soybean harvest (Figure 3-9).

When data are analyzed for forest-1 groups, of the farmers with less than 30% of natural forest on farm, 95% use diquat, 30% use paraquat, 5% use glyphosate, and 5% do not use desiccants before soybean harvest. For farmers with greater than or equal to 30% of natural forest on farm, 70% use diquat, 20% use paraquat, 10% use glyphosate, and 5% do not use desiccants before soybean harvest. Data from forest-2 groups reveal that all farmers with less than or equal to 20% of natural forest on farm use diquat, and 30% use paraquat. For farmers with more than 40% of natural forest on farm, 70% use diquat and paraquat, and 20% use glyphosate before soybean harvest (Figure 3-10).

Comparisons of means with regards to the percentage of soybean area in which the reported desiccants were applied (Table 3-5) reveal that there are no statistically significant differences between the financial groups. However, there is a significant difference ($P<0.01$) between the farms in Sorriso and Tapurah. Farmers in Tapurah sprayed desiccant herbicides prior to soybean harvest in 82% of their soybean area while farmers in Sorriso sprayed desiccants in 50% of their soybean area.

Insecticides and Biological Control

Data from financial groups demonstrate that 25% of pre-financed farmers manage insects with biological control, 70% with chitin synthesis inhibitors, 75% use methamidophos, 40% use endosulfan, 50% use pyrethroids, and 25% use other insecticides. Twenty percent of not pre-financed farmers use biological control, 70% use chitin synthesis inhibitors, 90% use methamidophos, 25% use endosulfan, 85% use pyrethroids, and 10% use other insecticides (Figure 3-11).

Data from municipal groups indicate that in Sinop, 20% of farmers manage insects with biological control, 70% with chitin synthesis inhibitors, 70% use methamidophos, 40% use endosulfan, 60% use pyrethroids, and 30% use other insecticides. In Sorriso, 25% of farmers use biological control, 65% use chitin synthesis inhibitors, 80% use methamidophos, 20% use endosulfan, 70% use pyrethroids, and 15% use other insecticides. In Tapurah, 20% use biological control, 80% use chitin synthesis inhibitors, 100% use methamidophos, 50% use endosulfan, 70% use pyrethroids, and 10% use other insecticides.

Results from forest-1 groups reveal that for farmers with less than 30% of natural forest on farm, 30% manage insects with biological control, 70% with chitin synthesis inhibitors, 90% use methamidophos, 30% use endosulfan, 70% use pyrethroids, and 15% use other insecticides. In the case of farmers with greater than or equal to 30% of natural forest on farm, 15% of farmers use biological control, 70% use chitin synthesis inhibitors, 75% use methamidophos, 35% use endosulfan, 65% use pyrethroids, and 20% use other insecticides (Figure 3-12).

Data from forest-2 groups show that for farmers with less than or equal to 20% of natural forest on farm, 40% manage insects with biological control, 60% with chitin synthesis inhibitors, 80% use methamidophos, 50% use pyrethroids, and 10% use endosulfan and other insecticides. Considering farmers with more than 40% of natural forests on farm, 10% use biological control, 60% use chitin synthesis inhibitors, 90% use methamidophos, 70% use pyrethroids, and 20% use endosulfan and other insecticides.

Fungicide Use

All farmers from all groups use triazole fungicides. Data from financial groups reveal that all pre-financed farmers use strobilurin fungicides and 20% use benzamidazole fungicides. Similarly, 90% of not pre-financed farmers use strobilurin, and 25% use benzamidazole. Data from municipal groups show that all farmers from Sorriso and Tapurah and 80% of the farmers in Sinop use strobilurin fungicides. The benzimidazole fungicides are used by 15% of farmers in Sorriso, 20% in Sinop, and 40% in Tapurah (Figure 3-13).

Data from forest-1 groups and forest-2 groups (Figure 3-14) indicate that the strobilurin fungicides are used by all farmers with less percentages of natural forest on farm, and by 90% of farmer with more percentages of natural forest on farm in both groups. The benzimidazole fungicides are used by 20% of farmers with less than 30% of natural forest on farms, and by 25% of farmers with greater than or equal to 30% of natural forest on farm in forest-1 groups, and by

30% of farmers with less than or equal to 20% of natural forest on farm, and by 40% of farmers with more than 40% of natural forest on farm in forest-2 groups.

Statistical comparisons of means with regards to the number of fungicide applications in the soybean plantation (Table 3-5) do not reveal any significant difference between groups in any of the four group comparisons: financial groups, municipal groups, forest-1 groups, and forest-2 groups.

Discussion

Seed Treatment

Although 25% more pre-financed farmers reported using insecticide for seed treatment, the product used by both groups was Standak insecticide. Standak contains the active ingredient fipronil and is consider the leading insecticide for seed treatment in Brazil. For protection against seed-borne and soil-borne fungi which cause decay, damping-off, and seedling blight, most of the farmers used fungicide for seed treatment.

Inoculation with Bradyrhizobium bacteria provides the soybean plant with nitrogen (N). Symbiotic N2 fixation is the main source of N for soybean plants (EMBRAPA, 2004). Inoculation usually increases crop yield, the %N in plant tissues, and post-harvest levels of N in the soil (Powers and McSorley, 2000). The Amaggi Group recommends the use of inoculation for seed treatment, however it did not have a significant impact in the result between financial groups.

With regard to municipal groups, farmers reported using the combination carboxin + thiram. According to the Vitavax-Thiram product label, the fungicides that combine the systemic action of carboxin with the surface action of thiram control various seed and seedling diseases. It is particularly effective against foliar blight (Rhizoctonia solani) and anthracnose (Colletotrichum truncatum). The effectiveness of this fungicide may explain why farmers in

Sinop did not report any foliar blight disease during the 2005/2006 soybean harvest period as mentioned in Chapter 2.

Independent of the percentage of natural forest on farm, almost all farmers reported using fungicide for seed treatment. According to the Vitavax-Thiram label, the use of fungicide for seed treatment often results in increased and more uniform stands of seedlings with a higher yield potential. Therefore, the percentages of natural forest on farm does not appear to reduce pesticide use for seed treatment, at least in terms of types of fungicide and insecticide used, since amounts of pesticide application in seeds were not statistically analyzed.

Herbicide Use

Desiccants before soybean planting

The desiccants currently available in the market are glyphosate (the brand name "Round-Up" in particular), paraquat, and paraquat + diuron. These products may be applied alone or mixed with 2,4-D, particularly in areas with high density of broadleaf weeds. Some weeds such as Ipomoea sp., Conyza bonariensis and C. canadensis, Richardia brasiliensis and Commelina benghalensis are tolerant to glyphosate and require the addition of associated herbicides for effective weed control (Vargas et al., 2006).

Farmers that practice the no-tillage system need to rely on herbicide use before planting soybeans to create the dried cover crop residues on the soil surface. The surface residues suppress weeds, moderate soil temperature and moisture, and can have allelopathic effects on weeds (Vargas et al., 2006). As mentioned in Chapter 2, all the farmers surveyed employed the no-tillage system, and consequently relied on the herbicide glyphosate to prepare the field for soybean plantation.

Results also demonstrated that there was no significant difference in the percent of farmers mixing the herbicide 2,4-D with glyphosate between the financial groups, among the municipal groups, and within forest-1 and forest-2 groups. Therefore, the hypotheses related to desiccants are rejected: there is no difference in desiccant use before soybean planting between the financial groups; among farm locations, or between farms with different amounts of forest cover.

Post-emergent herbicides

Results did not show significant differences in the percentage of farmers using specific post-emergent herbicides between the financial groups, among the municipal groups and within the forest-1 and forest-2 groups. For example, over 50% of farmers, regardless of financial status, location or different amount of forest cover, applied post-emergent herbicides such as imazethapir, chlorimuron ethyl, nitrophenyl ether and haloxyfop, and only 5% of pre-financed farmers from Sorriso in areas with higher percentage of forest cover do not use post-emergent herbicide. The only farmer that reported not using post-emergent herbicides explained that his area was new and it did not need herbicide use. The amounts that each farmer used was not analyzed.

The reason why the interviewed farmers use so many different post-emergent herbicides is that most farmers do not plant genetically modified soybeans (GM). Genetically modified herbicide-resistant Roundup Ready soybean plants (RR soybeans) require only one general purpose herbicide such as glyphosate. The percentage of farmers using glyphosate for RR soybeans in the study region is very small and is included with other post-emergent herbicides. To avoid weed resistance to glyphosate, it is recommended to rotate GM soybeans with conventional soybean and/or rotate the herbicide's active ingredients (Gazziero, 2006).

The constant use of the same herbicide class can cause resistance problems. According to Gazziero (2006), repeated use of herbicides that present the same mode of action such as plant hormones, photosynthesis inhibitors, cellular division inhibitors, or specific enzyme inhibitors, are partially responsible for newly resistant weed species. An invasive plant can have resistance to an herbicide product line, in which mode of action is similar; or the plant can have multiple resistances to different modes of action.

The results indicate that, contrary to the hypotheses, post-emergent herbicides are not used by fewer pre-financed farmers, nor are they used by fewer farmers in Sinop, since no significant differences were observed between financial groups, and among municipalities. Moreover, based on the observations, areas surrounded by forests do not seem to use fewer kinds of post-emergent herbicides.

Desiccants prior to soybean harvest

Based on the descriptive statistics, there is no significant difference in the percentage of farmers using the desiccants diquat, paraquat and glyphosate prior to soybean harvest between financial groups, among municipal groups and within forest groups. The desiccants diquat and paraquat are nonselective herbicides, for which the active ingredients only affect the green parts of plants sprayed, destroying the energy producing cells (chloroplasts) and rapidly desiccating the tissue. According to the Brazilian agriculture research and extension agency (EMBRAPA, 2004), paraquat should be used in areas where narrow-leaf weeds such as *Cardiospermum halicacabum* are predominant, while the product diquat should be used in areas where broadleaf weeds such as *Ipomoea grandifolia* predominate.

With regard to applications of desiccants prior to soybean harvest, statistical analyses revealed that farmers in Tapurah applied desiccants in a greater percentage of soybean area than the farmers located in Sorriso ($P<0.01$). This suggests that soybean farmers in Tapurah had more weed infestation in their crop or that the soybean plants were not dried enough to be harvested due to environmental conditions such as rainfall and moisture. In addition, as reported in Chapter 2, farmers in Tapurah had stinkbug infestation which causes foliar retention at the end of the soybean plant cycle. This might have contributed to the need for more extensive desiccant application.

Insecticide Use

Although Amaggi Group recommends that their pre-financed farmers adopt biological control strategies or insect growth regulators when possible, the percent of farmers adopting biological control methods is still small and there is no difference in the level of adoption between financial groups. The level of adoption of insect growth regulator insecticides is greater than the biological insecticides and equal between the financial groups. Therefore, the hypothesis that pre-financed farmers would use more biological and growth regulator insecticides than the not pre-financed farmers is rejected. Among the municipal groups, there are no large differences in percent of farmers adopting biological control and insect growth regulators.

Biological controls, such as *Baculovirus anticarsia* and insect growth regulators, used to control foliar feeding insects, are more effective for small caterpillars (Degrande and Vivan, 2006). Some farmers reported that they did not use biological control methods because of their ineffectiveness against stinkbugs, and that other chemicals applied to control other insects kill caterpillars as well.

According to Gassen (2002), stinkbugs are controlled by insecticides such as monocrotophos, methamidophos, endosulfan, fenitrothion, and trichlorfon. He argues that pyrethroid insecticides are not efficient against this type of pest. However, pyrethroid insecticides are generally recommended for some species of stinkbug. For example, cypermethrin, permethrin, and lambda-cyhalothrin are recommended for controlling *Piezodorus guildinii*, *Nezara viridula* and *Euchistus heros* by Brazilian Ministry of Agriculture. In some regions of Brazil, some accounts report that *Euschistus heros* is resistant to insecticides such as endosulfan (Degrande and Vivan, 2006).

During the interviews, some farmers reported using methamidophos and endosulfan to control stinkbugs and pyrethroid to control caterpillars at the end of the soybean cycle. However, based on the observations, there are no significant differences in percent of farmers using chemical insecticides between financial groups and among municipal groups.

