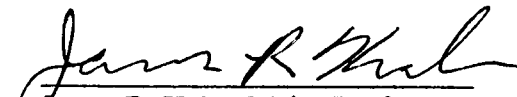
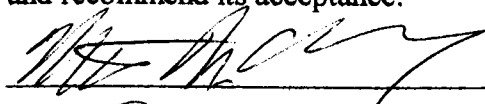


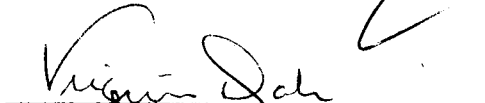
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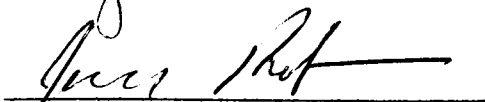
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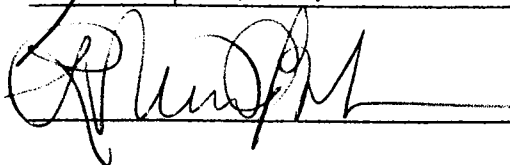

James R. Kahn, Major Professor

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Accepted for the Council:


Associate Vice Chancellor and
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**ECONOMIC ANALYSIS OF SUSTAINABLE AGRICULTURE IN
THE TROPICAL RAIN FOREST OF BRAZIL:**

Agricultural Techniques in Rondônia

A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Jill L. Caviglia
May 1998

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ABSTRACT

This paper examines the behavior of small scale farmers in Rondônia, Brazil and the agricultural methods they choose. In the Amazonia state of Rondônia the major source of deforestation is the use of slash and burn agriculture by small scale farmers. It is well documented that the adoption of a more sustainable method of agriculture can reduce deforestation drastically if utilized by a majority of the farmers (Myers 1994, Anderson 1993, Anderson 1990). Sustainable agriculture was introduced to the area about 10 years ago, but few farmers have adopted it. The determination of the factors which may increase the rate of adoption could help to identify which policies best address this issue.

This study examines the adoption of sustainable agriculture by farmers in Ouro Preto do Oeste, Rondônia. The theoretical framework is based on a family utility model. According to this model, the family chooses between sustainable and slash and burn agriculture based on which method of farming gives them the greatest utility. Empirical data and a discrete choice Heckman model are used to estimate the probability of adopting sustainable agriculture and the intensity of adoption (once the adoption decision is made).

The analysis concludes that the adoption of sustainable agriculture is influenced greatly by farmer organizations and by the knowledge that sustainable agriculture is an alternative to slash and burn agriculture. Imperfect information appears to be the main deterrent to the adoption of sustainable agriculture. Local farm organizations provide both information about and experience with sustainable agriculture in a short period of time and therefore influence the adoption rate. In addition, farmer characteristics such as

education level are found to play a role in the adoption decision. These results suggest that policies, which provide information about sustainable agriculture and support local farm organizations, can greatly increase the diffusion of sustainable agriculture in Ouro Preto do Oeste, Rondônia and similar settlements in the Amazon.

PREFACE

This study was developed from an interest in environmental economics, international issues, and tropical deforestation. A collaboration between the University of Tennessee and the University of Amazonas, Manaus has not only made the collection of empirical data possible, but has also provided the opportunity to better understand the deforestation issues which impact Brazil and the local farmers who live in the Amazon. The time spent collecting that data for this research and living in the Amazon was an unforgettable experience for the author. The hospitality of the faculty members at the University of Amazonas and the farmers in Ouro Preto do Oeste was remarkable and has helped to make this research successful. The study which is described in the pages that follows has allowed the author to explore the many economic issues which impact tropical deforestation.

Chapter 1 is the introduction and contains the motivation and methods which are used in the study.

Chapter 2 "Deforestation in the Brazilian Amazon" is a review of the Brazilian history which has led to the development of the Amazon and the beginning of a majority of the deforestation in the region.

Chapter 3 "Sustainable Agriculture" provides a general definition of sustainable agriculture. This type of agriculture differs among tropical regions. The chapter then continues with a specific definition of the type of sustainable agriculture to be used in this study in Ouro Preto do Oeste, Rondônia.

Chapter 4 “Addressing Market Failure Which Has Led to Tropical Deforestation with Discrete Choice Models” provides the economic framework and theory which supports the reduction of the deforestation rate in Brazil. The chapter continues with a literature review of economic studies on the adoption of new technologies in developing countries and relates this approach to technology adoption to the adoption of sustainable agriculture in the state of Rondônia, Brazil.

Chapter 5 “The Survey” explains the survey design, the data collection process and presents some of the important data in tables.

Chapter 6 “The Economic Model” is the data analysis section in which regressions are estimated and interpreted according to economic theory. This chapter first presents the addition that this dissertation can make to the economic literature, continues by presenting the economic theory to be used in the modeling, presents the regression results, and makes policy recommendations which may reduce the deforestation rate based on these results.

Chapter 7 summarizes this study, makes policy implications as to the best ways that the adoption of sustainable agriculture may be increased, and makes suggestions for further research.

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CHAPTER 1

INTRODUCTION

1.1 Tropical Deforestation

Tropical forests, which cover around 7.5 million km² of the humid tropics, are being destroyed at a progressively increasing rate (Myers 1994). Tropical deforestation is considered to be a major environmental crisis because of its international impacts on biodiversity loss and climate and because of its local impacts such as an increase in flood occurrence, the depletion of forest resources, and soil erosion (Baer 1995, Myers 1994, Anderson 1992, Mahar 1989). Tropical deforestation is not a new phenomenon since it has been occurring since the beginning of human activity, but it is the acceleration in the rate of deforestation which has captured the concern of the world (Kahn 1995). Policies are urgently needed to slow deforestation, discourage unsustainable uses of the forest, and to make sustainable uses profitable for the people who live in tropical forests (Fearnside 1990).

The determinants of participation in more sustainable uses of the forest are necessary to investigate if policies which promote alternative, more sustainable, uses of the forest are to be successful. One unsustainable use of tropical forests is slash-and-burn agriculture. Slash-and-burn agriculture is not the main source of deforestation in all parts

of the world, but it is concentrated largely in the Amazon and Central America (Myers 1994). One way of reducing the rate of deforestation in tropical forests which are effected by slash-and-burn agriculture would be to decrease the number of farmers who practice this type of agriculture.

The factors that influence the use and adoption of an alternative to slash-and-burn agriculture are investigated using an empirical model of adoption. This model investigates the probability that small scale farmers in the state of Rondônia, Brazil will adopt sustainable agriculture, and the extent of adoption once the adoption decision is made. The diffusion rate of this new farming technology is investigated according to the Mansfield model of technology adoption in which the adoption rate of new technologies occurs according to a logistic shaped curve. What is interesting in Rondônia, and also in many other developing countries, is that adoption has not occurred at a rapid rate even though the more sustainable methods of farming require less labor and can potentially increase profits (Holden 1993, Kebede *et al.* 1990, Sands 1986, Opare 1977). Policy implications are therefore made to address the low adoption rate of sustainable agriculture¹ in the settlement of Ouro Preto do Oeste, Rondônia.

¹ Sustainable agriculture refers to agriculture which maintains the environmental and ecological integrity of the soil, water, and land systems in the area while providing sufficient income to farmers through the inter-cropping of perennial and annual crops. The use of sustainable agriculture can reduce deforestation because unlike slash-and-burn agriculture it does not require the burning of forests in order to plant crops annually. Sustainable agriculture has been supported locally as well as globally because not only is the rate at which the forest is destroyed reduced when these methods of farming are adopted, but also the income and utility of the farmers who adopt this method of agriculture are increased.

1.2 Research Focus

This research will focus on the reduction of tropical deforestation through economic and welfare incentives which support the adoption of sustainable agriculture in the city of Ouro Preto do Oeste, Rondônia. Deforestation in this region of the Brazilian Amazon is mainly the result of small scale farming. Deforestation rates can, therefore, be reduced by addressing the source of deforestation, the agricultural methods. Many of the farmers who live in the southern regions of the Amazon, including Rondônia, were enticed by the government programs to move to the area for free land and an offer of a better life. Responding to these economic incentives, immigrants from the south and northwest of the country migrated to the Amazon and brought with them agricultural methods traditional to the more temperate climates from which they came. Since farmers have migrated to the Amazon, these agricultural methods have been found to be inappropriate methods of farming in tropical soils since they strip the soils of their nutrients, rendering the land useless for agricultural purposes (Mahar and Schneider 1994, Frohn *et al.* 1990, Moran 1990).

Just as economic incentives have helped create a problem, economic incentives might be used to help remedy the current situation. Unfortunately, little is known about why sustainable agriculture is adopted by some farmers and not by others in the tropical forests of Rondônia. An analysis of the factors which increase the rate of adoption is therefore necessary in order to make the appropriate policy action suggestions.

Farmers decisions and methods of agriculture are investigated from data which

was collected in the city of Ouro Preto do Oeste, Rondônia located in the southeastern border of the Brazilian Amazon. This area of the Amazon is an excellent location for this research for three reasons. First, Ouro Preto do Oeste is located in the state of Rondônia which is currently experiencing the highest rate of deforestation due to small scale farming in the country. Secondly, Ouro Preto do Oeste is a relatively developed city in the Amazon making the study of the area and the settlers possible. And thirdly, the city has recently established programs which support and encourage the use of sustainable agriculture. These programs include the dissemination of information about sustainable agriculture through workshops and the distribution of the seedlings which are used in inter-cropping.

It is expected that as more farmers adopt sustainable agriculture in Ouro Preto do Oeste that the deforestation rate will be reduced. The diffusion rate of this technology is, however, very low. The reasons why more farmers have not adopted this superior method of farming in terms of profit and sustainability are investigated. Implications are made as to the best way that the adoption of the more sustainable method of farming can be increased. The policy implications are, however, preliminary since this is the first step in a larger research objective. This research will be continued throughout the years as this relatively newly settled area of the Amazon is established and develops. Changes in agricultural techniques and deforestation rates will be recorded and analyzed as this research is extended.

The data which are used in this analysis were collected according to a time constraint and on a relatively small budget and are therefore limited. At the same time,

data remain sufficient for the analysis. In particular, the data allow the examination of the role that extension programs and farmer characterizations play in the adoption of sustainable agriculture in Ouro Preto do Oeste. The extension of the data from this pilot study, to broader research with fewer constraints, can lead to research results with broader policy implications..

1.3 The Role of Sustainable Agriculture in the Tropics

The alternative to slash-and-burn discussed in this chapter is known as sustainable agriculture. The terminology which is used in reference to sustainable agriculture is clarified here. The term "inter-cropping" refers only to the alley cropping of perennials together, or with annual crops. "Sustainable agriculture" refers to this inter-cropping practiced alone or in combination with other income sources which do not rely on the destruction of the rain forest, such as bee keeping and fish raising. Therefore, the term sustainable agriculture is used to reference both the use of inter-cropping and the income sources which do not rely on the destruction of the rain forest. A more detailed discussion of sustainable agriculture and inter-cropping can be found in Chapter 3.

Although sustainable agriculture can offer a solution to the increasing trends of deforestation, there is risk involved with adopting sustainable agriculture since developed markets have not been established to sell many of the native products of the forest which are harvested in intercropping plots. There is also risk involved because of the uncertainty as to how much income can be earned. Even though these deterrents exist, with the help of international grants, some farmers choose to try this new method of farming in

Rondônia.

It is important to point out that sustainable agriculture is not proposed here as a solution to the deforestation problem in Rondônia. Instead it is proposed as an alternative to slash-and-burn agriculture which can help to reduce the rate of deforestation by reducing the need for farmers to burn primary forest to plant crops. It is assumed that as more land is converted to sustainable agriculture, relative to slash-and-burn agriculture, that less land will be cut down and burned to support farm crops.

1.4 The Economic Model

An economic model, which illustrates the dichotomous choices between sustainable and slash-and-burn agriculture and whether to join APA or not, will be used to observe the behavior patterns of farmers under different circumstances. A Heckman model of estimation is used to measure not only the probability of adoption of sustainable agriculture but also the intensity of use of sustainable agriculture once it is adopted.

Tropical deforestation has been addressed at length in the economic literature in terms of both the micro and macro levels. However, there is little research which has addressed deforestation in terms of its reduction through the adoption of a new technology. By combining the technology framework first introduced by Griliches (1957) with more advanced regression techniques to help solve market failure at the local level, this research provides a unique analysis to address deforestation reduction.

The following chapters in this study present the deforestation problem and the history of deforestation in Brazil and Rondônia state, explain the role that economics can

play in the reduction of deforestation, analyze the situation in Ouro Preto do Oeste through economic modeling, and conclude with policy implications.

CHAPTER 2

DEFORESTATION IN THE BRAZILIAN AMAZON

2.1 The Deforestation Dilemma in Brazil

Deforestation in Brazil presents a crisis of many dimensions involving international, national, and local concerns. At the international level, there is great concern about the total amount of depleted forest (Anderson 1993, 1990). At the national level the government is concerned with economic stability and social problems. And, at the local level there are concerns about the impact of deforestation on the region's land, rivers, and soils.

The international, national, and local concerns provide different incentives in regards to the amount of deforestation which is desirable. Deforestation, however, impacts the local people, in particular local farm families, the greatest because in many cases it is their land that is destroyed in the process. The tropical forests of Brazil have been settled by many small farm families and ranchers. The impacts of deforestation are, therefore, felt by these families who depend upon the land for their livelihood.

A brief discussion of the international, national, and local issue follows. Although it is international concerns that have brought this crisis to the attention of world, it is local impacts which are of greatest concern. The small scale farmers who live in the

Amazon have played an important role in deforestation and can also play an important role in preservation. It is therefore vital that the situation is addressed at this level.

2.1.1 International Concerns

The main reason for the worldwide attention on tropical deforestation in Brazil is related to its global impact and the large size of the forest. The Brazilian tropical rain forest is the largest contiguous tropical rain forest in the world (Anderson 1993, 1990). It is believed that large scale tropical deforestation will contribute greatly to the greenhouse effect and a considerable loss of biodiversity. The Brazilian Amazon alone stores about 60 billion tons of carbon, equivalent to 8 percent of the total carbon dioxide present in the atmosphere (Baer 1995). Burning the forest releases the carbon into the atmosphere, increasing the greenhouse effect. The magnitude of carbon-dioxide increase, resulting from deforestation in the Amazon, is significant to cumulative global additions (Baer 1995, Pearce and Brown 1994, Schneider 1992a, Goldenberg 1990, Cockburn 1988). Carbon emissions from the Brazilian Amazon alone represented approximately 2 percent of total world carbon emissions in 1990 (Goldenberg 1992).

Another international concern is that large scale removal may bring about a reduction of biodiversity (Baer 1995, Pearce and Brown 1994, National Academy Press 1992, Anderson 1990, Mahar 1989). Tropical forests are the most species rich ecosystems in the world, and the Brazilian rain forest is no exception (Hartshorn 1992). The number of species world wide is not known, but it is believed that tropical forests world wide contain about one half and possibly up to 90 percent (Miller *et al.* 1993) of the

world's estimated 5 to 10 million species in just 7 percent of the earth's surface (Pearce and Brown 1994, Southgate 1994, Mahar 1989). For example, the Amazon rainforests support 30,000 species of plant life whereas South American temperate forests support 10,000 species of plant. In contrast to these numbers, North American forests normally contain only 10 to 15 species of plant (Mahar 1989). The quantity and variety of fish, bird, and insect life are also unmatched. In the Brazilian rain forest there are over 2,000 known fish species compared to 250 species in the Mississippi River system and the 200 species found in all of Europe (Mahar 1989). The destruction of the rain forest affects populations of these species. It is feared that if the Amazon rain forest is destroyed that many of these species will become extinct. Many of the species which have been lost have not been identified. Their inherent nature and aesthetic value along with potential agricultural and pharmaceutical values vanish with them (National Academy Press 1992).