With regards to forest groups, it was expected that farms with a higher forest cover would use less insecticides. According to Powers and McSorley (2000), maintenance of vegetation heterogeneity and diversity with regard to crops and proximate natural vegetation within a region, is an effective integrated pest management strategy for some pests. Non-crop vegetation may serve as a reservoir for predators and parasites of the pests; pests may also be attracted to the natural vegetation rather than the planted crop. However, results showed that farmers, regardless of different amounts of forest cover, applied biological and growth regulator insecticides, as well as different chemical insecticides. Therefore, there are no significant differences in percent of farmers using insecticides with regard to percentage of forest cover on farm.

Fungicide Use

Results indicate that most of the farmers between financial groups and among municipal groups used strobilurin and triazole fungicides and fewer farmers used benzamidazole fungicide. The former fungicides are recommended for controlling pathogenic diseases such as Asian Soybean Rust (Phakopsora pachyrhizi). As shown in Chapter 2, all farmers reported having Asian Soybean Rust in their soybean crops.

Fungicide application as a preventive treatment for Asian soybean rust is recommended prior to the detection of symptoms of the disease. Triazole fungicides combined with a strobilurin or a benzamidozole should be applied. The objective is to protect the soybean against rust and other diseases that occur during the flowering stage, such as anthracnose, leaf spot

(Corynespora cassiicola), foliar blight, and powdery mildew (Microsphaera diffusa). However, if disease symptoms are observed, then other fungicides that are effective in controlling the rust should be applied (Fundação Mato Grosso, 2006).

Spores of Asian soybean rust can travel hundreds of miles on a windy day and infection can occur in favorable weather conditions such as high air moisture and with temperatures between 18°C and 26°C (Wyse, 2005). Bearing this in mind, and the fact that the disease started in the south of Brazil, one would expect that farms located in the northernmost regions would require less fungicide applications. However, statistical analysis rejected the hypothesis that farms in Sinop apply fungicides fewer times.

Another hypothesis was that farmers with more forest cover would use less fungicide. It was expected that the forest would function as a windbreak, helping protect the crop from the spores of Asian soybean rust. However, results did not show significant differences in percent of farmers using insecticide within each forest groups. Moreover, statistical analyses with regard to the number of times that fungicide was applied did not reveal significant differences within forest-1 and forest-2 groups. Therefore, the hypothesis that farmers with more forest on farm apply fungicide fewer times is rejected.

The foliar blight disease (Rhizoctonia solani), also mentioned by farmers in Chapter 2, is efficiently controlled when adopting an integrated pest management strategy. There are no effective fungicides registered by the Ministry of Agriculture and Agrarian Reform (MARA) to control foliar blight disease. Nonetheless, experiments have shown that fungicides such as azoxystrobin, metconazole, pyraclostrobin + epoxiconazole, and trifloxystrobin + cyproconazole can effectively control the disease (EMBRAPA, 2004) and as shown in Table 3-4, some of these pesticides were used by farmers to control pathogenic diseases.

Conclusion

To sum up, most explanatory variables had no effect on pesticide use patterns, with the exception of desiccant use between the farms in Tapurah and Sorriso. The similarities in the data reject the hypotheses that pre-financed farms use fewer types of pesticide than not pre-financed farms, that the producers located in Sinop use less fungicide and apply it less often than the producers located in Sorriso and Tapurah, and that farms surrounded by natural forest or in close proximity to forest need less pesticide use. However, there are some interesting findings among the farmers. For example, all farmers, regardless of financial status, location, or amount of forest cover, rely on the herbicide glyphosate before soybean planting, since they adopted the no-tillage system for soil conservation. Also, farmers use different types of post-emergence herbicides, because most of their seeds are non-GM soybeans.

Table 3-1. Pesticide used for seed treatment as reported by farmers in Sinop, Sorriso, and Tapurah.

Common name	Trade name
Fungicide	
Carbedanzin + Thiram	Derosal Plus / ProTreat
Carboxin + Thiram	Vitavax-Thiram PM / Vitavax-Thiram 200 SC
Fluodioxonil + Metalaxyl - M	Maxin XL
Insecticide	
Fipronil	Standak 250 FS

Table 3-2. Herbicide used in soybean plantation as reported by farmers in Sinop, Sorriso, and Tapurah.

Common name	Trade name
Desiccants before soybean plantating	
Glyphosate	Glifosato* / Roundup* / Trop
2,4-D	not reported
Post-emergent	
Carfentrazone	Aurora 400 CE
Chlorimuron Ethyl	Classic / Clorimuron Master Nortox
Clethodim	Select 240 EC
Diclosulam	Spider 840 WG
Fenoxaprop-P-Ethyl + Clethodim	Podium S
Fluazifop-P-Butyl	Fusilade 250 EW
Fomosafen	Flex
Glyphosate	Glifosato* / Roundup*
Haloxyfop-Methyl	Verdict R
Imazethapir	Pivot
Lactofen	Cobra / Naja
Trifluralin	Trifluralina*
Desiccants before soybean harvest	
Diquat	Reglone
Glyphosate	Glifosato* / Roundup*
Paraquat	Gramoxone 200

*Trade names with many variations and not specified by farmers.

Table 3-3. Insecticide used in soybean plantation as reported by farmers in Sinop, Sorriso, and Tapurah.

Common name	Trade name
Cypermethrin	Cipermetrina Nortox 250 CE
Diflubenzuron	Dimilin 250 WP
Dimethoate	not reported
Endosulfan	Thiodan* / Endosulfan*
Lambda-Cyhalothrin	Karate Zeon 250 CS
Methamidophos	Metamidofós Fersol 600 / Tamaron BR
Methomyl	Lannate BR
Methyl Parathion	Folidol CS
Novaluron	Gallaxy 100 CE
Permethrin	Permetrina / Pounce / Talcord / Valon
Teflubenzuron	Nomolt 150 SC
Thiamethoxam + Lambda-cyalothrin	Engee Pleno
Thiodicarb	Larvin 800 WG
Triflumuron	Certero 480 CS

*Trade names with many variations and not specified by farmers.

Table 3-4. Fungicide used in soybean plantation as reported by farmers in Sinop, Sorriso, and Tapurah.

Common name[1]	Trade name
Azoxystrobin (S)+ Cyproconazole (T)	Priori Xtra
Carbendazim (B)	Bendazol / Derosal
Carbendazim (B) + Thiram (D)	Derosal Plus
Epoxiconazole (T) + Pyraclostrobin (S)	Opera
Flutriafol (T)	Impact 125 SC
Flutriafol (T) + Thiophanate-methyl (B)	Impact Duo
Myclobutanil (T)	Systane CE
Propiconazole (T) + Cyproconazole (T)	Artea
Tebuconazole (T)	Folicur 200 CE / Orius 250 CE
Thiophanate-Methyl (B)	Cercobin 500 SC / Cercobin 700 PM
Trifloxystrobin (S) + Cyproconazole (T)	Sphere

1. (T) = Triazole; (S) = Strobilurin; (B) = Benzimidazole; (D) = Dithiocarbamate

Table 3-5. Descriptive statistics and comparison of means of pesticide use. Comparisons between financial groups, among municipal groups, between farms with <30% forest and farms with ≥30% forest, and between farms with less ≤20% forest and farms with >40% forest. Table shows number of farms (N) in each group; minimum, maximum, mean, and standard deviation of values reported within each group; and t-test statistics for comparisons between groups.

	Comparisons	N	Min.	Max.	Mean	Std. Dev.		t-value	P
Desiccant use before harvest (% of soybean area)	Pre-financed	14	10%	100%	58%	34%		-1.037	0.308
	Not financed	18	0%	100%	70%	33%			
	1-Sinop	6	0%	100%	73%	43%	1-2	1.434	0.167
	2-Sorriso	16	10%	100%	50%	31%	2-3	-2.989	0.006**
	3-Tapurah	10	50%	100%	82%	19%	1-3	-0.482	0.646
	<30% forest	17	10%	100%	65%	34%		0.186	0.854
	≥30% forest	15	0%	100%	63%	34%			
	≤20% forest	8	14%	100%	59%	32%		1.188	0.253
	>40% forest	9	35%	100%	76%	27%			
Number of times fungicide was applied	Pre-financed	20	1	3	2.1	0.456		-0.080	0.936
	Not financed	20	2	3	2.2	0.319			
	1 Sinop	10	2	3	2.2	0.334	1-2	0.856	0.399
	2 Sorriso	20	1	3	2.1	0.353	2-3	-1.425	0.176
	3 Tapurah	10	2	3	2.3	0.483	1-3	-0.700	0.493
	<30% forest	20	1	3	2.2	0.492.		0.977	0.337
	≥30% forest	20	2	3	2.1	0.246			
	≤20% forest	10	1	3	2.2	0.576		0.433	0.670
	>40% forest	10	2	3	2.1	0.316			

**indicates t-value significant at P<0.01.

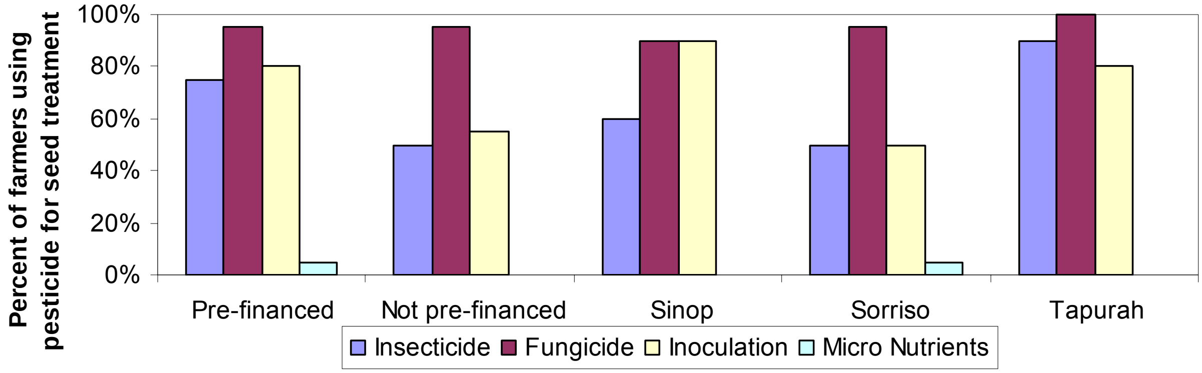


Figure 3-1. Pesticide and inoculant use for seed treatment for financial groups and municipal groups in 2006.

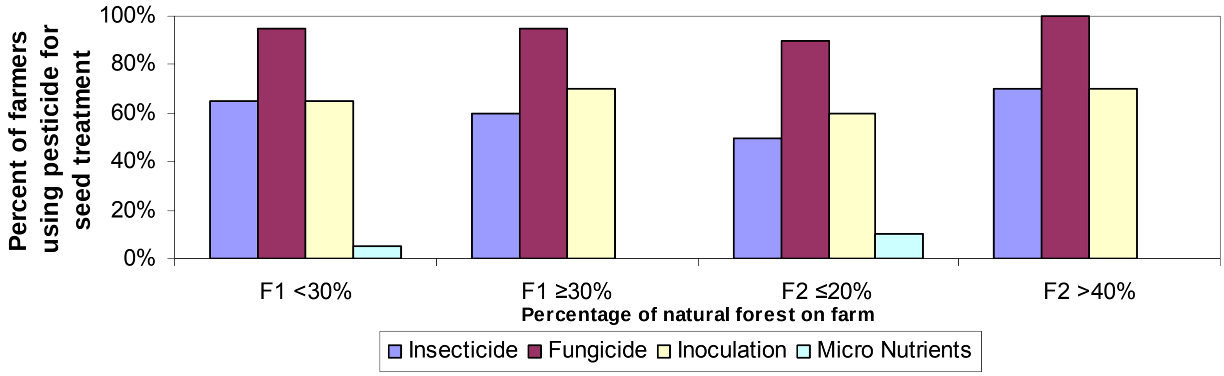


Figure 3-2. Pesticide and inoculant use for seed treatment for forest-1 groups (F1) and forest-2 groups (F2) in 2006.

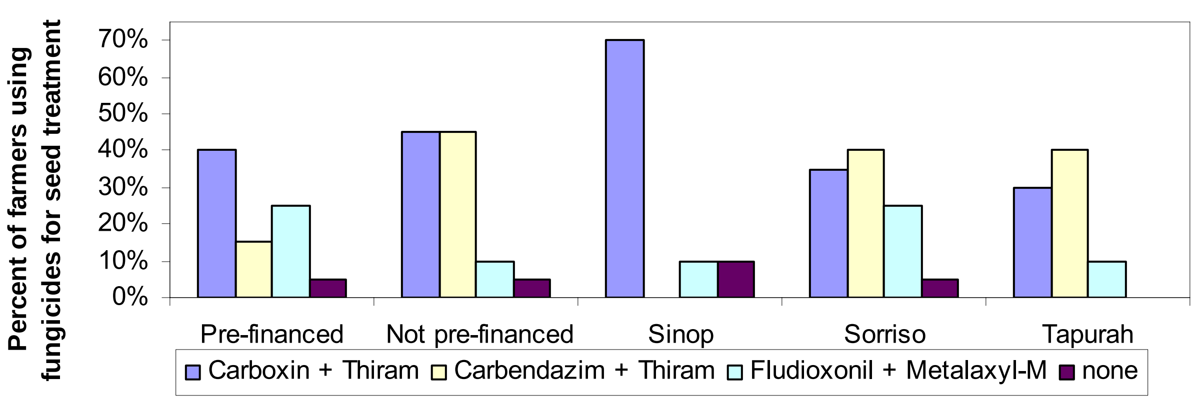


Figure 3-3. Fungicide use for seed treatment for financial groups and municipal groups in 2006.

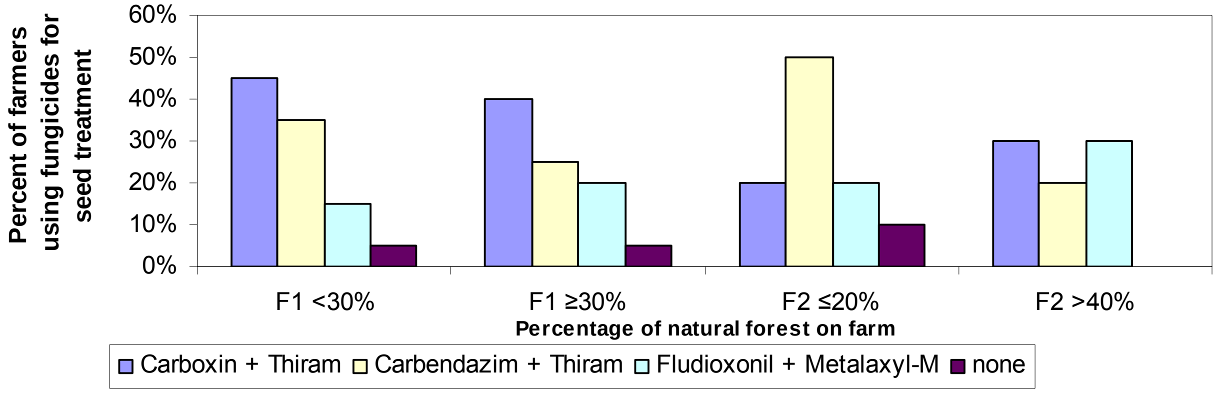


Figure 3-4. Fungicide use for seed treatment for forest-1 groups (F1) and forest-2 groups (F2) in 2006.

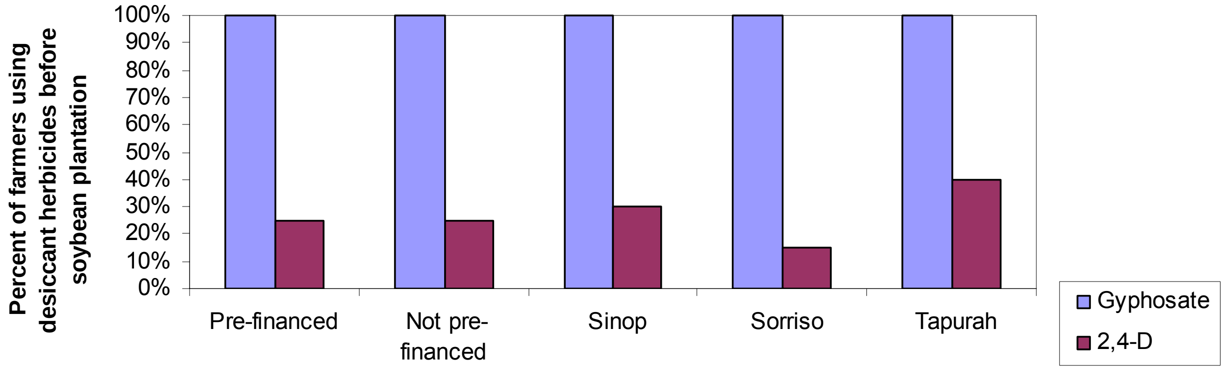


Figure 3-5. Desiccant use before soybean planting for financial groups and municipal groups in 2006.

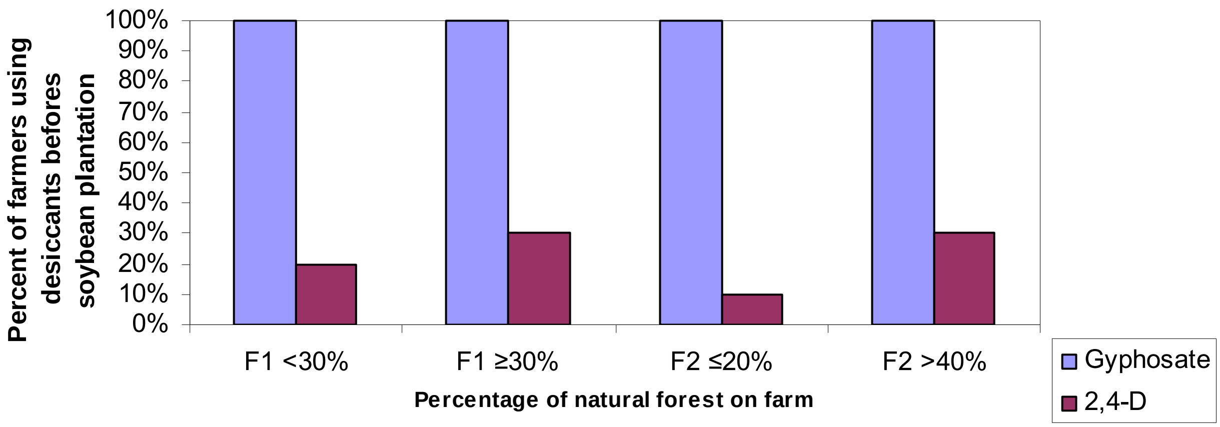


Figure 3-6. Desiccant use before soybean planting for forest-1 groups (F1) and forest-2 groups (F2) in 2006.

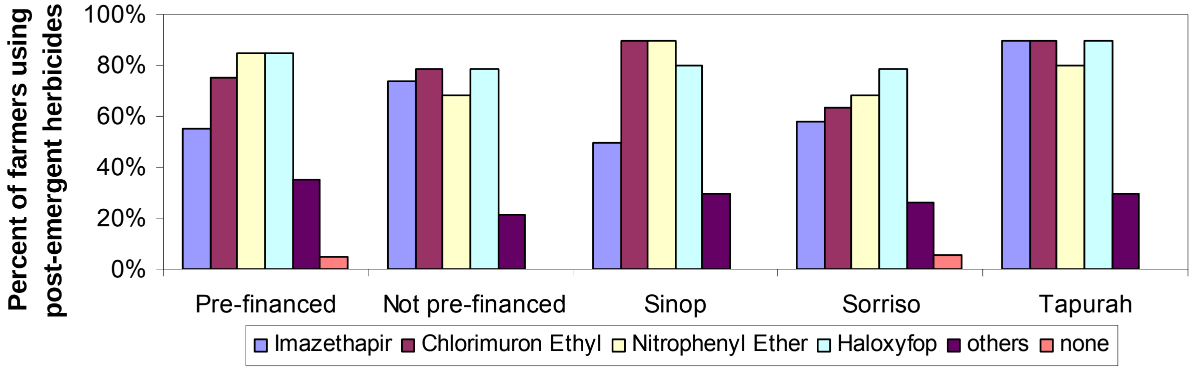


Figure 3-7. Post-emergent herbicide use for financial groups and municipal groups in 2006.

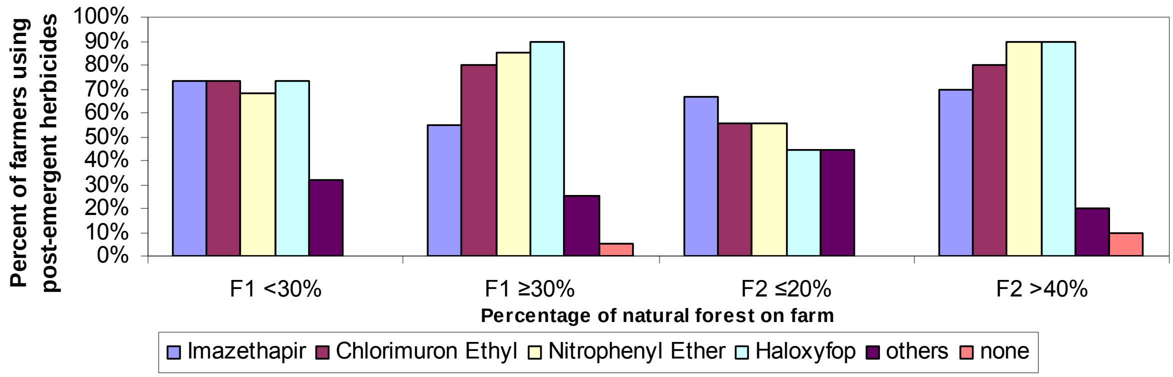


Figure 3-8. Post-emergent herbicide use for forest-1 groups (F1) and forest-2 groups (F2) in 2006.

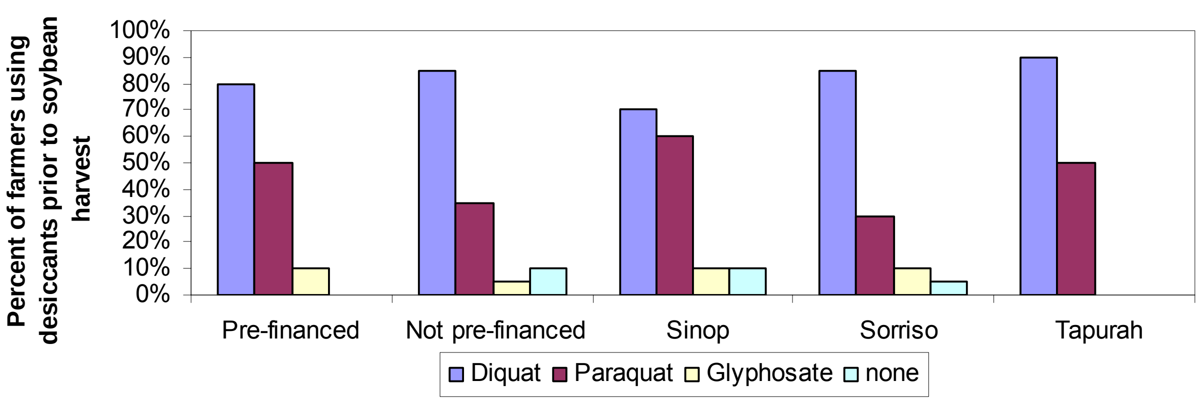


Figure 3-9. Desiccant use prior to soybean harvest for financial groups and municipal groups in 2006.