Biodiversity within the tropical rain forest and many similar ecosystems is essential to the balance and survival among organisms. Each species in an ecological system is likely to have a worth to the community far beyond its intrinsic value (Tietenburg 1988). Species contribute balance and stability to their ecological communities by providing food sources and nutrients, or by holding the population of another species in check and thus, increasing the likelihood of survival for each species in the community. Pollination systems, seed dissemination, and plant vegetation usually involve highly co-evolved species in tropical rain forests (Hartshorn 1992). For example, together several species of the Heliconia flower provide hummingbirds with year-round nectar. Responding to the supply of nectar, hummingbirds that live in tropical forests raise

their young during the period when there is maximum nectar production (Hartshorn 1992). This interdependence among species makes each individual species more resilient and productive when the ecosystem is intact, but more vulnerable when one part of the system is adversely affected.

2.1.2 National Concerns

At the national level, the Brazilian government is concerned with an increasing trend of poverty and over-population in the southern and north eastern regions of the country, especially in the populous southern urban areas. A colonization program of the Amazon Basin initiated in the late 1960's was intended to ameliorate the situation but instead resulted in an increase in deforestation, many unsuccessful farm establishments, and the beginning of slash-and-burn agriculture in the Amazon region by small scale farmers. The colonization program known as "Operation Amazonia" is discussed in detail in the following sections.

2.1.3 Local Concerns

At the local level, depletion of forest resources, soil erosion, increasing recurrence of floods, and the loss of biodiversity have occurred. Up to now, no human activity has affected more land in Amazonia or been more critical to human well-being than slash-and-burn agriculture (Myers 1994, Uhl *et al.* 1989). The essential characteristic of such cultivation process is that an area of forest is cut and burned to grow subsistence crops (Uhl *et al.* 1989). The land is typically cultivated until it can no longer support the harvest, overturned to pasture, and later abandoned. In addition, the economic failure of

many slash-and-burn farmers has lead first to rapid growth and then to impoverishment of rain forest cities as failed farmers migrate to rain forest urban areas such as Manaus, Belem, and Porto Velho.

2.2 Reforestation in Tropical Soils

Tropical deforestation is a critical problem because regeneration of the forest is often difficult, and at times, impossible. Unlike non-tropical forests, the soil in tropical forests is commonly devoid of many nutrients. Most nutrients are stored in the very thin layer of topsoil and the biomass of living organisms. The cycling of nutrients takes place through the litter fall and root uptake in tropical forests (Anderson 1990, Serrão and Toldeo 1990). In addition, microorganisms in the litter help make nutrients available to trees. Removal of the trees depletes essential nutrients from the ecosystem while escalating erosion, soil compaction, and weed infestation and disturbs the equilibrium created between nutrient storage and forest cover (Anderson 1993). Agriculture tends to rapidly exhaust the natural fertility by interrupting the litter fall and root uptake cycle. Eventually, five to ten years after cutting down the forest, the soil becomes void of most fertility and is abandoned.

Reforestation is difficult and costly. The long-term recovery after deforestation of tropical forests is what makes tropical deforestation so critical. Natural vegetation can recover after deforestation in some circumstances, but the loss of biodiversity of the primary forest often cannot be reversed (Uhl *et al.* 1989). Over intensive use of deforested sites in tropical rain forests can lead to permanent degradation of regional

ecosystems (Anderson 1990, Serrão and Toledo 1990, Uhl *et al.* 1988).

An example of the reforestation problem with tropical forests can be found in eastern Amazonia in the state of Pará. An area of 35,000 km was abandoned after a short-lived agricultural settlement. This area was monitored for regeneration, and after fifty years there is still little vegetation beyond scrub and brush growth (Myers 1994). Areas similar to this site that still have scant forest regrowth can be found in Columbia (Battjees 1988), Ecuador (Gentry 1989), and Peru (Dourojeanni 1988). There have also been cases where reforestation in poor tropical soils occurred. Buschbacher *et al.* (1988) found that some agricultural pastures in Pará, Brazil were able to recover 25 percent of the biomass of mature rainforest within eight years. These pastures were not used by farmers for long periods of time. Instead, the pastures were immediately abandoned after burning because of poor seed germination or for other management considerations. As the number of years that the land was used for agricultural purposes increased, Buschbacher *et al.* found that the degree of regeneration was reduced considerably. Nepstad *et al.* (1990) conclude in their study on tropical forest regeneration, that it may take centuries for forest regrowth to take place on abandoned pastures that have histories of heavy use.

2.3 Deforestation in the Brazilian Tropical Rain Forest

Brazil contains over one half of South and Central America's tropical forests (well over one quarter of the rain forests world wide) and deforestation is increasing at an alarming rate. In 1989 it was estimated that 30,000 km² were deforested in Brazil (1.4 percent of the total tropical forest) compared to 23,000 km² in 1979 (Myers 1994). The

total deforestation estimated to have occurred up until 1989 is 660,000 km². In comparison, Indonesia had the second highest level of deforestation for 1989 at 12,000 km² (Table 2.1). The rate of deforestation in Brazil is below the world wide average of 1.4 percent for that year, and the reason the percentage of forest burned is this low in Brazil is due to the fact that the country contains the world's largest expanse of intact forest in the world (Anderson 1993). When comparing different rates of deforestation, it is important to note that the sources of tropical deforestation differ among regions of the world (Table 2.2).

2.4 The Extent of Deforestation in the Brazilian States

On a percentage basis, deforestation in Brazil has been the highest in the states of Rondônia and Mato Grosso, followed by Maranhão, Acre, and northern Goiás. The northern states of Roraima and Amapá as well as the northern portions of Pará and Amazonas, have, so far, experienced little deforestation within their borders (Table 2.3).

Between 1988 and 1993 deforestation in the state of Rondônia, the state with the highest rate of deforestation, has increased by 10,050 km² to 68,050 km² or to 28 percent of the total state land area (Pedlowski *et al.* forthcoming). The total deforestation, with respect to the land area of the state, increased by 4.3% in 5 years.

Deforestation in the Amazon core is still limited. Most of the clearing has been concentrated largely in the Amazon periphery, the east-southeast-south-southwest perimeter. There exists a large area of the Amazon which is still in its original state, suggesting that policies which advance the conservation of the rain forest should

Table 2.1

Deforestation Statistics Tropical Moist Forests: 1989					
Country	Area (km²)	Original Extent of Forest Cover (km²)	Extent of Forest Cover (km²) 1989	Amount of Deforestation in 1989	
				(km²)	(%)
Brazil	8,511,960	2,860,000	2,200,000	30,000	1.4
Columbia	1,138,891	700,000	278,500	6,500	2.3
India	3,287,000	160,000	165,000	4,300	2.6
Indonesia	1,919,300	1,220,000	860,000	12,000	1.4
Malaysia	329,079	305,000	157,000	4,800	3.1
Mexico	1,967,180	400,000	166,000	7,000	4.2
Myanmar	696,500	500,000	245,000	8,500	3.5
Nigeria	924,000	72,000	28,000	4,000	14.3
Thailand	513,517	435,000	74,000	6,000	8.1
Zaire	2,344,886	1,245,000	1,000,000	4,200	0.4

Source: N. Myers, Tropical Deforestation: Rates and Patterns, page 30 in "The Causes of Tropical Deforestation: The economic and statistical analysis of factors giving rise to the loss of tropical forests," (Brown and Pearce, Eds.) University College London Press Limited, London (1994). This table includes the ten countries which have had the highest amount of deforestation in 1989.

Table 2.2

Worldwide Tropical Deforestation: 1991		
Source of Deforestation	Area Deforested (km²)	Location of Deforestation
Slash-and-Burn Agriculture	87,000 km ²	Almost entirely confined to Central America and the Amazon region
Cattle Ranching	15,000 km ²	
Roads and Mining	10,000 km ²	
Commercial Logging	45,000 km ²	2/3 of this total is from south east Asia

Source: N. Myers, Tropical Deforestation: Rates and Patterns, page 32 in "The Causes of Tropical Deforestation: The economic and statistical analysis of factors giving rise to the loss of tropical forests," (Brown and Pearce, Eds.) University College London Press Limited, London (1994).

Table 2.3

Deforestation in Brazil by State					
State	Area in Legal Amazonia (km²)	Area Cleared Through 1988 (km²)	Area Cleared Through 1990 (km²)	% of Area Cleared Through 1988 (km²)	% of Area Cleared Through 1990
Acre	152,589	19,500	21,332	12.8	14.0
Amapá	140,276	5,72	6,417	4.1	4.57
Amazonas	1,567,125	105,790	204,519	6.8	13.1
Maranhão	257,451	50,670	57,106	19.7	22.2
Mato Grosso	881,001	208,000	296,100	23.6	33.6
Pará	1,248,042	120,000	181,154	9.6	14.5
Rondônia	243,044	58,000	65,534	23.7	27.0
Roraima	230,104	3,270	5,341	1.4	2.3
Goiás	285,793	33,120	1,715	11.6	12.9
Total	5,005,425	598,922	839,218	12.0	16.8
Sources: 1988 statistics from: A. B. Anderson, Deforestation in Amazonia: Dynamics, Causes and Alternatives, page 1 in "The Earthscan Reader in Tropical Forestry" (Simon Rietbergen, Eds.) Earthscan Publishers Ltd., London (1993). The table includes all 9 states included in legal Amazonia borders. 1990 statistics based on Table 2 page 109 in : J. Goldemberg, Current Policies Aimed at Attaining a Model of Sustainable Development in Brazil, <i>Journal of Environment and Development</i> 1 (1) 105-115 (Summer 1992).					

concentrate on keeping this extensive area intact.

Little deforestation occurred in Brazil's Amazon before the 1970's. As of 1975, a total of only 3,000,000 hectares or about 0.6% of the Brazilian Amazon had been cleared. Between 1975 and 1987 the rate of deforestation steadily accelerated, increasing to 12,500,000 hectares by 1980, and the rate is constantly increasing (Moran 1993). The recent occupation and intensified use of the Amazon forest has been concentrated in the southern and eastern areas of the Basin. The rain forest is being destroyed by: cattle ranchers responding to government initiatives and subsidies, migrants engulfed in poverty and fleeing over-populated cities, loggers interested in precious hardwood, mining enterprises, land speculators, and hydroelectric projects (Baer, 1995). Of these sources of deforestation, agriculture has made the largest single impact (Southgate 1994, Baer 1995, Myers 1994, Mahar 1989).

2.5 Ouro Preto do Oeste, Rondônia

Operation Amazonia², migration, and government incentives have made profound impacts on deforestation in Brazil and, in particular, to the settlement of Ouro Preto do Oeste, which lies in the state of Rondônia, by introducing small scale agriculture to the area. The analysis performed in this study investigates how the deforestation rate may be reduced as agricultural methods are changed in Ouro Preto do Oeste. This small Amazonian city has been impacted by governmental settlement programs administered in

² Operation Amazonia was a government initiated program which was started in 1964 in order to establish settlements in the undeveloped Amazon region. This program was initiated in response to many social and political problems which existed in the populated regions of the northeast and southeast. See Appendix A for a detailed account of Operation Amazonia.

the 1960's through the 1980's. Ouro Preto do Oeste resides along BR-364, the 1,500 kilometer Cuiabá - Porto Velho highway. A map of the state can be found in Figure 2.1 where the city of Ouro Preto do Oeste and the six counties or regions of the city are outlined.

At the turn of the century this part of eastern Amazonia was a rich rubber producing area. Large scale settlement began during the late nineteenth century, which brought an estimated 103,000 immigrant workers to Rondônia by 1912 (Browder 1994). Following the decline in the Amazon rubber trade, economic activity stagnated until the 1940's. In the 1950's the area became an important source of tin and gold, however, the area was virtually inaccessible by land. In 1965 Rondônia's population numbered only 70,000 and the forest, which covered 80 percent of the state, was still intact.

The highway BR-364 is the only major paved road in Rondônia. It runs from the southern most city of Cuiabá and continues to the northern most city, Porto Velho, the capital of the state (see Figure 2.2). With the completion of BR-364 in 1968, migration increased tenfold and clearing of the forest was up by 3 percent within the decade. By 1988 this percentage was up to 23.7 percent (Mahar 1989). The regional makeup of the population also changed. Previously the vast majority of Rondônia's settlers were from the north and northeast. The new surge of migration brought small scale farmers in large part from the southern state of Paraná and also from the states of Mato Grosso, Minas Gerais, Espírito Santo, and São Paulo (Mahar and Schneider 1994, Pedlowski and Dale 1992). The government programs, called Operation Amazonia, were responsible for much of the migration to this area and, therefore, much of the deforestation. A discussion of

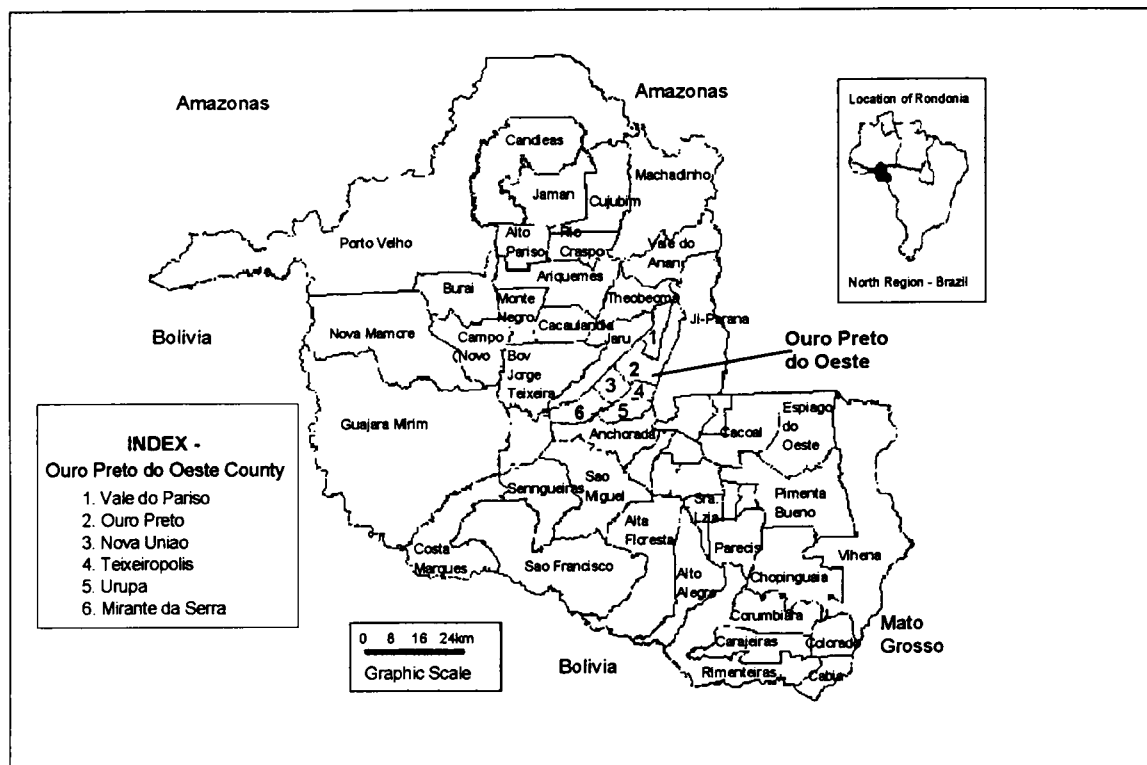


Figure 2.1
The State of Rondônia ³

³Source: Secretaria de Estado de Desenvolvimento Ambiental (SEDAM) 1996. "Mapa Político e Administrativo de Rondônia.