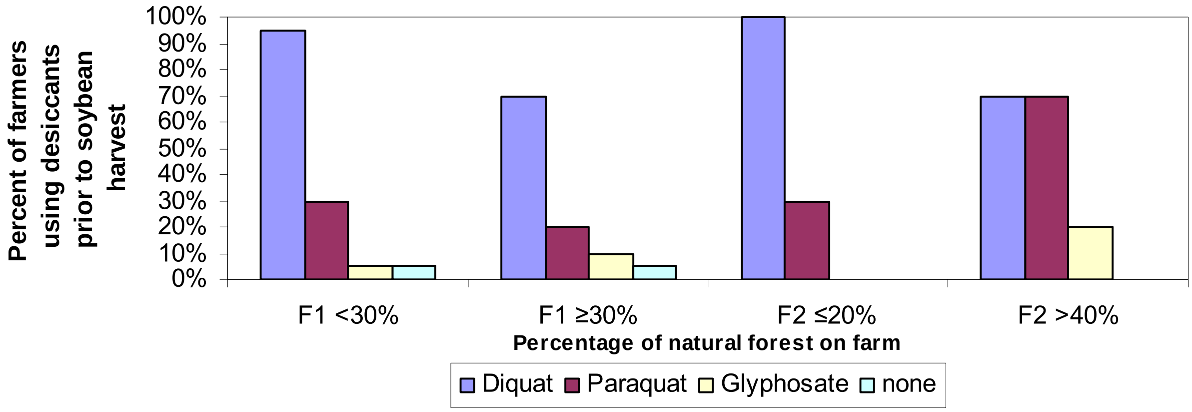


Figure 3-10. Desiccant use prior to soybean harvest for forest-1 groups (F1) and forest-2 groups (F2) in 2006.

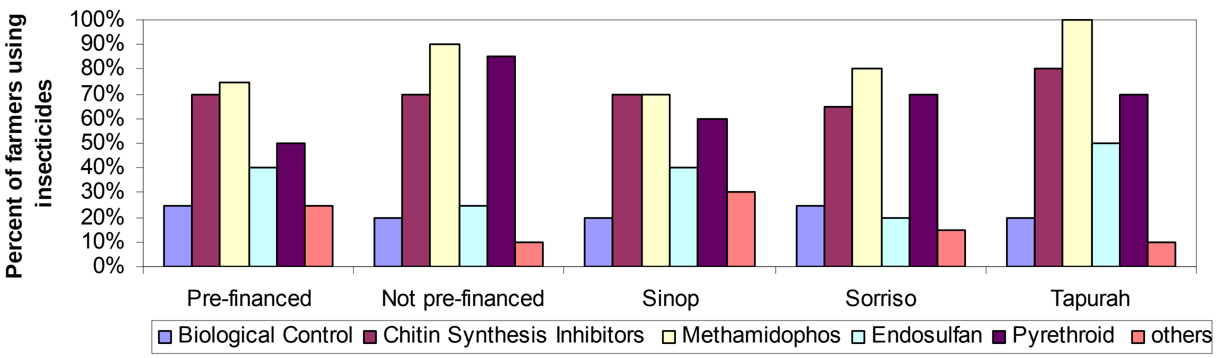


Figure 3-11. Insecticide use for financial groups and municipal groups in 2006.

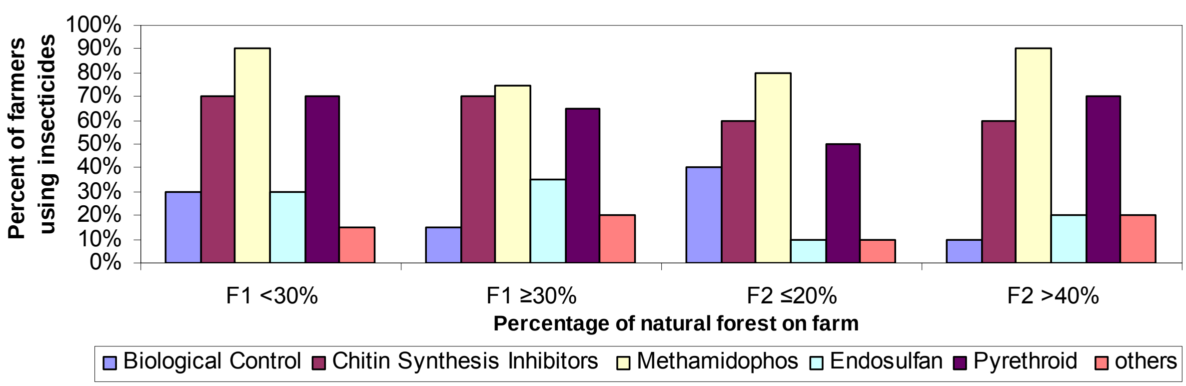


Figure 3-12. Insecticide use for forest-1 groups (F1) and forest-2 groups (F2) in 2006.

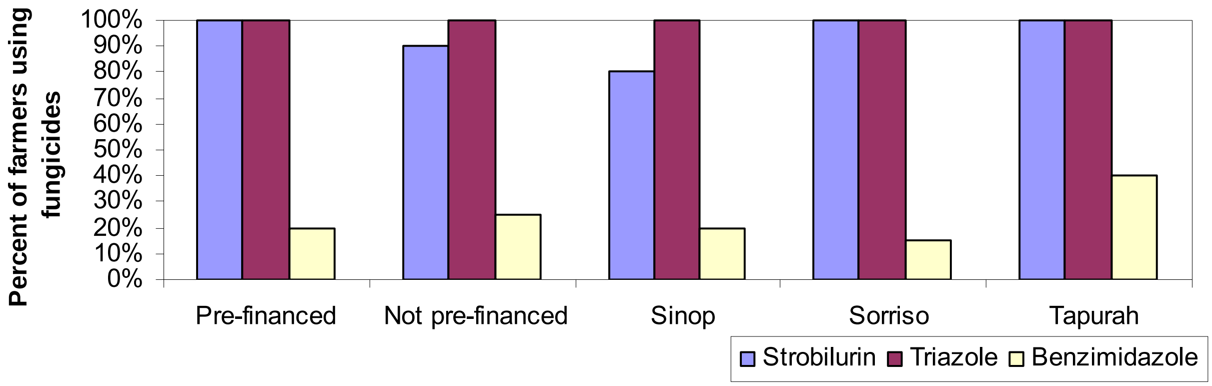


Figure 3-13. Fungicide use for financial groups and municipal groups in 2006.

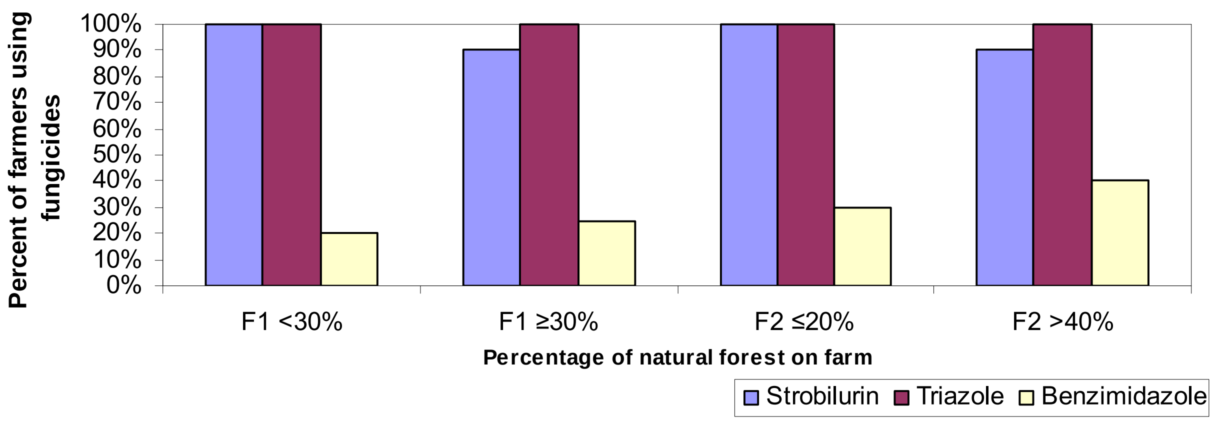


Figure 3-14. Fungicide use for forest-1 groups (F1) and forest-2 groups (F2) in 2006.

CHAPTER 4
SOYBEAN PROFITABILITY AND RISK MODELING

Introduction

The first objective of this chapter is to analyze if there are differences in soybean yield among soybean producers in the study region. Congruent with this objective, the following specific hypotheses will be tested: (1) The pre-financed group, who use management practices recommended by Amaggi Group, has greater yields than those who are not; and (2) the producers located in Sinop, where soybeans have been cultivated for fewer years, have lower yields than those located in Sorriso and Tapurah. The second objective is to present a case study comparing net revenues for the 2005/2006 soybean production year of a smaller and a larger farm. Reasons for the differences in this variable are explored. Finally, a risk modeling exercise, using Pallisade's @Risk© for Microsoft Excel, is conducted to evaluate the sensitivity of the net revenue of case study farms to fluctuations in the soybean price and the exchange rate with the US dollar.

To accomplish these tasks, first, the exchange rate, world soybean price and soybean production costs will be discussed. Then, statistical analyses of soybean yield in the 2005/2006 soybean harvest are undertaken and compared between the financial groups and among the municipal groups. Finally, net revenue per hectare for a larger and a smaller farm, both located in Sinop, are compared to discuss the difference in this variable and how it is affected by changes in exchange rate (Brazilian real related to the US dollar) and US dollar soybean price.

Exchange Rate

In early 1999, Brazil adopted a floating exchange rate causing the real to depreciate considerably from R$1.21/US$ to an average of R$1.52/US$ in January, R$1.91/US$ in February, and R$1.90/US$ in March (Marques, 2004). The devaluation of the Brazilian currency benefited exporters, while reducing the competitiveness of imports. Devaluation of the real related to the US dollar increases the producer price of internationally traded commodities such as soybeans while the agricultural inputs measured in foreign currency became more expensive. The devaluation of the real raised expected returns to soybeans, which in turn led to a 20% expansion in the area planted to soybeans in the 2000/01 crop year (Valdes, 2006).

Not only is the export price of soybean determined in U.S. dollars, but most of the operating costs such as fertilizer, pesticides, and fuel are also in U.S. dollars. Therefore, these costs increase when there is a local currency devaluation or an exchange rate increase. However when the real appreciates, these costs do not decrease at the same rate as the exchange rate (J. Y. Shimada, personal communication, November 21, 2006).

Since September 2004, the real started a new period of appreciation (Figure 4-1), affecting Brazil's competitive pricing and the profitability of its agricultural exports. By July 2006, the real had appreciated 32% against the U.S. dollar, making Brazilian products about one-third more expensive in importing countries (Valdes, 2006), which also resulted in a lower soybean producer price for Brazilian farmers. Reduced export competitiveness resulting from a less favorable exchange rate has caused protests in Brazil, with attempts to block deliveries and force the price up (Baer, 2006).

According to the Mato Grosso's Alliance for Agriculture and Cattle Ranching (FAMATO) and Mato Grosso's Association of Soybean Producers (APROSOJA), soybean producers' operating costs are closely linked to the exchange rate. In the 2006/2007 crop harvest, producers bought inputs at an exchange rate of R$2.30, and sold the production at an exchange rate of less than R$2.00. This is the third consecutive harvest period where producers buy inputs at a less favorable exchange rate than the exchange rate they receive when selling their product (Diário de Cuiabá, 2007).

Soybean Price (US$)

The soybean price is determined in the Chicago Board of Trade (CBOT), and current and future soybean demands are established. The Brazilian free-on-board (FOB) price is based on the CBOT price and the Rotterdam cost of insurance and freight (CIF) price (Machado and Margarido, 2000). The differential between producer price and the FOB price is 20% less in the case of Mato Grosso's producers. This differential is due to marketing margins of the trading companies such as port costs, transportation to port and taxation costs (Roessing, 2005; Valdes, 2006).

The history of international soybean prices has impacted soybean expansion and production in Brazil, as discussed in detail by Brum (2004): During the 1970s, high world soybean prices combined with government incentives resulted in an increase in Brazil's soybean production. In 1972, the soybean quotation in Chicago reached US$ 10.00/bushel (equivalent to 27.216 kilos), with direct impacts on the Brazilian producer's soybean price. From 1970 to 1977, Brazilian soybean production increased from 1.5 million tons on an area of 1.3 million hectares to 12.5 million tons on an area of 8.3 million hectares. In the last two years of the 1970s, soybean production decreased to 9.6 million tons due to weather-related losses.

During the 1980s the high growth rates in soybean production were diminishing due to uncertainties and risks related to this activity. In Chicago, the average annual soybean price was varying between US$6.00 and US$7.25/bushel during the first half of the decade. In 1985 until 1987, the average annual soybean price was varying between US$5.00 and US$5.50/bushel. In 1988, the average monthly soybean prices increased again reaching US$9.00/bushel due to a soybean supply crisis in the United States. However, the average annual soybean price was US$ 7.60 in 1988 and US$6.75/bushel in 1989 (Brum, 2004).

In the 1990s, the average soybean price in Chicago was US$6.20/bushel. Even though the international soybean prices were not high from an historical perspective, Brazilian soybean production increased significantly during the decade due to technological advances. Soybean production increased from 20.4 million tons in 1990 to 31.4 million tons and an area of 13 million hectares in 1999. The increase in area planted and higher production translated into a 35% growth in soybean export volume. This export expansion in Brazil led to changes in world prices, such as a 2 percent decline in world soybean prices in 2001 (Valdes, 2006). From 1999 to 2002, the average annual soybean price did not exceed US$5.00/bushel; and in 2003, the soybean price increased to US$6.34/bushel (Brum, 2004).

In 2004 there was an increase in the soybean prices due to the bad harvest period in the United States and to production losses in Brazil. In the beginning of March 2004, the soybean price reached US$9.60/bushel, the highest price since 1988. In 2005, the price in Chicago dropped 25% with regard to the previous year and producer prices in Mato Grosso decreased 28% in the same period (Diário de Cuiabá, 2007). Between 2006 and 2007, stimulated by the increased corn demand in the United States for ethanol production, the soybean price increased 25% in a year, increasing the Brazilian exports despite the low exchange rate (Riveras, 2007).

Production Costs

According to EMBRAPA, around 20% of total soybean production costs are for pesticides (Bickel and Dros, 2003). Fertilizers account for 30% or more of soybean cost of production (Goldsmith and Hirsch, 2006). The average transportation cost, when exporting soybeans, is 83% higher than in the United States, the largest soybean producer, and 94% higher than in Argentina, the third largest soybean producer (Valdes, 2006). Fuel is another expensive input in Brazil; from

2001 to 2007, the price of fuel increased 97%, while the price of diesel increased 213% (Diário de Cuiabá, 2007).

According to Roessing (2005) the soybean production cost for non-GM soybeans with two fungicide applications for Asian soybean rust was around R$1,303 per hectare in 2005 in central west and southeastern regions of Brazil. The FOB price was US$13.00 per 60kg bag (2.205 bushel) and the exchange rate was R$2.27 per U.S. dollar, equivalent to R$29.51 per bag. Since the producer price for farmers in Mato Grosso is 20% less due to marketing margins, the estimated producer price was approximately R$24.00 per bag. Roessing (2005) explains that for producers to break even, they would need to produce more than 54.31 bags (3.26 tons) per hectare in 2005, and as such, soybean farming was a very high risk endeavor. In the 2005/2006 harvest, the average soybean yield in Mato Grosso was 44 bags (2.64 tons) per hectare (L. M. Ribeiro, personal communication, June 13, 2007).

The president of FAMATO states that producers' income has accumulated a drop of 46%; in two consecutive soybean harvest periods, the loss accumulated was more than R$2.07 billion (Diário de Cuiabá, 2007). The average production cost in the 2007/2008 harvest period is already 25% higher in Mato Grosso: the producer who paid around R$950.00 to plant one hectare of soybean, will spend R$1.187, an increase of R$237.5 compared with the previous harvest period. This is a reflection of the 50% increase in production costs, on average. Therefore, the producer's debt and the high agricultural production cost given current price and exchange rates obstruct the expansion of cultivated area in Mato Grosso (A Gazeta, 2007).

Since from the individual producer's perspective, little can be done with regard to the soybean price and exchange rates, the alternative is to reduce costs or increase yield through better technology. Some options are available such as acquiring specific seeds recommended for the site, amendment corrections to the soil based on laboratory analysis of soil samples, avoiding unnecessary pesticide applications, minimizing mechanical damages to the product during harvesting, and perhaps, planting GM soybeans depending on weed infestation levels and seed royalties (Roessing, 2005). To reduce fuel costs, some farmers are producing their own biodiesel with oilseeds such as soybeans and sunflowers, as verified by the researcher in Tapurah (Figure 4-2).

Methods

Statistical Analyses

Comparisons of independent sample means were conducted to test for differences in soybean yield at a 95% level of confidence between financial groups and among municipal groups. The statistical analysis was conducted as follows: first, a pre-test (F-test) concerning two-population variances was carried out to test for equality of variances between groups (Ott and Longnecker, 2004). If the variances were equal, a two-tailed t-test for comparison of means from samples with equal variances was conducted; If the F-test revealed inequality between variances, a two-tailed t-test for unequal variances was conducted, both at a 95% level of confidence.

Net Revenue Analyses

In order to determine the profitability of soybean farms for one year on a smaller and a larger farm, total net revenue and net revenue per hectare is calculated by deducting soybean production costs from revenues for the 2005/2006 harvest. The soybean production costs for both farms were collected in June 2006 while conducting field work in the city of Sinop. The size of the larger farm is 14,000 hectares; 6,151 hectares are planted with soybeans and the farm is located 100 km from Sinop. The size of the smaller farm is 1,391 hectares; 650 hectares are planted with soybeans and it is located 22 km from Sinop.

In comparing net revenue analysis for both farms, the costs considered are: fertilizers, pesticides, seed, machinery operation, freight, leased land, salary, and machinery depreciation. Costs with salary and depreciation for the smaller farm are incorporated with machinery costs since it is leased. Financing aspects such as bank loans were not considered since they were not revealed by the landowners. Income tax (5.5%) is discounted from the revenue because it is common to register the property as a family enterprise rather than a corporation.

It is known that a part of the larger farm is leased and another part was bought in 1996; and that the smaller farm was bought in 2002. However, for the purpose of this analysis, the area planted to soybean is considered 40% leased, 60% owned. Land rental rates are paid in bags (60kg) of soybean. For land near Sinop, the rate is approximately five to six bags of soybean per hectare, depending how far the property is from the city, more precisely from the BR-163 (H. C. Ribeiro, personal communication, June 15, 2007). Hence, it is assumed that the smaller farm leases land at 6 bags per hectare since it is closer to the city, and the larger farm pays 5 bags per hectare since it is farther from the city.

Risk Analyses

Since soybean farmers are concerned with the uncertainty surrounding future values for exchange rates and world prices of soybean, a risk analysis was incorporated in the net revenue analyses using the @Risk© software application for Microsoft Excel. The @Risk routine performs a Monte Carlo simulation, which randomly generates values for uncertain variables according to a user-specified probability distribution and iteration limit. In the case of the present analysis, uncertain variables considered were the exchange rate and the world soybean price (Campbell and Brown, 2003).

For the purposes of this analysis, it is assumed that a triangular distribution would represent a reasonable description of the variable's uncertainty. A triangular distribution shows the range of possible values the variable's uncertainty could take and shows the probability of variables lying within any particular range of possible values. The function used is TRIGEN, which estimates the "minimum," "best guess" and "maximum" values for each variable. This function estimates the bottom and top percentile values and makes the distribution inclusive of the maximum and minimum values (Palisade Corporation, 2006).

The most likely values were based on the average exchange rate and soybean price in the study region during the year 2006. The maximum values and the minimum values for the exchange rate were based on the percentage that it varied over the last 3 years. The maximum and the minimum values for the soybean price were defined as the percentage that it varied in the year of 2006. Therefore, it is assumed that the exchange rate and the soybean price could vary 10% around the values of R$2.18 and US$ 9.60 respectively. The bottom percentile and the top percentile chosen for this analysis follow the procedure in Campbell and Brown (2003), where the extreme values for exchange rates occur at the 10% and 90% percentiles, and for share prices at the 5% and 95% percentiles.

The RiskTrigen functions are shown as:

- Exchange rate (Figure 4-1) = RiskTrigen(1.96,2.18,2.4,10,90);
- Soybean price (US$) = RiskTrigen(8.64,9.6,10.56,5,95).

The following three scenarios were modeled for both farms: (1) the impact of uncertainty in the exchange rate on net revenue per hectare while holding the world soybean price constant; (2) the impact of uncertainty in the exchange rate on the net revenue per hectare where the exchange rate affects pesticide and fertilizer costs, while holding the world soybean price constant; and (3) the impact of uncertainty in the soybean price on the net revenue per hectare while holding the exchange rate constant.

Results

Statistical Analyses

Comparisons of means with regard to soybean yield (measured in 60kg bags per hectare) in the 2005/2006 soybean harvest (Table 4-1) reveal that there are no significant differences between the financial groups. However, there is a significant difference ($P < 0.05$) between the farms in Sinop and Sorriso. Farmers in Sinop had an average soybean yield of 51.7 bags (3.1 tons) per hectare, while farmers in Sorriso had an average soybean yield of 56 bags (3.36 tons) per hectare.

Net Revenue Analyses

The analyses reveal that the larger farm had a net revenue of R$848,782 or R$138 per hectare. The production cost was R$930 per hectare of which 36.6% was for fertilizers, 20.9% for pesticides, 17.4% for machinery, 9.3% for salary and commission, 6.4% for soybean seed, 4.5% for leasing land, 3.8% for depreciation, and 1.0% for freight. The farmer's revenue was R$1,130 per hectare, since the yield was 54 bags (60 kg/bag) per hectare with an exchange rate of R$2.18 and soybean price of US$9.60 per bag, from which income tax (5.5%) was deducted and then production costs subtracted.

The smaller farm had a negative net revenue of R$-43,785 or R$-67 per hectare; a difference of R$205 compared with the larger farm's net revenue. The production cost was R$1,036 per hectare (R$106 greater than the larger farm) of which 35.7% was for pesticides, 34.1% for fertilizers, 14.8% for machinery, 6.1% for seed, 4.9% for leasing land, and 4.5% for freight. The farmer's revenue was R$1,025 per hectare, given the soybean yield of 49 bags per hectare with an exchange rate of R$2.18 and soybean price of US$ 9.60 per bag, from which income tax (5.5%) was deducted and then production costs subtracted.

Risk Analyses

Despite all the benefits and costs in producing soybean, there are some risks that farmers take when they enter this market. The soybean price is fixed in US dollars, and when converted to the real, it is subject to fluctuating exchange rates. The risk modeling incorporated in the net revenue analyses showed different results for the three different scenarios (Table 4-2).

In the first scenario (Figure 4-4), with the exchange rate varying 10% around R$2.18 and holding the soybean price at US$9.60 per bag, there is a 90% chance of the net revenue per hectare for the larger farm falling between R$9.73 and R$266. The minimum value for net revenue in this scenario is R$-45.64 and the maximum value is R$321.78. For the smaller farm, there is a 90% chance of the net revenue per hectare falling between R$-182.20 and R$47.28; the minimum value is R$-231.79 and the maximum value is R$97.23.

In the second scenario (Figure 4-5), with the exchange rate varying 10% around R$2.18 and with the exchange rate linked to the price of fertilizers and pesticides, while keeping the soybean price fixed at US$9.60 per bag, there is a 90% chance of the net revenue per hectare for the larger farm falling between R$76.75 and R$199.22. The minimum value for net revenue in this scenario is R$50.53 and the maximum value is R$226.63. For the smaller farm, there is a 90% chance of the net revenue per hectare falling between R$-91.76 and R$-42.92; the minimum value is R$-102.21 and the maximum value is R$-32.00.

In the third scenario (Figure 4-6), with the soybean price varying 10% around US$ 9.60 per bag while keeping the exchange rate at R$2.18, there is a 90% chance of the net revenue per hectare for the larger farm falling between R$35.25 and R$240.59; the minimum value is RS$-8.92 and the maximum value is RS$285.45. For the smaller farm, there is a 90% chance of the net revenue per hectare falling between R$-159.35 and R$24.52; the minimum value is R$-198.90 and the maximum value is R$64.69.