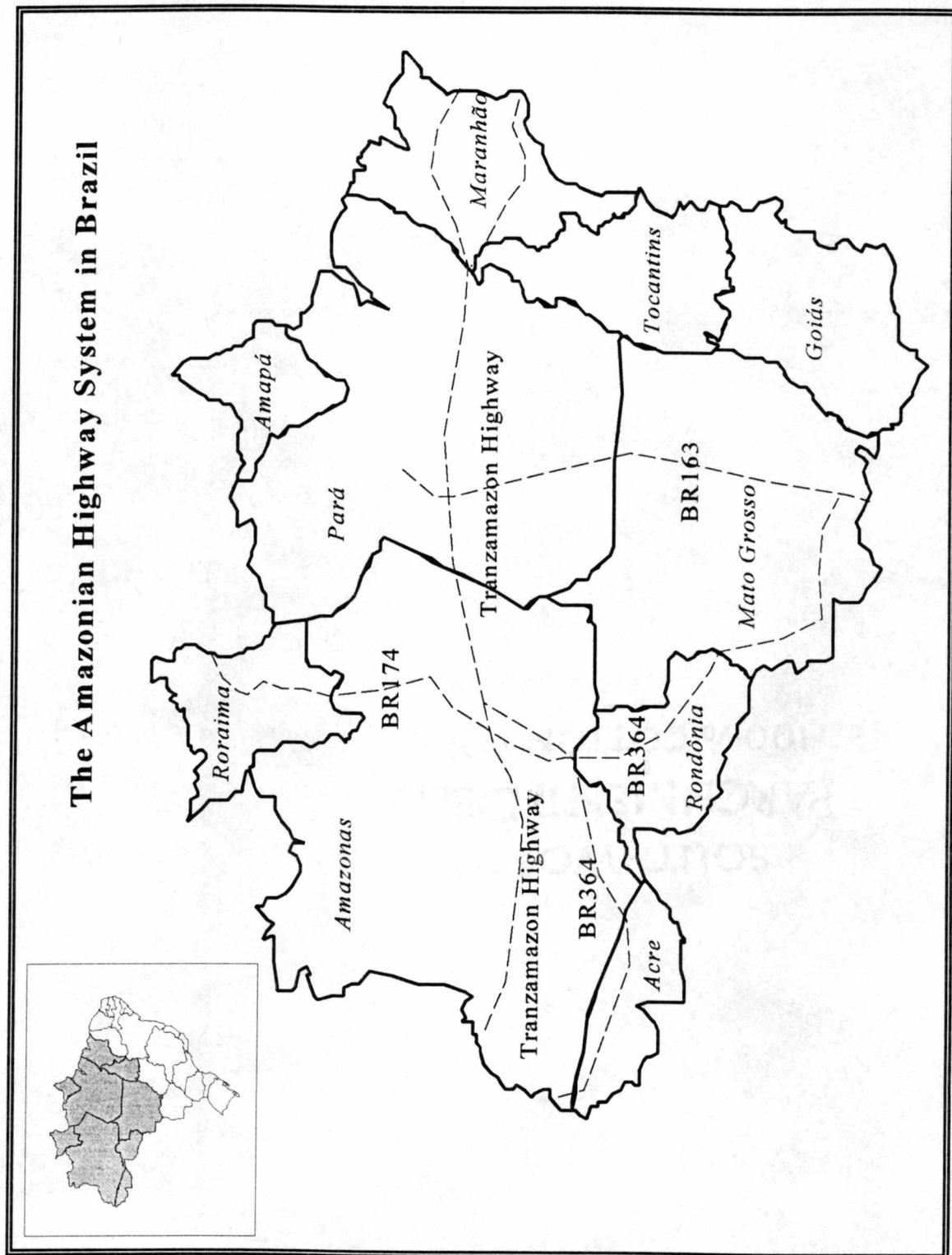


Figure 2.2
Map of the Amazonian Highway System in Brazil

these government programs and the impact that they've made on the tropical forest follows.

2.6 The Costs of Deforestation

Specific numbers as to the costs and benefits of deforestation in Brazil, or any other country, are difficult to estimate since these values can differ among the various levels of occurrence: international, national, and local, and since the estimation of many public goods is necessary. One interesting cost is the damage due to the carbon dioxide release due to deforestation. Pearce and Brown (1994) report an estimation of international costs in terms of carbon release. It is estimated that the conversion of primary forest into agriculture would give rise to carbon release damage of about \$4000-\$4400 per hectare⁴. The estimates allow for carbon fixation in the subsequent land use. In comparison, Schneider (1992b) reports an upper bound for land value in Rondônia of \$300 per hectare, while the data collected for this study finds an upper bound for land value of \$440 per hectare. This substantial difference between the international damage value and the price of land represents a market failure on the global level⁵. Market failures, on all levels, are discussed in detail in the following chapter.

In a similar study Grimes *et al.* (1994) calculate the value of a hectare of primary

⁴ This estimate is based on a study by Frankhauser (1993) which suggests a central value of \$20 of damage for every ton of carbon emitted.

⁵ In 1996 dollars the carbon damage from carbon release per hectare is \$4338-5432 and the Schneider land value is \$322. After correcting for inflation, the results are the same. The damage of carbon emitted is far greater than the value of the land, reflected in the price of land.

forest in the Ecuadorian Amazon based on the potential extraction of nontimber forest products. Sustainable agriculture plots are determined to have the highest net present value. The authors find that the net present value of one hectare of intercropping ranged from \$1257-\$2939, one hectare of agriculture was valued at less than \$500, and that one hectare of land devoted cattle raising ranged from \$57-\$287.

2.7 Causes, Sources, and Forces of Deforestation

It is important to make distinctions between *sources* and *causes* of deforestation because of the different implications of these terms. Panyoutou and Sungsuwan (1994) define the *causes* of deforestation as population pressure, migration and social pressures and the *sources* of deforestation as logging, slash-and-burn agriculture, and the others mentioned above. Pearce and Brown (1994) add to this definition fundamental *forces* which give rise to deforestation. These forces include the competition between humans and non-humans for land and economic market failures.

In the Amazonian state of Rondônia, the prime cause of deforestation is the government incentives to move and live in the Amazon while the sources are slash-and-burn agriculture, and the forces of deforestation, are the economic failures. The small scale farmers are, therefore, not solely responsible for the deforestation in Rondônia. Instead the farmers are recognized as poor individuals with few alternatives. They are motivated to provide a subsistence living for themselves and their families with the available resources.

2.8 Reducing Deforestation in Rondônia

In the Brazilian Amazon general tax policies, special tax incentives, the rules of land allocation, and poor government planning all helped to accelerate deforestation⁶ in combination with population growth, and the city of Ouro Preto do Oeste, Rondônia was no exception (Binswaner 1991). If all deforestation is to be halted in Rondônia, the farmers, cattle ranchers, miners, loggers, and families would have to be moved out of the area. Halting all development in Rondônia is an unrealistic and undesirable goal. More feasible approaches concentrate on decreasing the rate of deforestation toward a steady-state zero rate of deforestation some time in the near future, while taking into account ecological, social, and economic factors (Moran 1990). Sustainable agriculture can achieve these goals by allowing farmers and families to remain on their land longer and help to improve their welfare (Dale *et al.* 1994, Dale *et al.* 1993, Browder 1992). This agricultural technique is discussed in detail in Chapter 3.

⁶ The incentives created by tax policy, land allocation, and government planning which lead to the development and destruction of the Brazilian Amazon were initiated by Operation Amazonia. See Appendix A for a detailed account of this government program..

CHAPTER 3

SUSTAINABLE AGRICULTURE

3.1 Agricultural Practices in the Brazilian Amazon

The most common agricultural practice used in the Brazilian Amazon is slash-and-burn agriculture. It has been observed that subsequent to burning, forest agriculture can be achieved for an average of 10 years (Browder 1994, Dale *et al.* 1994, Pedlowski and Dale 1992, Dale and Pedlowski 1992, Frohn *et al.* 1990, Mahar 1989, Goodland 1980). A common land-use pattern is that farmers use the land for annuals crops for the first 2-3 years, and then convert the land to pasture and use it for this purpose until the land can no longer support grass (Dale *et al.* 1994, Pedlowski and Dale 1992, Dale and Pedlowski 1992 Fearnside 1990). After the soil is depleted of its nutrients, the farmer typically moves on to a new plot of land, resulting in the slashing and burning of more of the forest.

The small scale farmer is an important element of the deforestation crisis in Brazil because slash-and-burn agriculture is responsible for a majority of the deforestation (Myers 1994). One way of reducing deforestation would be to move these farm families, who use slash-and-burn agriculture, out of the rain forest. This potential way of reducing the deforestation rate is, however, unrealistic and undesirable. The role that more sustainable methods of agriculture can play in the preservation of the tropical forest is,

therefore, crucial to addressing the deforestation dilemma. Altering farming techniques could drastically reduce the deforestation rate if adopted by a majority of the farmers. This chapter continues by addressing slash-and-burn agriculture, sustainable agriculture, and the impacts that these agricultural methods make on crop production.

3.1.1 Land Use Trends

Farmers in the Brazilian Amazon typically follow the land-use pattern of burning the forest or older crops, planting annuals, and then converting the land to pasture. The land is typically converted to pasture when the soil decreases in quality and can no longer support crops. A study which measured the rate of decreasing soil quality in the Brazilian tropics is by Fearnside (1990). Measurements of soil production over a full annual cycle in Ouro Preto do Oeste, Rondônia, show that a twelve-year-old pasture produces at about half the rate of a three-year-old pasture. Fearnside found that yields decline due to the invasion of inedible weeds, soil compaction, and decreasing levels of available phosphorous of the soils (Fearnside 1990, Hecht 1981, 1983).

The tropical soils of the Brazilian Amazon are acidic (have a very low pH level), have high aluminum saturation, low exchangeable bases, and low nutrient content, adding up to low fertility (Villachia *et al.* 1990). Clearing and burning the tropical forests produces a temporary but substantial increase in soil fertility. Dramatic increases in potassium, calcium, magnesium, phosphorous, and pH as well as the reduction in aluminum saturation, occur due to this process (Serrão and Toledo 1990). The lack of phosphorous in tropical soils has been found to be the most limiting nutrient to agricultural

systems followed by the lack of nitrogen (Serrão and Toledo 1990, Fearnside 1990).

After the initial surge of nutrients being provided to the soil by burning, the nutrient base will become exhausted or limited after only three to five years (Serrão and Toledo 1990).

The use of leguminous woody species (perennial crops) can therefore add fixed nitrogen to these soils if used and managed by a sustainable agricultural system (Nair 1993, Fearnside 1990).

Rice, beans, and corn represent 58 percent of the total area crop in Brazil, while three tree crops: banana, cocoa, and coffee comprise 37 percent. The use of trees, native to the area, is not common practice. The second important trend of farmers in Rondônia has been the extensive conversion from crop cultivation to pasture formation and beef cattle production. Seeded pasture grass has become the dominant non-forest land use in Rondônia, increasing from 9.8 percent of the total area in 1980 to 25.6 percent in 1985 (Browder 1994).

3.2 Definition of Sustainable Agriculture

This study explores the use of an alternative method of agriculture known as sustainable agriculture to potentially reduce deforestation in the parts of the Brazilian Amazon where slash-and-burn agriculture is practiced. Sustainable agriculture provides the soil with nutrients by maintaining the forest cover and leaf regenerating systems (in particular nitrogen) thus expanding the time farmers can cultivate the land almost indefinitely (Nair 1993). Sustainable agriculture has the potential to increase both the welfare of society by reducing the need to cut down the forest to plant crops and the

welfare of farmers by reducing the labor input necessary for crop production and increasing income.

Sustainable agriculture is defined as agriculture which maintains the environmental and ecological integrity of the soil, water, and land systems in the area while providing sufficient income to farmers through the inter-cropping of different perennials in combination with other perennial trees and/or annual crops. In Brazil, this type of agriculture refers to the farming which maintains the quality and nutrients of the soil, permitting long-term use of each lot of land (Prinsley 1992). The extremely site specific nature of sustainable agriculture makes it difficult to develop precise recommendations for different areas around the world but some key concepts are well established. Sustainable agriculture in the Amazon involves inter-cropping or alley cropping which has several characteristics:

- combines the production of multiple farm crops with protection of the resource base;
- emphasizes the use of indigenous multipurpose trees and shrubs helping maintain the natural balance of ecosystems;
- is a well-planned system with positive social effects, economic effects, and ecological effects;
- is structurally and functionally more complex than mono-culture (Nair 1993, Luo and Han 1990).

Amazon farming will probably never be sustainable in the sense that it can fully replace all of the natural resources that it depletes. However, as Alemeida and Campari

(1995) define it, Amazonian farming can be considered sustainable when the ratio of private benefits and social costs to the environment rises (ie. when the private benefits increase at a more rapid rate than social costs). Alemeida and Campari continue by adding that sustainability can be increased in this setting by increasing the private cost of deforesting land by either internalizing the social cost of deforestation or by decreasing the cost of alternative agricultural systems such as sustainable agriculture.

Sustainable agriculture as used by small scale farmers in Ouro Preto do Oeste, Rondônia includes the inter-cropping of tree crops such as cupuacu, pupunha, acai, acerola, guarana, cacao, banana, orange, lime, coffee, and trees that have precious woods such as mahogany, Brazil nut, and rubber tress, in combination with annuals such as: rice, corn, beans, sugar cane, and manioc. The forest over story (tallest tree layer) is generally dominated by rubber, mango, Brazil nut, mahogany, pupunha, and other trees with valuable woods. The under-stories (lower standing trees) are composed of shade tolerant trees such as coffee, cacao, guarana, and cupuacu intercropped with annuals. In Ouro Preto do Oeste these systems are often used by small scale farmers in combination with other sustainable non-agricultural uses of the forest such as honey and fish harvesting.⁷

Tree crops protect the soil from degradation caused by leaching, erosion, and compaction, and they frequently have a higher tolerance to soil acidity and aluminum toxicity than annual crops (Browder 1994). As is consistent with the tropical soils of the

⁷ Four of the most frequently used examples of inter-cropping on a one hectare lot by these Rondônian farmers are: 1) 300 pupunha, 300 cupuacu, 200 banana, 50 mahogany, 100 Brazil nut and 200 other valuable wood trees; 2) 200 coconut, 200 cupuacu, 200 banana, and 100 valuable wood trees; 3) 150 graviola, 300 aracaboi, 50 Brazil nut, 50 mahogany, 100 acerola, 200 banana, and 50 other valuable wood trees; and 4) 1000 coffee, 400 pupunha, 50 mahogany, 200 banana, and 50 other valuable wood trees.