Discussion

Statistical Analyses

With regard to soybean yield, it was expected that pre-financed farms would have higher yields than not pre-financed farms due to the Amaggi Group's recommendations on best management practices and responsible pesticide use as mentioned in the previous chapters. However, this hypothesis was rejected because there was no statistically significant difference in soybean yields between the financial groups. This result may be explained by the fact that most farmers interviewed have adopted the same farming practices, such as the no-till system, crop rotation, and integrated pest management.

It was also hypothesized that farms in Sinop would have a lower average soybean yield than farms in Sorriso and Tapurah. In the recent past, the main economic activity in Sinop was timber production; agricultural production began after 1995 (Pichinin, no date). Since farm land in Sinop is relatively young, it was expected that it would have lower yields. The results showed that there is a significant difference ($P<0.05$) in soybean yield between Sinop and Sorriso, but not between Sinop and Tapurah.

The soybean yield in Sinop is lower than in Sorriso, confirming the initial hypothesis that areas in Sinop have lower yields. According to IBGE data (discussed in Chapter 1), the municipality of Sinop had a soybean productivity of 2.88 tons per hectare in the 2005/2006 soybean harvest, compared with 3.12 tons per hectare in Sorriso, and 3.06 tons per hectare in Tapurah. Although it is unknown if these differences are statistically different, they do lend support to the present study's findings.

Tapurah is also a relatively recently established municipality; land clearing began in the 1980s to make way for agriculture and cattle ranching. Nonetheless, this fact was not reflected in the results of this analysis, since there were no statistical differences between farms in Tapurah and Sorriso and between farms in Tapurah and Sinop. Mato Grosso's average soybean yield over the last few years has been approximately 50 bags (3 tons) per hectare (Folha do Estado, 2006). According to this analysis, the average soybean yield for the financial and municipal groups is above the state average.

Net Revenue Analyses

The results revealed that the smaller farm with 650 hectares of soybean area is losing money in the soybean business. Its net revenue per hectare was R$-67, while the larger farm with 6,150 hectares of soybean had a net revenue of R$138 per hectare; a difference of R$205 per hectare, of which 51.0% is due to soybean yield, and 48.2% is due to production cost (not including income tax).

According to Kaimowitz and Smith (2001), soybean in the Cerrado region is characterized by economies of scale. The large and modern processing and storage facilities, low cost access to transportation, infrastructure and financial, technological and marketing systems required to produce soybean competitively implies economies of scale at the sector level. Moreover, mechanized soybean production also exhibits economies of scale at the farm level.

According to Conte (2006), soybean producers in Mato Gosso benefit from economies of scale up to a threshold of 7,900 hectares. This helps explain why the larger soybean farm is more profitable than the smaller farm. Conte states that increasing returns to scale enables more efficient use of land, labor and machinery, and market advantages for the purchase of inputs and the sale of outputs. However, this study did not result in enough data to make any conclusions regarding economies of scale from these two farms.

There is a large literature that hypothesizes that small farms are more profitable (on a per hectare basis) than large farms, because of reduced labor costs (salaries/benefits) and labor supervision costs (Kuma, 1980). Although the above may be accurate when considering family farms that produce goods for home consumption and sell goods to local markets, the present analysis demonstrates that the size of the smaller commercial farm considered here is not more profitable due to reduced labor costs.

Another factor explaining the difference in net revenue per hectare between these two farms is that yield in areas that have been recently cleared is generally lower than in areas that have been cultivated for longer periods of time (A. L. M. Pissollo, personal communication, November 28, 2006). This is evident in the yield comparison between the smaller farm and the larger farm: 54 bags per hectare in the case of the larger farm and 49 bags per hectare in the smaller farm. In the previous year (2004/2005 soybean harvest), when the smaller farmer first planted soybeans in his farm, the difference in yield was even more exaggerated: in the larger farm where 4,950 hectares of soybean were planted, the yield was 53 bags per hectare; in the case of the smaller farm, 250 hectares of soybean yielded 36 bags per hectare.

Moreover, farmers entering the industry on land that was previously used for other purposes face other challenges as well. Initial investment costs required to farm soybeans are high. According to the smaller farm owner, he is indebted as a consequence of high investment costs such as land purchase, land clearing, soil preparation, and interest to pay on loans for land purchase, soil conditioning, and other farm operations; none of the above is included in this analysis. Furthermore, in the case of the smaller farm owner, he was new to the business which, although not quantified, undoubtedly imposed additional costs in the way of inefficiencies due to a lack of experience.

Although the smaller farmer is losing money, as the farm becomes more productive as the soil conditions improve and the farmer gains experience in the industry, it is expected to make positive net revenues. The break-even point for the smaller farm in this case would be approximately 52.5 bags per hectare with an exchange rate of R$2.18 and the soybean price of US$9.60 per bag.

Risk Analyses

Risk modeling was conducted to determine how the exchange rate and soybean price affect the viability of the farms in this case study and how the smaller farm is particularly susceptible to these fluctuations: a variation of 10% in the exchange rate without directly impacting pesticide and fertilizer costs (Scenario 1) showed that there was less than 5% risk of the larger farmer losing money with soybeans. For the smaller farmer that was already having a loss, there was more than 80% risk of losing money.

Variation of 10% in the exchange rate directly impacting soybean price and fertilizer and pesticide costs (Scenario 2) did not represent a risk of losing money for the larger farmer. For the smaller farmer, who was already losing money, it did not represent a chance of having positive net revenue but it did increase his losses. The frequency (y values on the triangular distribution) randomly chosen by @Risk for net revenues were higher for Scenario 2 than for Scenario 1, which led to a narrower dispersion of the net revenue values around the mean net revenue. This means that the chances of losing money and making profit were smaller for the farmers when variations in exchange rate directly impact fertilizer and pesticide costs.

Variation of 10% in the US dollar soybean price (Scenario 3) revealed a small risk of the larger farmer losing money, and more than an 85% risk of the smaller farmer losing money; the risks taken by both farmers are smaller in Scenario 1 and higher in Scenario 3. The smaller farm had a higher risk or higher probabilities of losing money than the larger farm in all scenarios.

Fluctuations in exchange rate and soybean price (US$) strongly influences the structure of the soybean industry. Small farmers have a smaller profit which renders them more susceptible to uncertainties in the exchange rate and soybean price. This helps explain why the industry is dominated by larger farms.

Conclusion

This chapter showed that there was no significant difference in soybean yield between the financial groups, since farmers, regardless of whether they were pre-financed by Amaggi Group or not, adopt the same agricultural practices such as the no tillage system. However, soybean farms in Sinop had lower yield than the farms located in Sorriso. This result lends support to the hypothesis that soybean yield in areas that were recently deforested is lower than in areas that have been cultivated for longer periods. The case study demonstrated that the smaller farmer is more susceptible to uncertainties in soybean price and the exchange rate. Moreover, the smaller farm was less profitable; this may be explained in part by the shorter length of time that the smaller farm was cultivated affecting soybean yield, and the farmer's lack of experience in soybean farming.

Table 4-1. Descriptive statistics and independent samples test for soybean yield in 2005/2006 harvest. Comparisons are between financial groups and among municipal groups. This table shows number of farms (N) in each group; minimum, maximum, mean, and standard deviation of values reported within each group; and t-test statistics for comparisons between groups.

	Comparisons	N	Min.	Max.	Mean	Std. Dev.		t-value	P
Soybean yield (60 kg bag per hectare)	Pre-financed	17	45	61	53.88	5.023		-0.862	0.395
	Not financed	20	45	63	55.23	4.456			
	1-Sinop	10	45	59	51.70	5.376	1-2	-2.474	0.020*
	2-Sorriso	20	48	63	56.05	4.084	2-3	0.790	0.437
	3-Tapurah	7	48	59.5	54.64	3.966	1-3	-1.298	0.238

* indicates t-value significant at P<0.05.

Table 4-2. Summary statistics for risk analyses, showing net soybean revenue per hectare for a larger farm (6150 ha) and a smaller farm (650 ha) in different scenarios: (1) exchange rate varying 10%, (2) exchange rate varying 10% and directly influencing pesticide and fertilizer costs, and (3) soybean price (US$) varying 10%.

	Min.	Max.	Mean	Std. Dev.	5%tile	95%tile
Scenario 1						
Larger farm	R$-45.64	R$321.78	R$138.01	R$76.49	R$9.73	R$266.00
Smaller farm	R$-231	R$97.23	R$-67.33	R$68.49	R$-182.20	R$47.28
Scenario 2						
Larger farm	R$50.53	R$226.63	R$138.01	R$36.57	R$76.75	R$199.22
Smaller farm	R$-102.21	R$-32.00	R$-67.33	R$14.58	R$-91.76	R$-42.92
Scenario 3						
Larger farm	R$-8.92	R$285.45	R$138.01	R$61.27	R$35.25	R$240.59
Smaller farm	R$-198.90	R$64.69	R$-67.33	R$54.87	R$-159.35	R$24.52

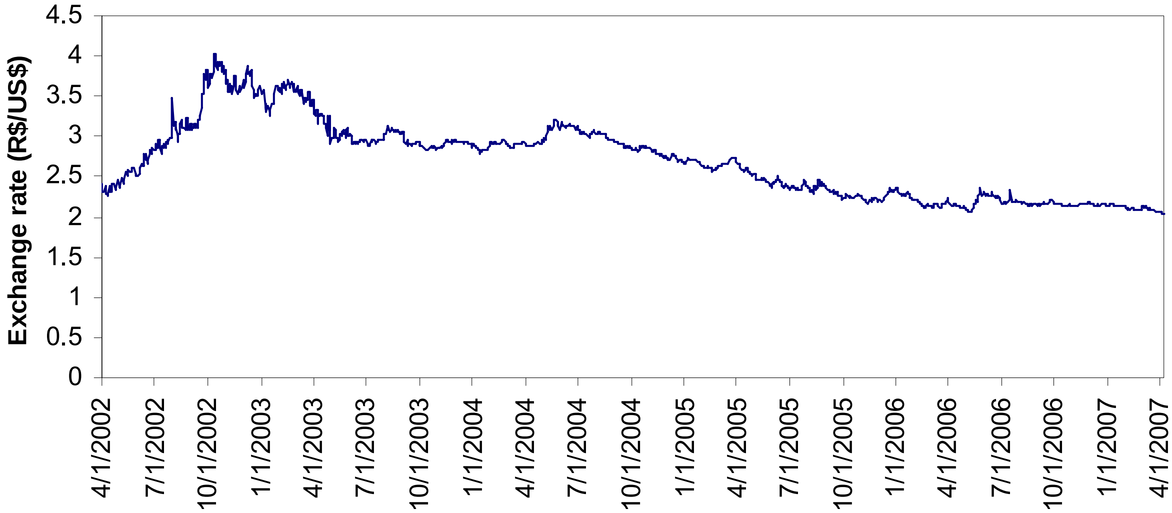
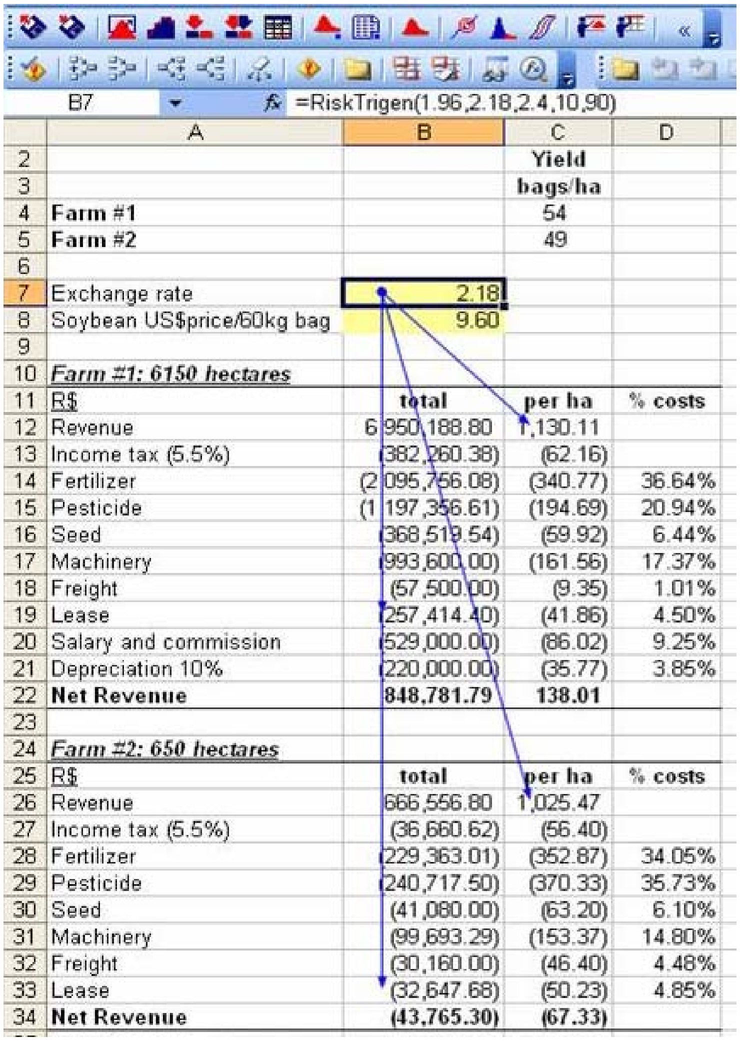


Figure 4-1. Trend line for the Brazilian real:US Dollar exchange rate from April 2002 to April 2007. [Source: FXHistory: historical currency exchange rates, 2007. OANDA corporation. Available from: http://www.oanda.com/convert/fxhistory (accessed May 2007).]

Figure 4-2. Biodiesel production with soybeans in a farm in Tapurah. Pictures taken by author June 23rd, 2006.



B7 =RiskTrigen(1.96,2.18,2.4,10,90)

	A	B	C	D
2			**Yield**	
3			**bags/ha**	
4	**Farm #1**		54	
5	**Farm #2**		49	
6				
7	Exchange rate	2.18		
8	Soybean US$price/60kg bag	9.60		
9				
10	***Farm #1: 6150 hectares***			
11	R$	**total**	**per ha**	**% costs**
12	Revenue	6,950,188.80	1,130.11	
13	Income tax (5.5%)	(382,260.38)	(62.16)	
14	Fertilizer	(2,095,756.08)	(340.77)	36.64%
15	Pesticide	(1,197,356.61)	(194.69)	20.94%
16	Seed	(368,519.54)	(59.92)	6.44%
17	Machinery	(993,600.00)	(161.56)	17.37%
18	Freight	(57,500.00)	(9.35)	1.01%
19	Lease	(257,414.40)	(41.86)	4.50%
20	Salary and commission	(529,000.00)	(86.02)	9.25%
21	Depreciation 10%	(220,000.00)	(35.77)	3.85%
22	**Net Revenue**	**848,781.79**	**138.01**	
23				
24	***Farm #2: 650 hectares***			
25	R$	**total**	**per ha**	**% costs**
26	Revenue	666,556.80	1,025.47	
27	Income tax (5.5%)	(36,660.62)	(56.40)	
28	Fertilizer	(229,363.01)	(352.87)	34.05%
29	Pesticide	(240,717.50)	(370.33)	35.73%
30	Seed	(41,080.00)	(63.20)	6.10%
31	Machinery	(99,693.29)	(153.37)	14.80%
32	Freight	(30,160.00)	(46.40)	4.48%
33	Lease	(32,647.68)	(50.23)	4.85%
34	**Net Revenue**	**(43,765.30)**	**(67.33)**	

Figure 4-3. Screen capture of the Microsoft Excel sheet showing the RiskTrigen formula for exchange rate and dependent variables in scenario 1.

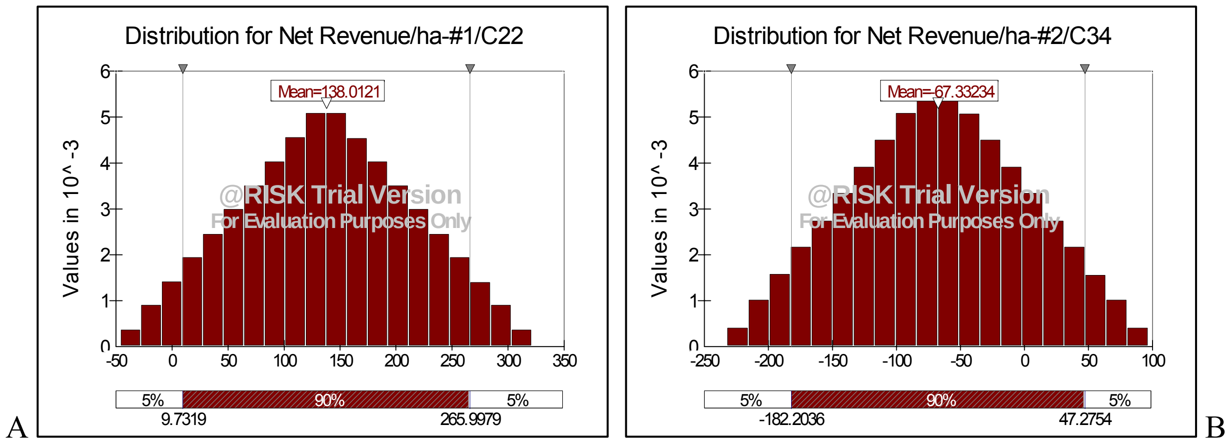


Figure 4-4. Triangular distribution for net soybean revenue in scenario 1: exchange rate varying 10%. A) Probability distribution for the larger farm. B) Probability distribution for the smaller farm.

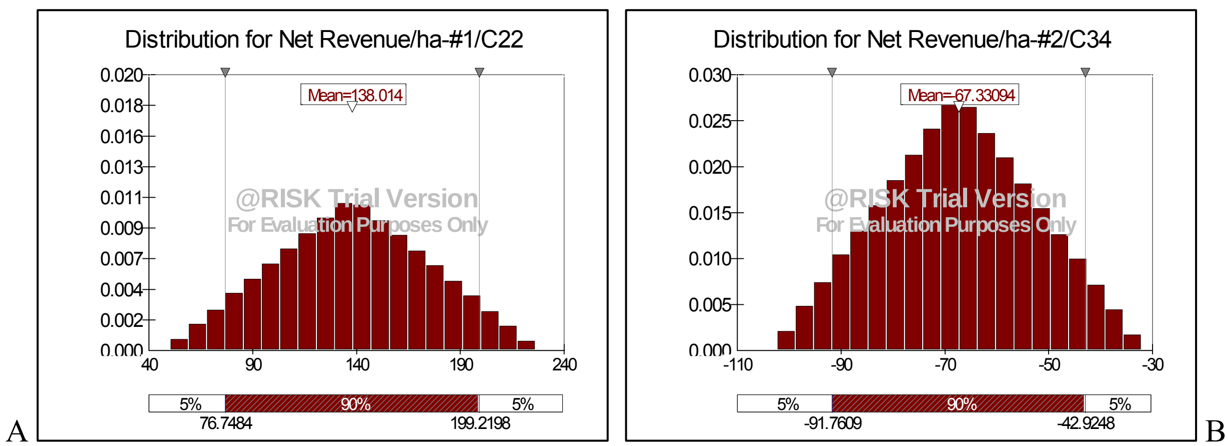
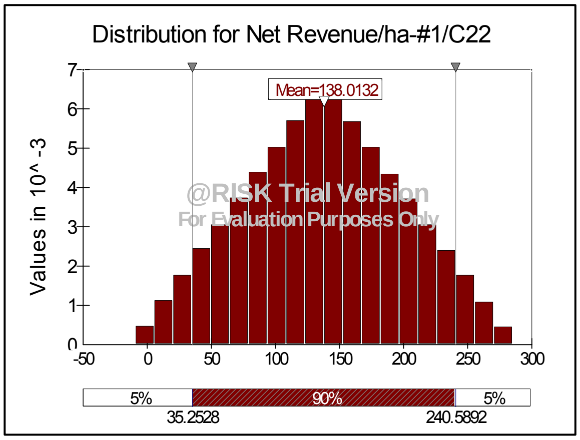
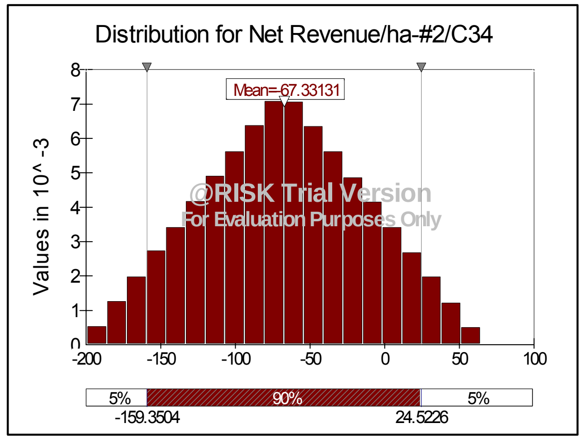


Figure 4-5. Triangular distribution for net soybean revenue in scenario 2: exchange rate varying 10% and directly influencing pesticide and fertilizer costs. A) Probability distribution for the larger farm. B) Probability distribution for the smaller farm.

A




B

Figure 4-6. Triangular distribution for net soybean revenue in scenario 3: soybean price (US$) varying 10%. A) Probability distribution for the larger farm. B) Probability distribution for the smaller farm.

CHAPTER 5
SUMMARY AND CONCLUSIONS

This study provided a comprehensive evaluation of the management practices adopted by soybean farmers in northern Mato Grosso, Brazil. The soybean farmers in Mato Grosso claim that they are adopting sustainable agricultural practices to meet the growing demand for food while minimizing their impact on the environment and natural ecosystems. They seem to be aware that intensive land use is unsustainable because of contamination of soil and water, and the importance of landscape conservation for the protection of biodiversity and recreation values.

Given that the Amaggi Group is well known for its environmental work with their pre-financed producers, the management practices adopted by soybean farmers who were pre-financed by Amaggi Group in the year of 2006 were compared to farmers who were not pre-financed by the Group. Moreover, based on the farms' location and the different biomes in northern Mato Grosso, differences in farming practices among the study farmers located in the municipalities of Sinop, Sorriso, and Tapurah were also evaluated.

Based on Amaggi Group's pre financing requirements such as having a registered Legal Reserve and not deforesting illegally, it was hypothesized that the pre-financed farmers are more likely to preserve forested area than farmers that were not. However, this hypothesis was rejected. This result may be explained by the fact that soybean buyers other than Amaggi Group may have similar pre-financing policies.

Comparisons among municipalities of farm forest cover, however, revealed that farms in Sorriso have a smaller percentage of natural forest on farm than farms in Sinop and Tapurah. This result lent support to the hypothesis that the producers located in Sorriso are less likely to preserve forested areas than those located in Sinop and Tapurah. Farms in Sorriso are situated in the Cerrado biome, while farms in Sinop are in the Amazon forest biome. According to the New

Forestry Code, 80% of the properties in the Amazon cannot be cleared, but only 35% of the properties must be conserved if located in the Cerrado. Although farms in Tapurah are also in the Cerrado biome, the municipality of Tapurah is not situated along the BR-163 highway, which could have contributed to a greater percentage of natural forest on farms compared to those located in Sorriso. It is generally accepted that in the Brazilian Amazon, deforestation occurs in proximity to roads (Pfaff et al., 2007).

With regard to soybean management practices, Amaggi Group recommends the adoption of the no-tillage system and that the area where no-tillage is implemented is increased. However, statistical analyses rejected the hypothesis that the pre-financed farmers have a greater percentage of soybean area in a no tillage system. It was also hypothesized that the pre-financed farmers have a greater cover crop diversity. Although this hypothesis was not tested statistically, survey data suggested that pre-financed farmers are interested in diversifying their production, since more pre-financed farmers reported planting different cover crops, besides millet and corn.

Among the municipalities, it was expected that farmers in Sorriso would use a higher percentage of their soybean area to plant corn as a cover crop, since the municipality of Sorriso is the fourth largest corn producer in Brazil. However, this hypothesis was rejected. One possible explanation is that high levels of precipitation in the region of Sorriso could have delayed the soybean harvest and consequently the planting of corn in the study year (2006).