Brazilian Amazon, most of the 17 major soil groups found in Rondônia are dystrophic, high in acidity and aluminum content, interspersed with patches of well-drained nonhydromorphic, red-yellow eutrophic podzols (Browder 1994). Tree crops also make relatively low demands on soil nutrients, in comparison to annual crops, because of efficient nutrient recycling. Important to the success of sustainable agriculture systems is the choice of trees which can be harvested for their fruits, wood, or nuts and sold in the market (Uhl *et al.* 1989).

Dale *et al.* (1993) found that farmers in Rondônia who used innovative management systems for their farms (such as growing predominantly perennial crops and inter-cropping trees such as rubber, cocoa, palm oil, coconuts, or Brazil nuts) made a better livelihood than those who used traditional methods. These farmers did not have pastures or income from cattle but averaged more than twice the income in 1990, of traditional farmers. They also had a much higher probability of staying on their original plot of land.

Although sustainable agriculture has shown some promising preliminary increases in soil quality and/or soil integrity (Ruddell 1995, Adriance 1995, Nair 1993, Dale *et al.* 1993), sustainable agriculture cannot be considered a cure-all for tropical farming problems. One problem with sustainable agriculture is that plans cannot be transferred from one region of the world to another, but rather must be uniquely designed for each use and soil type. Another drawback is that most of the intercropping plots are fairly new. There is no specific evidence as of yet that sustainable agriculture systems can be cultivated infinitely, although this may be possible. Compounding the problem of the lack

of scientific evidence to support the long-term use of the soils in these sustainable systems is that many tropical soils differ so greatly from plot to plot making numerous studies necessary. Currently studies are being done on the soil integrity of sustainable agricultural plots in Rondônia⁸, but since the plots are less than 5 years old, conclusive results are not expected for at least 10 years. As Fearnside (1990) has pointed out, research in agroforestry and the effects of sustainable agriculture in the tropics is still in its infancy.

3.3 The Use of Sustainable Agriculture Around the World

The use of sustainable agriculture by small scale farmers has been increasing around the world. In Peru, a program which supports sustainable agriculture and the use of data collection as a tool for learning began in 1990 with the support of the grassroots organization World Neighbors⁹ (Ruddell 1995). After only one planting season, yields and incomes increased for the participating farmers. In Guatemala, a group of dedicated farmers under Marcos Orozoco, a former Minister of Agriculture, has promoted sustainable agricultural methods. The results have been a reduction in slash-and-burn agriculture throughout the country, increased yields, and the increased use of natural fertilizers (Adrianne 1995). In Honduras, the group Familia y Medio Ambiente, has found that the sustainable agricultural practice of inter-cropping has increased yields by using flowering plants as an aid in pest control.

⁸ Technosolo, Porto Velho, Rondônia, a Brazilian and Dutch company is mapping the soil types of the entire state and studying the effect of sustainable agriculture on soil integrity, 1997.

⁹ World Neighbors is a grassroots support program based in the United States which supports various programs in Central and South America to educate farmers about sustainable agriculture (Ruddell 1995, Adrianne 1995).

Similar success can occur in Ouro Preto do Oeste if one can determine the best way to increase the adoption rate of sustainable agriculture. One way of motivating farmers to switch to this type of agriculture in Brazil is to first determine the factors that the farmers respond best to such as: subsidy and loan programs, education programs, or information about this type of agriculture and then to work with the local people to determine the best approach to the problem. Educational and outreach programs have been administered in Ouro Preto do Oeste, Rondônia. The educational programs consist of annual union meetings which inform and assist farmers in the use of sustainable agriculture. While the outreach programs were initiated by a local NGO (non governmental organization), IPHAE (Instituto de Pre-História, Agricultura, e Ecologia) in the 1980's, the adoption rate has been low. The influence that these programs have on the adoption of sustainable agriculture in Ouro Preto do Oeste is investigated in Chapter 6. These programs are treated as independent variables in the regression analysis to determine their effects on the adoption and extent of the use of sustainable agriculture.

The local support of small farmers is necessary since financial support has been difficult to obtain from banks and government organizations in Central and South America for the peasant farmer. Many government programs which support improvements in agriculture have been designed primarily for the economies of scale of large farms with access to the financial capital to buy machinery, chemical fertilizers, and pesticides. Therefore, groups like World Neighbors and similar non-government organizations, that provide access capital have made a significant impact on the adoption of sustainable agriculture in developing nations. These groups have found that programs which involve

local farmers have had great success.

3.4 Financing of Sustainable Agriculture Programs

One way of financing sustainable agriculture in a self sufficient manner is through small micro loans to the farmers. Banks providing low interest loans to small enterprises have become successful in the developing countries of Latin America, Africa, and Asia. The Grameen Bank is perhaps the most successful and publicized. This bank, an institution that pioneered lending to the landless poor in Asia's poorest country, Bangladesh, was founded by Muhammad Yunus, an economics professor at Bangladesh's Chittagong University (Stackhouse 1994). Since 1976, Grameen's 1.8 million borrowers have deposited about \$50 million with the bank. Grameen customers, whose only collateral is the shirts on their back, have borrowed \$844 million and have repaid 98 percent of their loans. This repayment percentage is above the performance of most commercial banks which average less than 93 percent, and above the performance of Japan's biggest banks, loaning to major industrial clients, which have a default rate of 3 percent (Fragasso 1995). Grameen's record has been so successful that governments from Malaysia and several U.S. cities have copied it (Waxler 1994).

Similar to the Grameen Bank, Women's World Banking (WWB) provides poor entrepreneurs access to finance information and markets. Founded in 1979, WWB has grown to provide over \$150 million in loans to 500,000 women in 40 countries with a repayment rate of 98 percent (Howell 1993).

The success of these two programs is believed to stem from the bottom up

approach which provides the means for self sufficiency. The result of micro loan programs are as impressive as they are consistent. Businesses have expanded their incomes, increased job opportunities, provided gains in self-confidence, community participation, and improved family functioning (Waxler 1994). World Bank programs which typically provide financial assistance do not result in self sufficient businesses but instead instill a dependency on international assistance. It is for this reason that many of their programs have received criticism. One example of a World Bank program that has received much criticism is the completion of highway construction in the Brazilian Amazon which was integrated with a World Bank settlement program (POLONORESTE). This settlement program resulted in large scale destruction of the rain forest and much criticism (see Appendix A).

Whether micro loans, education programs, or subsidies are used as the means to support sustainable agriculture, it is the bottom up approach, which includes farmers in the decision making process, which can add to the success of the program. As these micro loan programs have shown, self sufficiency can motivate farmers to maintain sustainable practices. Although micro loans have been a successful means of providing capital to small poor farmers, they are not currently necessary in order to support the adoption of sustainable agriculture in Ouro Preto do Oeste.

These loans are not necessary in the settlement of Ouro Preto do Oeste since the economic constraints have not been an issue in the adoption process. IPHAE (a local NGO) and labor organizations like APA have provided seedlings free of charge to farmers who have chosen to plant intercropped plots and/or join the organizations. Economic and

capital constraints are commonly deterrents to the adoption of new agricultural technologies in developing countries (Miller and Tolley 1989, Holden 1993, Kebede *et al.* 1990, Jaeger and Matlon 1990, Norris and Batie 1987, Savagado *et al.* 1994, Rahm and Huffamn 1984, Shakya and Flinn 1985). Since an initial cash investment is not necessary for the farmers in Ouro Preto do Oeste¹⁰, theory would predict that the adoption rate of the new technology would be high since there are labor and income benefits that are expected when sustainable agriculture is adopted. The adoption of sustainable agriculture is, however, very low in Ouro Preto do Oeste. Therefore other capital constraints such as stored wealth and labor are investigated in the regression analysis in Chapter 6.

3.5 The Role of Economics in the Adoption of Sustainable Agriculture

A bottom up approach to the deforestation problem in the Brazilian Amazon is especially important because it addresses the problem at the local level. The typical farmer living in the southern borders of the Brazilian Amazon migrated to the area due to government incentives and promises of a better life. The farmers are responsible for a majority of the of the deforestation in the area (Myers 1994), but destruction only continues because the farmers are burning the forest in order to provide food for themselves and their families. Anderson and Ioris (1992) found that small scale farmers and rubber tappers on Combu Island in the Brazilian Amazon had high and apparently sustainable economic return from the extraction of forest resources, such as fruits. Key to

¹⁰ The farming equipment which is necessary for the intercropping plots does not vary greatly from the equipment used in slash-and-burn agriculture. Farming equipment generally consists of low cost hand tools. In addition, the use of fertilizers and herbicides do not play a role in intercropping.

the success of these extractivists was the combination of proximity to a major market and appropriate resource management. Economic considerations are therefore an important part of the adoption process. Sustainable agriculture must be profitable if it is to be adopted by small scale farmers who depend on the economic returns of agricultural products for their livelihoods.

CHAPTER 4

ADDRESSING MARKET FAILURE WHICH HAS LED TO TROPICAL DEFORESTATION WITH DISCRETE CHOICE MODELS

4.1 The Role of Economics in Deforestation

Deforestation in the Amazon Basin of Brazil is the result of various market and government failures. These market and government failures account for the human and social pressures which occurred during the settlement of this area and the social and economic problems which exist in the country today. These circumstances which have led to deforestation in Brazil are the result of poorly defined property rights for land ownership, ill conceived government policies that unfairly secure advantages to some farmers and ranchers through subsidies, and the divergence of social and private costs and benefits resulting from assigning different values to the forest. Although property rights are now secure in the area, and the governmental policies which supported deforestation are for the most part abolished, the deforestation trends are continuing in the Amazon region of Brazil.

Market failure has occurred on global, national, and local levels and has resulted in deforestation rates that are well above optimal levels. Independent of the level of occurrence, all of these market failures impact the decisions of local farmers and their land

use choices. A discussion of market failure and how it will be addressed follows.

4.2 Market Failures

Traditional economic solutions to market failures are the allocation of property rights, taxing the source of the market failure, subsidizing correct behavior, the use of tradable permits, and the creation of markets by the government that induce proper market incentives. These solutions cannot be expected to yield an optimal solution (one where the marginal costs and benefits are equated) to Amazon deforestation because of the complexity of the situation. Each of these solutions, individually, may only address a portion of the problem. For example, when property rights became more defined, the rate of deforestation in the Amazon did not decrease. And, in the state of Rondônia, farmers are continuing to burn their lots as they gain titles with no apparent concern for the future. Taxing and/or the use of marketable permits is not feasible in this area of the world since the economy is not well developed and the farmers are very poor.

Subsidizing correct behavior, such as the use of sustainable agriculture, is a potential solution. But, as is pointed out in Chapter 3, financial assistance of small enterprises and farmers in developing nations has often been unsuccessful (Waxler 1994). Instead, programs which support self-sufficiency have been highly successful (Fragasse 1995, Southgate, 1994, Waxler 1994, Howell 1993). Therefore successfully subsidizing sustainable agriculture would require the use of educational programs to teach farmers how to plant and maintain these systems and therefore require a substantial commitment.

Without these education programs sustainable agriculture will most likely fail. IPHAE¹¹ representatives studied sustainable agricultural systems in Ouro Preto do Oeste. These systems were subsidized by the government¹² and put in place without educational support. The Technosolo study found that these systems were not maintained and were unsuccessful in producing any goods which could be harvested and sold. The market failures which have resulted in tropical deforestation can be classified on global, national, and local levels. These classifications are discussed in the following sections as discussed below.

4.2.1 Global Market Failure

Global market failures have occurred as global and international economies have placed benefit values on the standing forest. These global benefits such as nonuse and existence values have not been reflected in global markets. As mentioned in Chapter 2, one example of a cost that deforestation has imposed on the global level is the addition in carbon emissions which add to greenhouse gases. Pearce and Brown (1994) estimate that the carbon damage due to the conversion of primary forest for agricultural purposes is about \$4000-\$4400 per hectare of tropical forest¹³. At the same time the private value of

¹¹ IPHAE is a non governmental organization (NGO) headquartered in Porto Velho, Rondônia. This NGO assisted farmers in planting intercropping plots in three settlements of Rondônia; Ouro Preto do Oeste, Ariquemes, and Jamari.

¹² Based on an unpublished study which analyzed intercropping programs initiated in 1990 by IPHAE (an NGO headquartered in Porto Velho). Pieter Van Der Veld, an independent Dutch agronomist employed by IPHAE to administer the study. (Pieter Van Der Veld and Monique Berensden, personal communication, November 1996).

¹³ This estimate is based on a study by Fankhauser (1993) which suggests a central value of \$20 of damage for every ton of carbon emitted.

land was found to have an upper bound of \$440 per hectare in Ouro Preto do Oeste in this research endeavor. If the existence and non-use values which global entities place on the standing forest are included in the value of each hectare of forest, the total would be well over \$4400 per hectare. The disparate values between global and private land prices define the global market failure due to tropical deforestation.

4.2.2 National Market Failure

The national level market failures which have led to deforestation in Brazil are related to a national increasing trend of poverty and over-population in the southern and north eastern regions of the country and the national debt (Kahn and McDonald 1995, Frohn *et al.* 1990, Moran 1990). Various failed governmental programs aimed at ameliorating these problems have led to deforestation in the tropical region of the country. These government failures began in the 1960's with the launching of the colonization program known as "Operation Amazonia". This settlement program began the development of the Amazon region and ended with many unsuccessful farm establishments and the beginning of slash-and-burn agriculture in the Amazon region by small scale farmers¹⁴.

4.2.3 Local Market Failure

The market structure of the Brazilian farm settlements of the Amazon are based on annual crops which can be bought and sold easily in well-developed markets. But,

¹⁴ See Appendix A for a detailed account of Operation Amazonia.

unfortunately it is the growth of the market for these products that destroys the rainforest. Products native to the area, such as fruit, nuts, and honey do not have well developed markets and are, therefore, much more difficult to sell. Trading native products could provide incentives to maintain the rainforest instead of cutting it down.

In a study of non-timber forest products (fibers, canes, resins, oils, fruits, and nuts) in Ecuador, Grimes *et al.* (1994) find that the present value of the net revenue from the non-forest timber goods is \$2830. The value of non forest timber goods was found to be significantly higher than other forest uses in the area, including agriculture in which the present value is estimated to be less than \$500. The value or price of these goods is subject, however, to supply and demand. Organized markets are necessary in order to sell these goods.

One reason that the rate of return of the forest has been undervalued on the local level is because of missing markets (Pearce and Brown 1994). There are many products and functions of the forest which are not being valued by the farmers who cut and burn the tropical forest. Products such as nuts, fruits, and medicinal plants are not being harvested because there are no organized local, national, or state-wide markets to sell these products. Even if these markets did exist, the lack of a developed transportation system prevents the bringing of these products to market. Scientists and non-governmental organizations are working to find products other than rubber and Brazil nuts which can be harvested and sold in new and developing markets. Some of the scientists and organizations are addressing the overwhelming problems of communication and transportation (Holloway 1993). When these products and functions are not included in

the calculation of the value of the forest, the opportunity cost of cutting it down is greatly reduced.