Related to soybean planting practices, one important finding was that although GM soybeans are legally permitted to be planted in Mato Grosso, the percentages of area planted among the study farmers were low. Results indicate that farmers are not very interested in planting GM soybeans. This is likely due to the fact that in the case of pre-financed farmers, they were receiving better prices for non-GM soybean. Amaggi Group exports non-GM soybean through a private port thus reducing transportation costs. In addition, farmers did not perceive advantages in planting GM soybeans, since there is no difference in production costs between GM soybeans and non-GM soybeans (Fundação Mato Grosso, 2006).

Survey data did not show any major differences between financial groups with regard to pathogenic diseases; all farmers reported having Asian rust and some farmers reported having anthracnose and foliar blight disease in their soybean crops. Stinkbugs, whiteflies, and caterpillars were the insect pests most often reported in the farmers' soybean crop as well as nematodes. Among the municipalities, high levels of precipitation in the regions contributed to the appearance of Asian rust and foliar blight, however, farmers located in Sinop were the only ones who did not report foliar blight in their crop, maybe as a result of the fungicide used for seed treatment.

With regard to pesticide use, it was hypothesized that the pre-financed farmers use fewer types of pesticides than those who are not, due to the fact that the Amaggi Group recommends that pre-financed farms practice integrated pest management and as such, use inoculations in seed treatment, adopt biological control or insect growth regulators when possible, and vary the types of pesticides used to avoid insect and weed resistance. However, the survey data did not support this hypothesis since all farmers appeared to have adopted similar integrated pest management strategies.

The assumption that farms surrounded by natural forest or in close proximity to forest need to use less pesticides, led to the hypotheses that the producers located in Sinop use less fungicide and apply it fewer times than the producers located in Sorriso and Tapurah, and that farms with a higher percentage of forest cover use fewer types of pesticides. However, statistical analyses did not reveal differences in the number of times fungicides were applied among the municipal groups; and based on survey data, proximity to forest or amount of forest cover on farm did not appear to affect pesticide use patterns. However, farmers in Tapurah applied desiccants prior to soybean harvest in a greater percentage of soybean area than the farmers located in Sorriso. This result can be partially explained by the fact that the soybean plants were not dried enough to be harvested due to heavy rainfall and high levels of moisture in the region. Farm proximity to forested area likely was not a factor.

There were some interesting trends in pesticide use among the farmers. Farmers, regardless of financial status, location, or amount of forest cover, reported using fungicide for seed treatment. Farmers also rely on the herbicide glyphosate since no-tillage requires a pre-harvest herbicide application to dry the soybean plants. Farmers also use different types of post-emergence herbicides because most of their seeds are non-GM soybeans. The percentage of farmers adopting biological control methods is small due to its ineffectiveness against stinkbugs. Finally, an average of two fungicide applications per crop was observed among the farmers.

With regard to soybean yields, the hypothesis that pre-financed farmers have greater yields than those who are not was rejected. Although the Amaggi Group recommends that the pre-financed farmers adopt good farming practices, there were no differences in soybean yields between pre-financed and not pre-financed farmers. This result may be explained by the fact that most of the interviewed farmers have adopted the same farming practices, such as the no-till system, crop rotations, and integrated pest management.

Among the municipalities, the hypothesis that the producers located in Sinop have lower yields than those located in Sorriso and Tapurah was partially rejected. Soybean farms in Sinop had lower yield than the farms located in Sorriso but similar yield when compared to farms in Tapurah. Since farm land in Sinop is relatively younger than farm land in Sorriso, the result lends supports to the assertion that soybean yield in areas that were recently deforested is lower than in areas that have been cultivated for longer periods. The case study presented in Chapter 4 also supports this finding.

In a study of two case farms, the smaller farm was less profitable compared to the larger farm due to dissimilarities in soybean yield and production costs. The great difference in net revenue per hectare may be explained in part by economies of scale in soybean farming (although this was not tested in the study), the shorter length of time that the smaller farm was cultivated, and the farmer's lack of experience in soybean farming. Moreover, the case study also showed that the smaller farmer was more susceptible to risks and uncertainties in the exchange rate and soybean price. Variations in these variables increased the risk of the smaller farm increasing his losses.

This study provides feedback to the Amaggi Group about the farming practices adopted by their pre-financed farmers, not pre-financed farmers and whatever differences that may be the result of their specific location in northern Mato Grosso. This information is important in that it can serve to direct Amaggi Group's extension programs to enable farmers to overcome barriers to the adoption of good farming practices and protect environmental values. In addition, the analytical framework presented here can be applied to other agricultural regions, showing whether or not adoption of similar management practices can be sustainable, produce less environmental impact, and be economically viable.

This study identifies a number of areas for further research. In the case of smaller farms and given the current soybean price and the exchange rate, benefit-cost analysis of farm diversification, biodiesel production and conservation tillage, for example, could be particularly fruitful with environmental and energy concerns. Increasing the productivity of soybean farming is also critical. New varieties of soybeans that are better suited to the physical and biological conditions of the region can increase supply from the existing agricultural land-base. How producer cooperatives can improve farm-gate prices is also an interesting area to be pursued. These innovations may have a significant impact on reducing deforestation and the expansion of soybean production toward the Amazon forest.

APPENDIX
SEMI-STRUCTURED INTERVIEW

Tópico 01: Sobre a fazenda (últimos 2 anos, ano atual, estimativa para o próximo ano)

Fazenda: ( )própria ( )arrendada Ano de compra:___________	Situação em que se encontrava: ( )pastagem degradada ( )cultivo de soja ( )mata fechada ( )juquira ( )esterada ( )semi-aberta ( )outro:______
Distância da cidade(km): _____________	Último ano de desmate:______________ Área (ha): ________________________

Área total da propriedade (ha):	Planta safrinha? ( )não ( )sim
Área de soja plantada: Safra 2003/2004 (ha): saca/ha: Safra 2004/2205 (ha): saca/ha: Safra 2005/2206 (ha): saca/ha: Safra 2006/2007 (ha): saca/ha:	Safrinha: ( )milho ( )milheto ( )sorgo ( )outro:___ Safra 2003/2004 (ha): Safra 2004/2205 (ha): Safra 2005/2206 (ha): Safra 2006/2007 (ha):
Planta outro tipo de cultura? ( )não ( )sim Outra cultura: ( )feijão ( )arroz ( )algodão ( )outro:____ Safra 2003/2004 (ha): Safra 2004/2205 (ha): Safra 2005/2206 (ha): Safra 2006/2007 (ha):	Possui área de pastagem? ( )não ( )sim Área de pastagem (ha): Cabeça de gado: Ano 2004: total: /ha: Ano 2005: total: /ha: Ano 2006: total: /ha: Ano 2007: total: /ha:
GMO: ( )não ( )sim, safra:___________ ha:__________	Presença de árvore no pasto: ( )nativa ( )reflorestada ( )n.a.

Tópico 02: Boas Práticas Agrícolas

O que o senhor entende por "Boas Práticas Agrícolas"? ( )aumento de custo ( )redução nos custos ( )preservação do meio ambiente ( )conservação do solo ( )aumento no rendimento ( )aumento na produtividade ( )outro:_____________________	Boas Práticas agrícolas adotadas e desde quando: ( )plantio direto, ano:_____ ( )rotação de cultura, ano:_____ ( )controle biológico, ano: _____ ( )outro:__________________________________
Por que essas práticas foram adotadas? ( )exigência do financiador ( )conscientização própria ( )exigência dos clientes ( ) exigência do fornecedor ( )outro:_________________	Essas práticas têm mostrado algum resultado? ( )sim ( )não
Que tipo de resultado essas práticas tem mostrado? ( )resultados econômicos ( )resultados na produção ( )no meio ambiente ( )na conservação do solo ( )melhor visto no mercado ( )captação de mais clientes ( )outros:_________________	Que outros resultados gostaria de ter: ( )econômicos ( )resultados na produção ( )no meio ambiente ( )na conservação do solo ( ) no mercado ( )captação de mais clientes ( )outros:________________________________

Plantio Direto	Controle Biológico
Desde quando: Hectares de soja plantados: Época de plantio: Vantagens: Desvantagens: Resultado na produção de soja:	Desde quando: Hectares de soja plantados: Época de plantio: Vantagens: Desvantagens: Resultado na produção de soja:

Resultados econômicos: └ nos custos: └ na rentabilidade:	Resultados econômicos: └ nos custos: └ na rentabilidade:

Rotação de soja com pasto	
Desde quando: Freqüência: Hectares de pasto: Hectares de soja: Quantas cabeças de gado/ha.: Época de plantio: Época de criação de gado:	Vantagens: Desvantagens: Resultados na produção (kg/carne/há ou @/há): Resultados econômicos: └ nos custos: └ na rentabilidade:

Tópico 03: Reserva Legal e Área de Preservação Permanente

Possui área de Reserva Legal? ( )não ( )sim Área (ha): ___________ ou % _______________ Se sim, RL é: ( ) nativa ( ) reflorestada Área averbada ( )sim ( )não	Possui área reflorestada ( )não ( )sim Área:_____________ espécie:________________ Se não, pretende reflorestar? ( )não ( )sim Se sim, que espécie de árvore pretende plantar?
Possui área de preservação Permanente? ( )não ( )sim. Se sim, qual é a largura? ____________ São áreas ( )nativa ( )reflorestada: espécie:___________	Se não, pretende reflorestar? ( )não ( )sim Se sim, que espécie de árvore pretende plantar?

Tópico 04: Conservação do Solo

Há áreas mais propícias a erosão do solo? ( )não ( )sim	Na sua propriedade tem erosão de solo? ( )não ( )sim. Se sim, quantos ha.?________________
Tem conhecimento por que a erosão ocorre? ( )não ( )sim, por que?	Como o senhor controla a erosão do solo? ( )boas práticas agrícolas ( )não controla

Tópico 05: Pestes Agrícolas

Que tipo de doenças agrícolas tem na sua propriedade? ( )erva daninha: ( )patogênicos: ( )ferrugem ( )outros:___________ ( )nematóide: ( )cisto ( )galha ( )insetos: ( )lagarta ( )percevejo ( )mosca branca	Classifique de 1 a 6 p/ a mais severa a menos severa: ( )erva daninha ( )patogênicos/ferrugem ( )nematóide ( )mosca branca ( )percevejo ( )lagarta

Etapas	**Agro-químicos**	**Combater:**
Dessecação plantio	( )Roundup original ( )Rondoup Transorb ( )Roundup W.G. ( )24D ( )Glifosato ( )Paraquat ( )outros:________________	
Tratamento semente	Inceticida: ( )Standak ( )Fungicida: ( )Vitavax Thiran Inoculante: ( )não ( )sim:____________	
Pós emergente	Folha larga: ( )Pivot ( )Classic ( )Cobra ( )outro: ____________ Folha estreita: ( )Verdict ( )outro:______________	
Inseticida	Biológico: ( )não ( )Baclovirus ( )Larvin ( )outro:	

	Fisiológico: ( )Nomolt ( )outro:______________ Veneno: ( )Metamidofós ( )Talcord ( )Endosulfan ( )Folidol ( )outro:___________________	
Fungicidas	( )Ópera ( )Folicur ( )Cercobin ( )Priori ( )Impact ( )Priori xtra ( )Impact Duo ( )Stratego ( )Sphere ( )outro:___________________	
Dessecação colheita	( )Round-up ( )24D ( )Gramoxone ( )Reglone ( )Smash	
Quantos hectares plantados com culturas resistentes a nematóides?		
Qual é o destino das embalagens vazias? ( )Tríplice lavagem ( )reciclagem ( )devolução das embalagens ( )jogado no lixo ( )aterro privado ( )outro:________________		

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BIOGRAPHICAL SKETCH

Carolina Maggi Ribeiro was born in São Miguel do Iguaçu, Paraná state, Brazil and was raised in Rondonópolis, Mato Grosso where she graduated from high school in 1998. She earned a bachelor's degree in business administration from The Centro Universitário Franciscano do Paraná in Curitiba in December 2004. During these studies, she also studied accounting for three years and participated in an extracurricular course in management consulting. In her last year as an undergrad student she worked in the Finance Department of Fertipar Fertilizers do Paraná. Before attending the University of Florida, she undertook some course work in environmental issues.