In total, these failures prevent Brazilian farmers who live in the Amazon from making the best long-term choices for Brazil and the rest of the world (Pearce and Brown 1994, Kahn and McDonald 1994, Miller *et al.* 1993). The economic theory behind the forest is simple: if it can be shown that forests are of more value standing than when felled, then they are more likely to be preserved (Corry 1993). The inequality between private and social values makes the solution more difficult than the theory suggests. The farmer who cuts down the forest places a private value of standing forest at a much lower level than the social value which reflects the values of biodiversity, forest products, and native plants and animals. The felled forest is often, unfortunately, of more value to the private farmer.

4.3 Addressing Market Failure

Market failures occurring on global, national, and local levels make it difficult to find an optimal solution to deforestation on all levels simultaneously. The optimal rate of deforestation is determined as the level of deforestation where the social and private benefits of the standing forest are equal. On each level, market forces are not securing the economically correct balance of land conversion and land conservation (Pearce and Brown 1994). This situation occurs because, as with all public goods, those who convert or destroy the forest do not have to compensate those who value the standing forest.

The economic solutions mentioned earlier do not result in zero deforestation, but

rather an economic balance of conversion and conservation, resulting in the optimal rate of deforestation. Simultaneously solving for an optimal rate of deforestation on all of these levels is not possible since benefits differ across tiers. Kahn (1995) points out that deforestation rates which are optimal from a national level may not be optimal from a global point of view because the country will only consider the domestic costs and benefits and not take into consideration global nonuse or existence benefits. International level benefits of the tropical forest include nonuse and existence values. National benefits may include timber for trade and the conversion of forest to coffee plantations to support national trade balances and the national economy. And on the local level, benefits of the forest include conversion to farms and ranches to support subsistence living. These differing optimal levels of deforestation can be represented in Figure 4.1. In this figure the marginal costs are presented for the private (MPC), national (MSC_N), and global (MSC_G) levels where MPC stands for marginal private cost and MSC stands for marginal social cost. The intersection of the different marginal costs and the marginal benefit (MB) indicate the optimal private (D_P), national (D_N), and global (D_G) levels of deforestation. The optimal level of deforestation decreases as more uses of the forest are included in the marginal cost measurements.

Since an optimal solution cannot be found to help reduce deforestation, a second best solution which induces a change in behavior can result in both an increase in the welfare on the local level as well as society. The rate of deforestation can be decreased in some regions of Brazil by altering traditional farming techniques and using sustainable agricultural practices. These methods could provide the financial support of farmers for

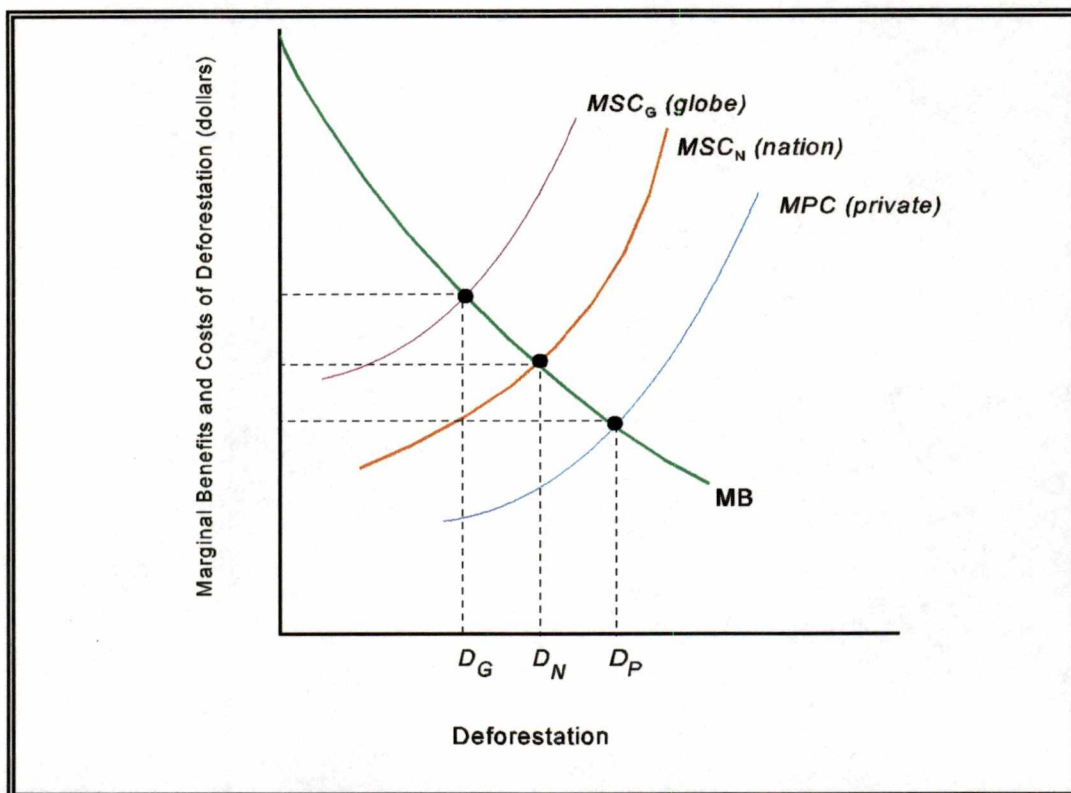


Figure 4.1
Global, National, and Private Optimal Levels of Deforestation

an extended period of time while increasing the amount of time spent cultivating on each lot (Dale *et al.* 1994, Goodland 1980). Sustainable agricultural practices have been used successfully by the indigenous people of the area for centuries (Kahn 1995, Anderson 1993). The practice is therefore supported by many professionals as a sustainable technique and a promising alternative to slash-and-burn agriculture, although it is not a cure all for the deforestation problem.

Increasing pressures from population, in an increasingly more densely populated area, may contribute to the success of sustainable agriculture. Most small farmer deforesters of the 1990's have, however, come from within the Amazon region. The greatest threat to deforestation in the Amazon today is, therefore, from intra-regional migration. According to Almeida and Campari (1995) the issue is no longer how to prevent farmers from migrating to the Amazon, but how to ensure that the farmers who occupy Amazonian land remain on their farm lots, reducing migration into the interior of the Amazon where deforestation has been minimal.

4.4 Sustainable Agriculture and the Decision of Farmers

Deforestation may be reduced by solving market failure at the local level. In particular, local market failure can be resolved by altering the agricultural techniques of a majority of farmers who practice slash-and-burn agriculture. It is possible that a new method of agriculture which results in less environmental damage would be adopted by farmers if the private cost of the alternative method of agriculture is decreased. As the private cost of alternative methods of agriculture such as sustainable agriculture are

decreased, the relative price of slash-and-burn agriculture will increase. The market failure can, therefore, be internalized as the relative benefits of the standing forest increase on the local level.

Sustainable agriculture was introduced to the Ouro Preto do Oeste region of Rondônia in the 1980's. Since the introduction of sustainable agriculture, very few farmers have adopted the new agricultural technique. One reason for the slow diffusion rate of sustainable agriculture in Ouro Preto do Oeste is that it is believed that many of the farmers in this area are not aware of the potential profits that sustainable agriculture can provide. It is also believed that many of the farmers who are informed about sustainable agriculture and the potential profits may not be willing to take the risk of switching to an unfamiliar method of farming. For both of these reasons, the lack of knowledge and risk averse behavior, many farmers have not adopted the new method of farming. Relatively high discount rates (Ehui *et al.* 1990) increase the incentive to use slash-and-burn agriculture.

Under the present conditions, farmers are making rational decisions. Slash-and-burn methods may be more profitable in the short run, but as the soil quality declines, profits fall (Goodland 1980). Short term decisions and the dependence on farming for their livelihood have made sustainable methods of agriculture often unaffordable. Since most of these farmers do not have access to capital or loans, the option to burn and plant is often the choice of farmers when outside assistance with more sustainable methods of farming is not available.

There is a risk involved in adopting sustainable agriculture since there are no fully

developed markets to sell the products which are grown such as: cupuacu, pupunha, acai, and acerola, to name a few, while there are well developed markets for annual crops. The establishment of infrastructure and markets is key to maintaining a healthy economy which can support the commercialization of forest products. In addition there is a risk involved with income, since it is not known whether these products can be easily sold or not.

Another deterrent to adopting sustainable agriculture for these farmers, is that a large initial capital investment is required if outside assistance is not provided. The seedlings necessary in order to plant a one hectare sustainable agricultural plot are costly and can range from \$450-\$900. This expense can represent up to 33 percent of the annual income of the farmer in Ouro Preto do Oeste. In addition, changing to a new method of farming will require investments in terms of education and finances. A great deal of information and training is necessary in order to switch to new agricultural methods. It is therefore important that policies address these issues and help to reduce the risks that are involved for the farmers.

4.5 Diffusion and Adoption Literature

Studies which have addressed local market failure in developing countries by the adoption of new techniques of agriculture have investigated a wide variety of technologies. A common theme throughout these papers is that the adoption of new techniques which increase welfare and/or income often have low diffusion rates (Holden 1993, Kebede *et al.* 1990, Sands 1986, Opare 1977). Many farmers are either not willing to adopt the new technology or are constrained by capital resources and cannot adopt the

potentially superior technology. This observation was also made in Ouro Preto do Oeste. Only 12 percent of the farmers, from a random sample, used sustainable agriculture even though the technique was shown to improve welfare and income of those farmers who used it.

The adoption of technical innovations in agriculture has attracted considerable attention among developmental and environmental economists since the majority of the population of developing countries derives its livelihood from agricultural production. New technologies in agriculture can provide the opportunity to increase production, yield, and income in these developing countries (Feder and Zilberman 1985). The low rates of adoption in developing countries are contrary to what economic theory might predict, since economic theory asserts that the technology which yields the highest benefits will be adopted. Conventional diffusion analysis asserts that a rational individual will adopt a technology that is more profitable or will provide a greater utility. These technologies are often not being adopted often because of a lack of information about the technology, a lack of capital assets, the lack of transportation necessary to transport inputs, and because of a local custom or tradition which may be associated with the older technology or method of farming.

Models which estimate the adoption of new techniques and technologies in developing countries have focused on different issues compared to models for developed countries. The adoption decision literature was first introduced in terms of firms' decisions in developed countries. Much of the literature, which has focused on the adoption decision of firms in the U.S., disregards social factors and concentrates on the

issues of market size, market characteristics, industry size, risk, and the characteristics of the new technology (Hannan and McDowell 1984, Oster 1982, Griliches 1957). Unlike developed countries where well-formed industries exist and information is relatively easy to obtain, the adoption of new technologies and farming methods in developing countries is often influenced by various social factors in addition to economic factors. It is therefore essential that social factors are considered in the modeling process. For example, Kebede *et al.* (1990) found that in Ethiopia the adoption of new technologies in farming is determined by both economic and social variables and that social variables are crucial to the probability model. Adessina and Zinnah (1993) show that the perceptions of technology and the social impacts that the new technology would make are major factors in determining adoption for farmers in Sierra Leone. And, as Holden (1993) has found, farmers in Zambia had been given the choice to switch from the more traditional slash-and-burn agriculture to a new maize processing system which would reduce the labor requirement by as much as 40 percent and generate higher profits. The adoption of the superior technology was not made by many farmers because the traditional means are supported by the social system. In addition, Holden found that in areas where there was a dependence on farm income, and alternative off-farm income was not available, the risk involved in adopting the new technology increased.

The farmers in the Ouro Preto do Oeste region of Rondônia have various choices as to how they can farm their land. They can grow the more traditional European crops such as corn, rice, beans, manioc, and coffee; grow perennial crops native to the area, such as pupunha, cupuacu, and valuable woods; convert the land to pasture and raise cattle; or

choose any combination of these land uses. The choices that these farmers make depend partially upon their past farming experience, assets, and information. These considerations can be represented using a probability model explaining the choices that a farmer can make between using sustainable agriculture and using slash-and-burn agriculture.

The development and analysis of this model is discussed in detail in Chapter 6. The analysis tests the role that information, education, and local organizations play on farmer choice. It is suggested from the literature review that the more highly educated farmers who have knowledge of sustainable agriculture and participate in local farm organizations are more likely to adopt sustainable agriculture. Variables such as education level, knowledge of sustainable agriculture, union participation, and others are investigated in the analysis. This chapter discusses models which estimate the probability of adopting a new technique of agriculture and provides the motivation for the model which is used in the analysis.

4.6 The Introduction of Diffusion and Adoption to Economic Literature

The diffusion of innovations in agriculture was introduced to the economic literature with the seminal work of Griliches (1957). The literature now contains a broad spectrum of approaches and models to the diffusion process and the adoption decision of the farmer. Essentially these approaches differ from one another in their degree of, concern with, and emphasis on, the relative importance of different factors and variables which are likely to influence the adoption of an innovation (Argarwal 1983).

The adoption model developed by Griliches was further refined by Mansfield (1971).

Mansfield defined the pattern of adoption by a logistic or S-shaped adoption curve of increases in the number of farmers who adopt the new technology, plotted against time (Figure 4.2). When an innovation is first introduced, a firm may be uncertain regarding its profitability and success should the firm adopt it. This uncertainty is reduced over time as the information about the innovation and the number of firms which adopt it, accumulate. As the information increases, the probability that the innovation will be adopted increases, resulting in an S-shape diffusion curve or a logistic (learning) curve.

The rationale for this diffusion pattern through time is that the adoption of an innovation accelerates initially as it becomes more widely known and competitive pressure compels its adoption. Eventually the rate of adoption slows as the number of firms not employing the innovation declines. When the technology is first introduced, the prospect of an innovation can offset the risks associated with the use of a new process, and as more firms adopt it the risks are further reduced. Uncertainty is reduced in proportion to the number of firms already using the technology. The speed of the response is assumed to be related to the size of the stimulus.

Mansfield tested the model on a sample of 12 process innovations in 4 industries: bituminous coal, iron and steel, brewing, and railroads. He found that his model could support the logistic diffusion pattern of adoption very well. He also explored interindustry diffusion and found that the diffusion patterns differ among industries, finding a more rapid rate in more competitive industries. The next section contains a discussion of studies which investigate agricultural technologies in developing countries that are based upon this diffusion theory.

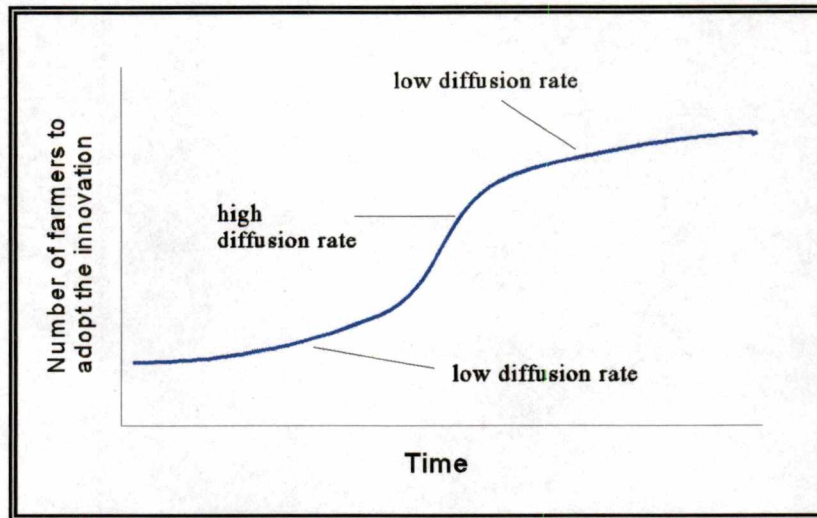


Figure 4.2
Logistic Diffusion Curve

4.7 Overview of Agricultural Adoption Literature

The seminal work of Griliches (1957) first introduced the adoption choice by farmers to this literature. In this paper, Griliches studied the factors responsible for the wide cross-sectional differences in past and current rates of the use of hybrid corn in the United States. Griliches derived a diffusion path of adoption and concluded that “the process of innovation, the process of adopting and distributing a particular invention to different markets and the rate at which it is accepted by entrepreneurs are amenable to economic analysis” (p. 501). Since the Griliches paper, studies have distinguished between two and three categories into which the adoption choice studies fall (Adesina and Zinnah 1993, Nowak, 1987, Argarwal 1983), but since then four distinct paradigms have surfaced which can categorize adoption decisions of farmers in developing countries. These categories include the human capital framework, the innovation diffusion framework, the economic

constraint framework, and the adopter perception framework (see Table 4.1).

4.7.1 The Adoption Choice Frameworks

The human capital framework and innovation diffusion framework were the first to be explored in the literature. Griliches' paper (1957), the first study of the adoption and diffusion of new technologies, falls into the human capital category. The economic constraint framework was soon to follow (Adesina and Zinnah 1993, Nowak, 1987, Argarwal 1983). The adopter perception framework is the most recent approach to be examined (Adesina and Zinnah 1993). A review of these four adoption choice frameworks is provided in the following four sections. Each of the frameworks is first defined, followed by a review of some studies which fall in the appropriate category. The model of adoption of sustainable agriculture by small scale farmers in Ouro Preto do Oeste investigates the role that each of these frameworks can make in the adoption decision. The importance of issues such as human capital constraints, economic constraints, the role of information, and farmer perceptions are investigated in the model.

Although the distinction between paradigms is not always obvious, the category in which each study falls is based on the factor that influences the adoption decision the greatest. In addition, a few examples of how studies of this type may be extended past the adoption decision are examined in section 4.35. In addition to providing a description of studies, Table 4.1 arranges the studies discussed in the following sections by category.

Table 4.1
Framework of the Literature Review

The Adoption and Diffusion of New Farm Technologies Studies in Developing Countries				
	Framework			
	human capital model	innovation diffusion paradigm	economic constraint model	adopter perception model
Assumption	the adoption of a new technology is determined by characteristics which are unique to that individual	the access to information is a key factor to determining adoption decisions	economic constraints are the major determinants of adoption behavior	the perceived attributes of innovations condition adoption behavior
Studies	Strauss <i>et al.</i> (1991), Lin (1991), Akinola and Young (1985)	Hussain <i>et al.</i> (1994), D'Souza <i>et al.</i> (1993), Feder and Slade (1984), Opare (1977)	Miller and Tolley (1989), Holden (1993), Kebede <i>et al.</i> (1990), Jaeger and Matlon (1990), Norris and Batie (1987), Savagado <i>et al.</i> (1994), Rahm and Huffamn (1984), Shakya and Flinn (1985)	Saha <i>et al.</i> (1994), Adesina and Zinnah (1993), Gould <i>et al.</i> (1989), Lynn <i>et al.</i> (1988)

4.7.2 Human Capital Framework

The human capital framework suggests that the adoption of a new technology by an individual (firm or person) is determined by characteristics which are unique to that individual (Strauss *et al.* 1991, Lin 1991, Akinola and Young 1985). In the case of farmers these include: education, age, experience, and family size. According to this framework only those individuals who fit a certain character type will adopt the new technology (i.e. those in a certain age and education cohort).

The human capital framework was inspired by Shultz (1964) who argued that the frequent introduction of new technologies results in a disequilibrium and suboptimal use of inputs and technologies even though in static agriculture, resource allocation is efficient. Thus, changes in the technological environment increase the farmer's ability to perceive, interpret, and respond to new events in the context of risk.

Other studies which fall into the human capital framework are Strauss *et al.* (1991), Lin (1991), and Akinola and Young (1985). Strauss *et al.* (1991) studied the role of education and extension programs in the adoption of technology of rice and soybean farmers in the central-west region of Brazil. The authors found that farmer education has a positive impact on the diffusion process of both upland rice and soybean technology adoption. Lin (1991) used the diffusion of hybrid rice in the Hunan province of China in order to examine the effects of education on the adoption of the new technology. The results of the Lin study are consistent with the hypothesis that those farmers with higher educations are more likely to adopt hybrid rice. In addition, Lin also found farm size to be

positively and significantly related to adoption, suggesting that smaller farms in China may pose restraint to technological change. Akinola and Young (1985) studied the decision process of individual cocoa farmers in Nigeria in order to determine the factors which influence their decisions which are made in terms of land-use and cocoa production. The authors found evidence that income, size of the family, age, and distance to the market have the greatest effect on the adoption of new coco techniques. In particular, they found that wealthier younger farmers were more likely to adopt the new technology.

The human capital framework suggests the need for the consideration of farmer and household characteristics. As the studies which have been reviewed have shown, characteristics such as education, age, and family size can play important roles in the adoption of new technologies by small farmers in less developed countries. These characteristics are, therefore, included in the analysis performed in Chapter 6. In the analysis education level and age play significant roles as in the studies by Schultz (1964), Strauss et al. (1991), Lin (1991) and Akinola and Young (1985). The human capital paradigm asserts that younger farmers are more likely to adopt new techniques and technologies. The analysis in Chapter 6 may or may not support this conclusion of the human capital paradigm, therefore, factors other than farmer specific characteristics are also investigated to determine the rate of adoption of sustainable agriculture in Ouro Preto do Oeste.

4.7.3 Innovation Diffusion Paradigm

The innovation diffusion framework asserts that access to information is a key factor to determining adoption decisions. The problem of adoption is reduced to communicating information on the technology to the potential end users. According to the framework, programs that emphasize the use and means of communication and on-farm prototypes can influence risk averse non-adopters to adopt (Hussain *et al.* 1994, D'Souza *et al.* 1993, Feder and Slade 1984, Opare 1977). Therefore, according to this framework, a rational farmer will adopt a superior technology when information is obtained about how it is used, and obtained, and/or information is gained as to its expected results. This information may be passed on through means such as government or non-government supported programs, independent research, or advice from neighboring farmers.

The innovation diffusion paradigm concentrates on the impact that knowledge of the technology can make on the adoption decision. Studies which fall under this framework are Hussain *et al.* (1994), Feder and Slade (1984), and Opare (1973).

Hussain *et al.* (1994) used the diffusion framework to determine the impacts of training and visit extension programs on the adoption of new wheat technologies by farmers in the Pakistan Punjab. The authors found that when the quantity of extension programs increased that quality did not necessarily increase equally. Even so, an increase in the number of extension programs increased farmers' knowledge and adoption of the new technology.

Feder and Slade (1984) determined how information affects the adoption decision of farmers in India and found that as farm size increases so does the information acquired, at

a cost by the individual farmers. And, as information increases so does the adoption of the new technology. Therefore farmers with larger farms, farmers with better access to information, or farmers with more human capital will adopt the new technology earlier than other farmers.

Opare (1977) investigated the adoption of new cocoa growing techniques in Ghana and found that the most important predictor of adoption is growers' knowledge of principles underlying recommended practices. The farmers who best understand the new technology are more likely to adopt it.

All three studies reviewed here support the theory that information and knowledge of a new technology can increase the rate of adoption. As the knowledge of the new technology increases, the rate of adoption is expected to increase. The studies also point out that the spread of information in rural areas of developing countries can be difficult. Information about sustainable agriculture is a relevant issue in Ouro Preto do Oeste. It was found that only 24 percent of the farmers who were interviewed had heard about or had knowledge of sustainable agriculture. Of those who knew about sustainable agriculture, 89 percent chose to adopt the new technology. These percentages suggest that information plays a vital role in the adoption of sustainable agriculture in Ouro Preto do Oeste. The role that information plays in the adoption of sustainable agriculture is therefore included in the regression analysis in Chapter 6.

4.7.4 Economic Constraint Framework

The economic constraint framework contends that economic constraints reflected in asymmetrical distribution patterns of capital and labor endowments are the major determinants of adoption behavior (Miller and Tolley 1989, Holden 1993, Kebede *et al.* 1990, Jaeger and Matlon 1990, Norris and Batie 1987, Savagado *et al.* 1994, Rahm and Huffman 1984, Shakya and Flinn 1985). Some constraints which may fall into this category for farmers are farm size, wealth, debt, capital equipment, and access to financial capital. According to this paradigm, when capital and labor constraints are not binding, adoption will occur.

Studies which fall under this framework include Miller and Tolley (1989), Holden (1993), Kebede *et al.* (1990), Jaeger and Malton (1990), Savagado *et al.* (1994), and Shakya and Flinn (1985). All six studies found that access to capital in the different forms (fertilizer, workers, money capital, farm equipment, and stored wealth) encourage the adoption of new technologies and crops.

In all these studies the access to capital, in one form or another, increases the rate of adoption. For example, Holden (1993) studied the adoption of new maize farming and fertilizing techniques in northern Zambia. Holden found, from the examination of six villages, that those areas which experienced rapid expansion of new maize and fertilizer technology had a favorable price ratio between fertilizer and maize output, limited access to off-farm employment, and a supply of capital equipment to handle fertilizer supply and maize marketing. These results imply that those farmers who cannot find off-farm employment are full-time farmers, and those which have access to capital equipment are

more likely to adopt the new technology. The economic constraint framework introduces the restrictions that the access to capital goods or equipment can pose, especially for small, poor farmers in developing countries.

The analysis performed in Chapter 6 investigates the role that capital constraints play in the adoption of sustainable agriculture in Ouro Preto do Oeste. Factors such as debt, capital equipment, and per capita income are investigated in addition to capital constraints such as labor availability and wealth.

4.7.5 Adopter Perception Framework

The adopter perception framework suggests that the perceived attributes of innovations condition adoption behavior (Saha *et al.* 1994, Adesina and Zinnah 1993, Gould *et al.* 1989, Lynn *et al.* 1988). The farmer's preconceived judgements of technology and their attitudes toward it determine their adoption choice. These perceptions can be influenced by a variety of social characteristics such as traditions and customs. This framework suggests that adoption is more likely to occur when local traditions and customs are accounted for.

Papers which fall in this category include Saha *et al.* (1994), Adesina and Zinnah (1993), and Gould *et al.* (1989). One study which focuses on incomplete information in the adoption process is Saha *et al.* (1994). The authors developed a framework of technology adoption under incomplete information dissemination and output uncertainty in order to determine the role that expected income gains from the new technology (among other variables) play in the adoption of a new technique among Texas dairy farmers which

can increase the milk production of cows by 10-20 percent. They focused on the analytical and empirical implications of incomplete information in the adoption process. They argued that producers' choices are significantly affected by their exposure to information about the new technology and determined that the farmers' expectations of yield and adoption costs are the sole determinants of the adoption decision.

Adesina and Zinnah (1993) found similar results when they tested the influence of farmers' perceptions of technology specific characteristics on the technology adoption decision of mangrove swamp rice farmers in Sierra Leone, Africa. Farmers' perceptions of the technology specific attributes of the modern rice varieties were determined to be the major influences in determining adoption.

Perceptions of new technologies and techniques can play a major role in developing countries where customs and traditions dominate economic and social behavior. New techniques and technologies that conflict with local traditions are not likely to be adopted by many farmers. The analysis in Chapter 6 does not investigate this paradigm in terms of attitude towards sustainable agriculture. Attitude or feelings toward a particular technique of agriculture are difficult to measure. Instead, the role of farming experience is investigated. It is expected that the farmers who have used slash-and-burn agriculture for many years are more likely to have adverse feelings towards different methods of farming.

4.7.6 Extensions of the Adoption Literature

The following articles are a small sample of how the adoption choice literature may be extended past the adoption decision. One possible extension is that simulations can be

made based upon the probability results and regional characteristics and statistics to determine the impacts of the new technologies on local economies, welfare distribution, and the environment.

Renkow (1993) used a multi-market model of technical change in food production in order to simulate the long-run economic impacts of various technological programs available for wheat farmers in Pakistan. Renkow was interested in determining whether policies which promote new wheat technologies are evenly distributed among income groups. Using data collected in a 1987 survey in the Punjab province, Renkow determined that the traditional programs which promote adoption of the new technologies are reasonable. Capital assets of the family prior to adoption do effect the benefits received. Net consuming households, those which purchase more farming products than they produce, stand to be the major beneficiaries of productivity increases resulting from the technological progress.

Coxhead and Warr (1991) investigated the distributional effects of technological changes using a computable general equilibrium model to simulate three hypothetical forms of technological change: factor neutral - labor saving, capital using and, labor using - land saving. The nature and magnitudes of these technological changes are illustrative of individual technical innovations in developing country agriculture. The model distinguishes between commodities which are traded internationally from those which are not, technologies which are fixed from mobile factors of production, and technologies which contain technical changes from different factor biases. The simulations suggest three conclusions: that farmers who do not adopt the new technology may be forced to do

so later on due to losses, that other sectors may suffer when technological improvements are made in the agricultural sector, and that gains from production may be constrained when there is a lack of necessary complimentary inputs.

4.8 The Role of Adoption Choice Models in Developing Country Studies

The four major frameworks in the literature on technology adoption each emphasize different factors which are important in the adoption choice. This research will help determine which factors are the most important in the adoption of sustainable agriculture in the Ouro Preto do Oeste region of Brazil. A key to understanding why more farmers do not choose new technologies in developing countries may be a lack of capital assets and requirements, infrastructure problems, governmental intervention, and a wide variety of other considerations that are unique to each region, as the four paradigms discussed suggest. In addition, the analysis in Chapter 6 investigates the role that farm unions and associations play in the adoption of sustainable agriculture. These organizations have served as a means of spreading information on sustainable agriculture. Unions provide educational programs on how to plant the inter-cropping systems and harvest honey, and have provided, free of charge, the seedlings which are used in inter-cropping.

The analysis of farmers in Ouro Preto do Oeste is interesting since no initial capital investment is required for those farmers who receive free seedlings from local organizations and unions. Economic theory predicts that the capital investment and risk averse behavior are the major deterrents to the adoption of new technologies. According to this theory, the adoption of sustainable agriculture should, therefore, be relatively high

in Ouro Preto do Oeste since the capital investment is zero and because the risk is relatively low. The risk is reduced as farmers learn about the experiences of other farmers who have adopted sustainable agriculture at union organized workshops. The diffusion of sustainable agriculture is, however, low. One major reason for the low diffusion rate could be that the area is lacking in a developed communication system. Technical feasibility and increases in yields, income, and/or production are not enough to guarantee adoption in developing countries. Information and the diffusion of information also play a major role and for this reason these variables are investigated to determine the role that they play in the adoption of sustainable agriculture in Ouro Preto do Oeste.

This chapter has investigated the market failures which have led to deforestation in the Brazilian Amazon. The analysis determines that addressing the market failure on the local level can reduce deforestation rates rapidly if sustainable agriculture is adopted by many of the farmers who use slash-and-burn agriculture. This chapter continues by reviewing how the economic literature on the adoption of new farm technologies in developing countries has emerged from the seminal work of Griliches (1957) to include not only human and economic characteristics, but also economic constraints, information constraints, and farmer perceptions. In addition to progress in the economic and social considerations, the modeling techniques that are used to illustrate the dichotomous choice of adopting a new technology or not, have also advanced from simple ordinary least squares (OLS) models to probit and logit probability models, to more complex discrete choice models such as tobit and Heckman models. The advancement of the modeling techniques in this literature is discussed in Appendix D.

CHAPTER 5

DATA COLLECTION AND ANALYSIS

5.1 Data Used in the Analysis

The data which are used to estimate the probability of adopting sustainable agriculture and the extent of adoption consist of data collected in Ouro Preto do Oeste, Rondônia from small farms. The goal of the data collection was to develop information which allows for the testing of hypotheses about the determinants of participation in sustainable agriculture. The data set is used to determine which factors can best promote the adoption of sustainable agriculture by more farmers. The data are a micro level grouping of small farm information collected using an oral survey conducted at the homes of a majority of the farmers. A select number of the variables collected are used in the regression analysis which is described in Chapter 6. This chapter describes the data collection process, survey design, and data in detail.

5.2 Survey Design

The data used in the analysis of farmer behavior in Ouro Preto do Oeste, Rondônia were collected over a five month period and are divided among two different groups. The first group was collected according to stratified random sampling, and the second group was collected from farmers who participated in the local farmer union, the Association of

Alternative Producers (APA). The survey, designed to be given orally, was written according to the guidelines in Fink and Kosecoff (1985) for cross-sectional data collection. An oral questionnaire was chosen since a majority of the people who were interviewed do not read or write. A majority of the questions are closed-ended with several choices since these are more precise and, therefore, easily transferred into data which can be used in regressions analysis. All terms are defined fully in the questionnaire, which is attached as Appendix B, in English, and Appendix C, in Portuguese.

The survey was preceded by an introduction by the assistant, Walmir de Jesus, a farmer from the area, who explained the purpose of the survey, described the research to be conducted with the information gathered, and identified the interviewer and her qualifications. There was no compensation offered to respondents. Objective facts about the family and household were asked first and the more subjective questions were asked afterward. The survey ended with closed-ended questions in category scales (a lot of influence, some influence, no influence) which could be answered quickly after the end of a long interview (a range of 30 to 60 minutes).

Standardized interviewing techniques (Fowler and Mangione 1990) were used in order to minimize interviewer related error. The questions were read exactly as worded. Participation by the assistant, Walmir de Jesus, a native to the area, was done in the same manner in each interview. The answers only reflected what the respondent said. Differences in interviews may have occurred between early and late interviews as the interviewer learned to speak Portuguese better. The assistant, fluent in Portuguese, had to intervene more often in the early interviews.

The surveys developed by Witcover and Vosti (April, May 1996) for research in the Brazilian Amazon, were used as guidelines for questions about native trees and local farm practices, such as the differences in harvest in the rainy and dry seasons and the names of native trees and fruits. In addition, local terminology in terms of the Portuguese language and farming terms were aided by a review of these surveys.

The Witcover and Vosti surveys (April, May 1996) were conducted as part of a project by the International Food Policy Research Institute (IFPRI). The Institute's research program reflects a worldwide collaboration to identify and analyze alternative national and international strategies for meeting the food needs of the developing world on a sustainable basis, with particular emphasis on low-income countries and the poorer groups in these countries. Those surveys were administered to approximately 150 small to medium scale households in two colonization projects of western Brazilian Amazon in the states of Acre and Rondônia. The purpose of the project was to provide socioeconomic information on land-use patterns, the factors hypothesized to influence land-use decisions, and demographic characterizations of the households.

The final form of the questionnaire which was administered in this study evolved through approval by a University of Tennessee research and survey committee, review of the Witcover and Vosti surveys (April, May 1996), and collaboration with University of Amazonas socioeconomic researchers and Brazilian surveyors in Ouro Preto do Oeste. The survey was pilot tested on farmers who participate in the University of Amazonas agricultural programs and at the labor union of rural workers headquarters in Ouro Preto do Oeste (Sindicato dos Trabalhadores Rurais- STR). A total of 12 pre-tests were

administered. These pre-tests were followed by discussions and modifications to the document to answer the realities met in the field.

5.3 Data Gathering

It was determined that about 150 farmers and their families would be interviewed in the city of Ouro Preto do Oeste. This total represents 4.49 percent of the populated lots in the city. This total was chosen in order to collect a representative sample of the area (in terms of population of the six counties of Ouro Preto do Oeste) considering time and budget constraints.

The interviews were conducted over a five month period (September 1996 - January 1997). The limited time period permitted the desired number of interviews to be collected, but did not allow for many interviews to be conducted at the home of the farmers in January, the height of the rainy season. This is when many of the Association of Alternative Producers (APA) member interviews were conducted at APA headquarters. Budget constraints allowed for the interviewer to be assisted by a local farmer, who was payed, and for a jeep, which was rented, but could not allow for the interviews to be extended through the assistance of additional interviewers. Additional interviews were collected in each of the six counties beyond the goal number of interviews, to allow for some of the interviews to be dropped if the analysis determined any observations to be outliers. These additional interviews brought the total number of the city interviews to 171.

The first data set which was collected is a stratified random sample of 171 farmers

who live in the city of Ouro Preto do Oeste which represents 1.47 percent of the rural population, 3.07 percent of total farm lots, and approximately 5.12 percent of the populated lots. The data set is stratified in order to represent each of the six counties equally according to the number of lots residing in each. The advantages of this type of sampling over simple random sampling is that it is more precise and it permits the surveyor to choose a sample that represents the various groups and patterns in the desired proportions (Fink and Kosecoff 1985). The second data set is a sample of 25 farmers who participate in the labor union APA. The data represents 64.10 percent of the active members. The population of the Ouro Preto do Oeste is 97,941 according to 1994 census updates, 11,617 of which is rural and 86,324 of which is urban (Editoria Turística 1994). The city is divided into 6 different counties: Ouro Preto, Valé do Pariso, Nova União, Mirante da Serra, Urupá, and Teixeropolis, see Figure 5.1 for a map of these six regions. The center of the city of Ouro Preto do Oeste, the county of Ouro Preto, serves as the city center, and contains the post office, bank, and farm and labor unions. This county is developed to a greater extent compared to the remaining five counties. Ouro Preto county has well developed infrastructure in the forms of well organized markets and stores as well as electricity and telephone services. The five remaining counties have well developed markets in the center of the counties, but are lacking in electricity and telephone services. The six different counties are divided according to the year of settlement, soil type, and geographical boundaries.

The 150 interviews were divided among these six different regions according to population density and number of farms lots in the region in a stratified random sample.



Figure 5.1
Map of the City of Ouro Preto do Oeste: Division Among the Six Counties

The interviews were divided according to the number of lots in each region, in an attempt to represent each region spatially in terms of populated lots, since the purpose of this research is not only to represent the farmer but also to represent the land use in the city of Ouro Preto do Oeste. See Table 5.1 for population and lot numbers.

The smallest number of interviews were conducted in Ouro Preto county. Although this area had the highest rural population, it has the smallest number of farm lots and, therefore, was allocated the smallest number of interviews. Ouro Preto county has 440 lots, comprising of 7.9 percent of the total lots in the city. Therefore 7.9 percent or 12 of the total 150 goal interviews were conducted in this area. The remaining number of

Table 5.1
Population Figures

Ouro Preto do Oeste City Population 1994						
	Rural Population	Urban Population	Total Population	Number of Lots	Average* Size of lot (hectares)	Beginning Year of* Settlement
Ouro Preto	4462	40156	44618	440	101.53	1970
Vale do Pariso	1395	9097	10492	1239	92.96	1976
Nova Uniao	1492	9340	10772	991	80.90	1978
Mirante da Serra	1360	8870	10230	703	44.10	1980
Urupa	1763	11001	12765	1362	33.39	1980
Teixeropolis	1205	7860	9065	834	85.20	1976
Total	11617	86324	97941	5569	70.64	
Source: "Estado de Rondônia: Rodoviário, Político, e Estatístico: Nova Divisão Política," (Map) Editora Turística e Estatística LTDA, Gioãna, Gioás, 1994.						
* based on the survey which was conducted as part of this research						

interviews were calculated in the same manner (Table 5.2)

There are two reasons why the Ouro Preto county has the highest rural population and the smallest number of lots. First, since this was the first area to be settled, the lots which were given away by the government were, on average, 100 hectares, while the lots which were given away and sold by the government in later years were smaller. Ouro Preto, therefore, has more people, on average, living on each lot. Second, the rural population was overestimated by the Brazilian statistical agency (Editora Turística e Estatística). In the early settlement years of the 1980's the rural population represented 11 percent of the total population, but it is likely that this percentage has changed since the 1980's. However, it is this percentage which is used to estimate the 1994 rural population (Editora Turística, 1984). This percentage has likely decreased over the ten year settlement of the area as the central urban area has developed and other, more rural counties have expanded around the city center. The overestimation of rural population is another reason that the number of lots is used for the stratified random sample rather than the rural population figures.

The distance between interviews, in terms of lots, was determined in order to represent the areas equally, and to obtain spatial variation in topography, soil type, and other spatial characteristics. These six areas of the city are similar in topography and soil type and have been settled according to soil production. The best soils were settled first, leaving the lower quality soils to later farm establishments. Again referring to the Ouro Preto county, since the goal number of interviews, 12, is determined to represent 440 lots equally in terms of space every 37th house was chosen. However, the number of lots

Table 5.2
Lot Statistics

Agricultural Lots In Ouro Preto do Oeste 1996-1997					
	fraction of lots in municipal	calculated # interviews	goal # of interviews	# lots between interviews	actual # of interviews
Ouro Preto	0.0790	11.85	12	36.66	15
Vale do Pariso	0.2225	33.38	33	37.55	35
Nova Uniao	0.1780	26.70	27	36.70	36
Mirante da Serra	0.1262	18.93	19	37.00	24
Urupa	0.2446	36.69	36	37.83	36
Teixeropolis	0.1498	22.47	23	36.26	25
Total	1.0001	150.015	150		171
Source: "Município de Ouro Preto do Oeste" (Map) Ministério da Agricultura, Instituto Nacional de Colonização e Reforma Agrária, Coordenadoria Especial do Estado de Rondônia, 1984.					

between interviews determined for each area were difficult to maintain since on average 30-50% of the lots are uninhabited. Instead each 10-20 lots were interviewed, depending upon the number of uninhabited lots in the county.

If the house was unoccupied at the time of the interview or the owner of the lot was not available (or a relative of the owner), the next house on the same side of the road was interviewed, and if the same occurred at the next house, the next house was interviewed on the same side of the road. This occurrence was generally uncommon since most of the farmers stay close to, or on, their lots during the time of year the surveys were conducted, (September - December) which is the end of the burning period and the beginning of the planting season.

There was only one refusal to participate in the survey. This was in the Mirante da Serra area. The high response rate is attributed to two factors: first, culturally, Brazilians are generally very hospitable to strangers and would go out of their way to make anyone comfortable; and secondly, because of the lack of contact with people, the farmers were generally happy to see and talk to outsiders. Most of the farmers and their families do not leave their farms on a daily basis (especially during the rainy season) due to a lack of transportation, long distances to town centers, and very poor road conditions.

The target number of interviews was reached and surpassed in five of the six counties (Table 5.2). A few extra interviews were conducted, when possible, in case some of the interviews had to be dropped.

The majority of the 25 APA interviews were completed at the labor union/association headquarters when different members arrived for meetings or brought in their harvest of

honey. Interviewing these members at the headquarters could possibly lead to a bias since the other interviews were conducted on the farm lots. Many of the APA members were visited during the five month interview period to learn about and observe the inter-cropping systems. During these visits questionnaires were not administered, but these farmers were interviewed at APA's headquarters after these visits when other lots were difficult to visit. These visits minimized the possible bias which could result from conducting the interviews off of the lot. These interviews were conducted at the labor union headquarters during the month of January, the height of the rainy season when travel to the farm lots is difficult and often impossible.

5.4 The Survey

The survey questions consisted of inquiries about the individual farmer, the family, characteristics of the lot, harvest, other forms of income in addition to farming, knowledge of sustainable agriculture, use of sustainable agriculture, and major influences determining farming techniques. This information is applied to the estimation of the probability that a farmer will adopt sustainable agriculture or become a member of the organization APA which supports the sustainable use of the forest. It is likely that these estimations rely greatly on farm and farmer characteristics.

The questions concerning individual farmer included inquiries about age, education level, and experience farming. Family questions included information about family size, age of the family members, education levels, farming equipment owned, other types of equipment, and number of farm animals (including cattle, pigs, chickens, sheep, and

goats). Characteristics like these generally influence the decisions that farmers and households make. For example, as the level of education of the household increases, it is expected that the knowledge of sustainable agriculture and groups like APA would increase, and therefore increase the probability of adopting sustainable agriculture or becoming a member of APA. It is expected that age, education, equipment, and durable goods have a positive relation with the probability of adopting sustainable agriculture.

Lot characteristics which were collected include the size of the lot, number of hectares of: pasture, primary forest, secondary forest, agriculture, and inter-cropping. It is expected that the division of the lot between forest, agriculture, and pasture will affect the dependent variable; the probability of adopting sustainable agriculture. It is expected that those farmers who practice sustainable agriculture have larger areas of virgin forest since they do not have to cut and burn the forest to plant crops. But a conflicting factor which may also increase the probability of adoption is a small amount of virgin forest. Those farmers who hold relatively small amounts of virgin forest may need to find an alternative way of farming as the amount of land that can be converted to annual crops approaches zero. This can support the effect that necessity can play in the adoption decision. It is expected that the average number of hectares burned per year decreases as the probability of adoption increases since the farmers who use sustainable agriculture are expected to burn less on their lots.

Questions about agriculture income and income unrelated to agriculture were also asked. Income unrelated to agriculture includes income from social security and jobs such as the selling of perfume or crafts or any other service unrelated to farming. Questions

about income derived from agriculture provided information about the harvest of all perennial and annual crops, milk harvest, and meat harvest, the amount of each item that was sold, and at what price. It is expected that as income increases the probability of adopting sustainable agriculture will increase as well. Those farmers with higher incomes have a lower risk which is associated with the adoption of new land uses. If the new land use fails, those farmers with higher incomes have greater income reserves to rely on.

The farmers knowledge of any type of sustainable agriculture was recorded for both groups of farmers and, if sustainable agriculture was used, then in-depth questions were asked as to the extent, the number of years of use, generated income, and income and crop harvest before the use of sustainable agriculture. This information is used to determine if income is greater for those farmers who have adopted sustainable agriculture.

The last section of the survey attempts to determine the major factors which could effect the agricultural practices of the farmer. Questions were asked to determine the extent of the effect that family, neighbors, free seedlings, free seed, bank loans, valuable wood, and soil type have on the farmers choice of agricultural techniques.

5.5 Data Overview

Data collected in these interviews are used in the modeling and analysis chapter, Chapter 6. The variables derived from the data collection and their abbreviations are presented below. A brief overview of the most pertinent variables including farm and family characteristics, lot characteristics, wealth measurements, income, and harvest are presented in the following tables. These variables are divided among the two data groups:

non-APA members and APA members and are shown in terms of mean, standard deviation (in prentices), and percentage (where appropriate).

5.5.1 Variables

Farmer Characteristics

AGEHH- age of the household head (in years)
EDUHH - education in years of the household head (in years)
FARMEXP - years farming of the household head
FARMYEAR - years farming on lot of the family
UNION - number of associations/unions the family participates in
ST - state of birth
SP - state of birth of parents
OURO - dummy variable pertaining to Ouro Preto county
VALE - dummy variable pertaining to Vale do Pariso county
NOVA - dummy variable pertaining to Nova Uniao county
TEIX - dummy variable pertaining to Teixeropolis county
MIR - dummy variable pertaining to Mirante da Serra county
URUPA - dummy variable pertaining to Urupa county

Lot Characteristics

SIZELOT - size of lot
HECAGR - number of hectares devoted to agriculture
PERAGR - percent of lot devoted to agriculture
HECPAS - number of hectares devoted to pasture/second growth
PERPAS - percent of lot devoted to pasture/second growth
HECFOR - number of hectares devoted to primary forest
PERFOR - percent of lot devoted to primary forest
HECSA - number of hectares devoted to sustainable agriculture
DISTOPO - distance to city

Family Characteristics

FAMILY - number of family members living on the lot
MEN - men ≥ 10 years of age
BOY - men < 10 years of age
WOMEN - women ≥ 10 years of age
GIRL - women < 10 years of age
AVEAGEHH - average age of husband and wife (in years)
AVEDUHH - number of years of education (average of husband and wife)
AGEW - age of woman of household (in years)
EDUW - number of years of education of woman of household

YEAR - year of migration to Rondônia

GARDEN - garden size (in square meters)

number of the following items owned: horses, chickens, cattle, pigs, televisions, sheep, satellite dish, goats, tractors, equipment for use with animals, cars, trucks, motorcycles, wheel barrow, telephones, refrigerators, bicycles, other lots, other houses, city houses, workers, chain saws, other types of equipment

Burning

BURNDAY - number of days of work necessary to burn (1996)

BURNP - number of people working during burning (1996)

EQP- equipment used to burn (1996)

AVEBURN - number of hectares burned (2 year average - 1995 and 1996)

Production

HARANN - 1995 harvest annuals in bags (rice, corn , beans, manioc)

HARPER - 1995 harvest perennials - measured in number of fruit with the exception of coffee which is measured in bags (coffee, coco, banana, citrus, cupuaçu, pupunha, açaí, acerola, mahogany, other valuable wood, mango, coconut, jack, abacati)

Inputs: price and quantity (labor (days), fertilizer (bags), pesticides (bags), herbicides (bags))

MILK - production in number of liters (rainy and dry season), in reais (1996)

TOTINPUT - total inputs used for agriculture in reais (1996)

MILKINC - total milk income in reais (1996)

MILKPRO - total milk production in reais (1996)

Sustainable Agriculture

SEEDL - seedlings provided (1- yes 0 - no)

TOTINC - income after the use of sustainable agriculture in reais (1996)

USESA - use of sustainable agriculture (1- yes 0 - no).

KNOWSA - knowledge of sustainable agriculture

HECSA - hectares devoted to sustainable agriculture

YEARSA - year sustainable agriculture was first adopted

INCHO - other sustainable forms of income (bee-keeping, fish raising) in reais (1996)

HARBEF - Harvest before the use of sustainable agriculture in the year preceding the adoption

Influences in Farming Techniques and Choices (ranked from 1-3)

neighbors, association/union, free seed, free seedlings, bank loans, market for annuals, market for perennials, soil quality, standing precious wood, Ouro Preto farmers, parents

Income

MONEYINC - 1995 - 1996 income earned from agriculture (perennial+annuals+other forms+milk+income from sustainable agriculture (honey and fish)) - in reais (1996)

OTINC- other forms of income unrelated to agriculture in reais (1996)
 FAMINC - total family income (perennial+annuals-inputs+other forms+milk+income from sustainable agriculture (honey and fish)) - in reais (1996)
 PERCAP - income per capita - in reais (1996)
 PERMILK - milk as percent of income
 PERHON - honey/fish as percent of income
 PERANN - annuals as percent of income
 PERPER - perennials as percent of income
 VEH - vehicles owned in reais (1996)
 DURABLE - durable goods (vehicles+farming equipment+tractors+city houses) in reais (1996)
 RES - resources (durable goods + cattle) - in reais (1996)
 TOTINC - income after the use of sustainable agriculture - in reais (1996)
 TOTINCB - income before the use of sustainable agriculture - in reais (year preceding the adoption)

5.5.2 Data Comparison

Table 5.3 presents farm and family characteristics for the two groups of data (APA and non-APA farmers) which were collected. Comparing the two groups of farmers, there is a significant difference in the age, farming experience, and education levels between non-APA and APA farmers. APA members are on average younger, have less experience farming, and have higher education levels. There is no significant difference in the number of family members on the lot between the two groups.

Table 5.4 compares the lot characteristics of the two groups of farmers in terms of lot size and the activity to which the land is devoted. APA members and non-APA members, on average, hold similar size lots, but the division of the land among agriculture, pasture, virgin forest, and inter-cropping varies. APA members do not hold a significantly different number of hectares devoted to agriculture or pasture. However, APA members do hold a significantly greater number of hectares which are devoted to primary forest and

Table 5.3
Farm and Family Characteristics of Farms in Ouro Preto do Oeste

Farm and Family Characteristics* comparison of the stratified random sample (non-APA members) and APA members			
Characteristics	Non-APA Members (n=171)	APA Members (n=25)	t -statistic
Average Age of household heads (years)	46.20 (12.97)	33.62 (6.35)	7.77
Number of Years Farming of the household head	36.57 (14.89)	24.12 (7.39)	6.67
Number of Years on the lot of the household head	17.18 (5.86)	16.48 (5.24)	17.18
Number of Years of School of the household heads	2.48 (2.46)	3.86 (2.10)	-2.9
Number of People on the lot	8.42 (6.02)	9.89 (4.64)	-1.4
*The top number in each block represents the average and the number underneath in parenthesis represents the standard deviation associated with that mean.			

Table 5.4
Lot Characteristics of Farms in Ouro Preto do Oeste

Lot Characteristics* in hectares (1 hectare=2.47 acres)			
	Non-APA Member (n=171)	APA Members (n=25)	t -statistic
Size of Lot	70.64 (46.12)	74.45 (55.71)	-0.33
Agriculture	7.42 14.51% (6.54)	6.94 13.98% (5.87)	0.37
Pasture	46.45 61.54% (37.69)	33.46 43.58% (31.27)	1.89
Primary Forest	16.67 23.78% (18.88)	31.46 33.67% (34.09)	-2.12
Inter-cropping	0.11 0.17% (0.47)	2.59 8.78% (2.56)	-4.69
Average Burn/Year	6.70 (8.84)	2.025 (2.56)	5.51
*The top number in each block represents the average, the number underneath the first number represents the percentage of the lot devoted to each activity, and third number, underneath, in parenthesis, represents the standard deviation associated with that mean.			

intercropping. These comparisons support the idea that APA members have higher amounts of land devoted to the sustainable uses of the forest in comparison to the average farmer.

Table 5.5 presents the various ways in which wealth can be measured among the rural farmers. Comparing the two groups of farmers, APA members have less cattle, land, and durable goods in terms of city houses, but none of these vary significantly from non-APA members. The only significant difference between the two groups in terms of the wealth measurements is the difference in vehicle value. The value of vehicles is significantly higher for non-APA members. The value of the land is estimated based on the resale value of the total lot for each county. An average resale value was estimated based on data on average resale value per hectare for each county from the local labor union of rural farmers¹⁵ and from farmers who had sold or bought lots in 1996. The value of the land is based on the estimated value of land for each county and reflects the capitalized value of soil quality based upon annual crop productivity. The similarity in wealth between the two groups of farmers suggests that capital equipment and capital resources may not be required to adopt sustainable agriculture.

Table 5.6 provides information on family income and income distribution among different activities. APA farmers have, on average, a significantly higher dollar income in agriculture, due to a higher income from perennial crops (rather than annual crops). APA members also have a lower dollar income in terms of milk, but a higher average income from honey and fish. The income of APA member families is higher but not significantly

¹⁵ Sindicato dos Trabalhadores Rurais (STR), Ouro Preto do Oeste, Rondônia.

Table 5.5
Wealth of Farmers in Ouro Preto do Oeste

Wealth Measurements* (in Brazilian Reais R\$1= \$US1) ¹⁶			
Activity	Non-APA Members (n=171)	APA Members (n=25)	t-statistic
Cattle	16,250.00 (17846.10)	12,280.00 (8763.29)	1.78
Durable Goods (farm equip, city houses, vehicles)	22,054.86 (24003.88)	18,444.00 (13821.01)	1.08
Farming equipment	2,260.99 (26601.99)	2,958.00 (7333.34)	-0.43
Houses in the city	584.80 (2591.30)	2,200.00 (5016.64)	-1.58
Vehicles	2,959.07 (8145.26)	1,000.00 (16005.23)	2.79
Land - total value of land, lot size is variable	26,225.61 (22862.96)	25,468.00 (19690.14)	0.18
*The top number in each block represents the average and the number underneath, in parentheses, represents the standard deviation associated with that mean.			

¹⁶ This exchange rate represents the average exchange rate for 1996 according to the National Trade Data Bank and Economic Bulletin Board - products of Stat -USA, U.S. Department of Commerce (1997).

Table 5.6
Income from Farm and Other Activities of Farmers in Ouro Preto do Oeste

Family Income (September 1995 - August 1996) (in Brazilian Reais R\$1=\$US1) ¹⁷			
Activity	Non-APA Members (n=171)	APA Members (n=25)	t-statistic
Agriculture (annuals+perennials- work and fixed costs)	2,112.56 30.06% (4338.03)	3,527.52 44.22% (2817.90)	-2.16
Annuals	496.01 12.30% (1017.52)	695.56 10.63% (828.38)	-1.09
Perennials	1,616.55 21.67% (4206.50)	2,831.96 35.49% (2797.34)	-1.90
Milk	2,612.05 47.52% (3177.40)	1,763.57 23.81% (1493.71)	2.20
Fish and Honey	9.06 0.08% (93.78)	1,194.76 17.54% (964.03)	-6.15
Other (social security and any income unrelated to farming or agriculture)	1,718.57 25.59% (4627.06)	182.96 16.64% (2058.18)	0.40
Total	6,309.52 (7588.84)	6,654.11 (4331.15)	-0.33
Total Per Capita	1,055.40 (1790.63)	841.13 (496.37)	-7.08
*The top number in each block represents the average, the number underneath the first number represents the percentage of family income devoted to each activity, and third number, underneath, in parentheses, represents the standard deviation associated with that mean.			

¹⁷This exchange rate represents the average exchange rate for 1996 according to the National Trade Data Bank and Economic Bulletin Board - products of Stat -USA, U.S. Department of Commerce (1997).

different than non-APA members. Per capita income is, however significantly lower for APA members. Further analysis is necessary in order to determine how the difference in family income effects agricultural practices. APA members do have higher percentage of income coming from the activities which support sustainable uses of the forest such as honey and fish harvesting and perennial crops and a smaller dollar income (and smaller percentage of income) in the activities which are more destructive to the forest such as the harvest of annual crops and milk harvest (which requires large plots of pasture). The income value in Table 5.6 does not include household consumed crops. For this information see Table 5.7 which includes a dollar value of all harvested crop, including those crops which are sold in local markets and consumed in the household.

Table 5.7 provides information on the total value of the agricultural harvest and the distribution of this value among different farm activities. Harvest value is the total harvest of agricultural crops in dollar terms. Crops that were sold on the market are used in the estimation at there market values. If the crop was not sold by the family, the average price for the crop in 1996 is used in the estimation of the harvest value. The information in this table is similar to that of Table 5.6. APA farmers have, on average, a significantly higher harvest value in agriculture, due to a significantly higher harvest value from perennial crops (rather than annual crops). APA members also have a significantly lower harvest value in terms of milk, but a significantly higher harvest value from honey and fish.

The largest difference between the income values and harvest values are the differences between total agriculture income (Table 5.6) and total agriculture value and between perennial income (Table 5.7) add perennial harvest value. The amount by which

Table 5.7
Total Value of Harvest from Farm Activities of Farmers in Ouro Preto do Oeste

Family Crop Harvest (September 1995 - August 1996) (in Brazilian Reais R\$1=\$US1) ¹⁸			
Activity	Non-APA Member (n=171)	APA Members (n=25)	t-statistic
Agriculture (annuals+perennials-work and fixed costs)	4289.07 (8715.80)	8939.54 (5425.05)	-3.6
Annuals	2500.70 (4978.47)	3465.47 (3429.92)	-1.21
Perennials	2055.02 (5252.70)	4165.19 (3384.77)	-2.46
Milk	2652.51 (3137.62)	1841.18 (1391.52)	2.18
Fish and Honey	19.76 (156.17)	1578.82 (1030.18)	-7.40
Total (annuals+perennials+milk +fish+honey)	7227.98 (9804.43)	11050.66 (6001.90)	-2.7
*The top number in each block represents the average, the number in parentheses, represents the standard deviation associated with that mean.			

¹⁸This exchange rate represents the average exchange rate for 1996 according to the National Trade Data Bank and Economic Bulletin Board - products of Stat -USA, U.S. Department of Commerce (1997).

milk income and milk harvest value differ is by the same percent for both the income and harvest values. The income for non-APA members is 1.5 times greater than the income for APA members while the harvest value for non-APA members is also 1.5 times greater for non-APA members. The use of harvest values therefore do not make any relative changes in the income data. The differences between annual and fish and honey income and harvest values are also similar between the two groups. There is large difference between income and harvest value of perennial crops for the two farmer groups. The income from perennial crops for APA members is 1.5 times greater than non-APA members. The value of perennial harvest is however different. The harvest value of perennial crops is two times larger for APA members than for non-APA members. This suggests that the difference between the two groups of agriculture income and agriculture harvest value is do solely to the difference in perennial income and value.

Perennial fruits are harvested from the inter-cropping plots. These results suggest that APA farmers are growing more of the fruits which are supported by inter-cropping, but that the markets in which these farmers can sell these products are undeveloped or lacking since the products are not being sold to the extent that annual crops and milk are being sold.

The number of hectares burned on average, over a two year period, and the percent of the lot burned, based on the same two year period are plotted in the following two graphs to determine if the two data groups differ in terms of burning behavior patterns. A two year average is used because it was determined that the number of hectares which are burned can vary greatly from year to year for each household. Two years was however,

the greatest extent to which the farmers could answer the questions which referred to their burning choices, accurately. Both of the figures (Figure 5.2 and Figure 5.3) plot the "percent of farmers" on the y axis. The percent of farmers is plotted in order to account for the different sample sizes. A comparison of these two graphs supports the premise that the two groups of farmers differ in terms of burning behavior and reinforce the need for further analysis. There are significant differences in the number of hectares which are burned between the two groups (Table 5.4) .

An analysis of these APA and non-APA members is made in Chapter 6 in order to determine the probability of adopting sustainable agriculture and to determine if the diffusion of sustainable agriculture can be increased with policy. The non-random sample, APA members, who support the sustainable use of the forest, provides a vital role in this analysis since the adoption of sustainable agriculture is very low among non-APA members. Less than 12 percent of the stratified random sample uses inter-cropping and/or harvests honey. The non-random sample of relatively homogenous households, permits for additional implications to be made about land use decisions. Variables such as income, lot size, the percent of the lot burned, land value, the number of unions which the family participates in, and the percent of the lot which is primary forest are used in the regressions analysis found in Chapter 6.

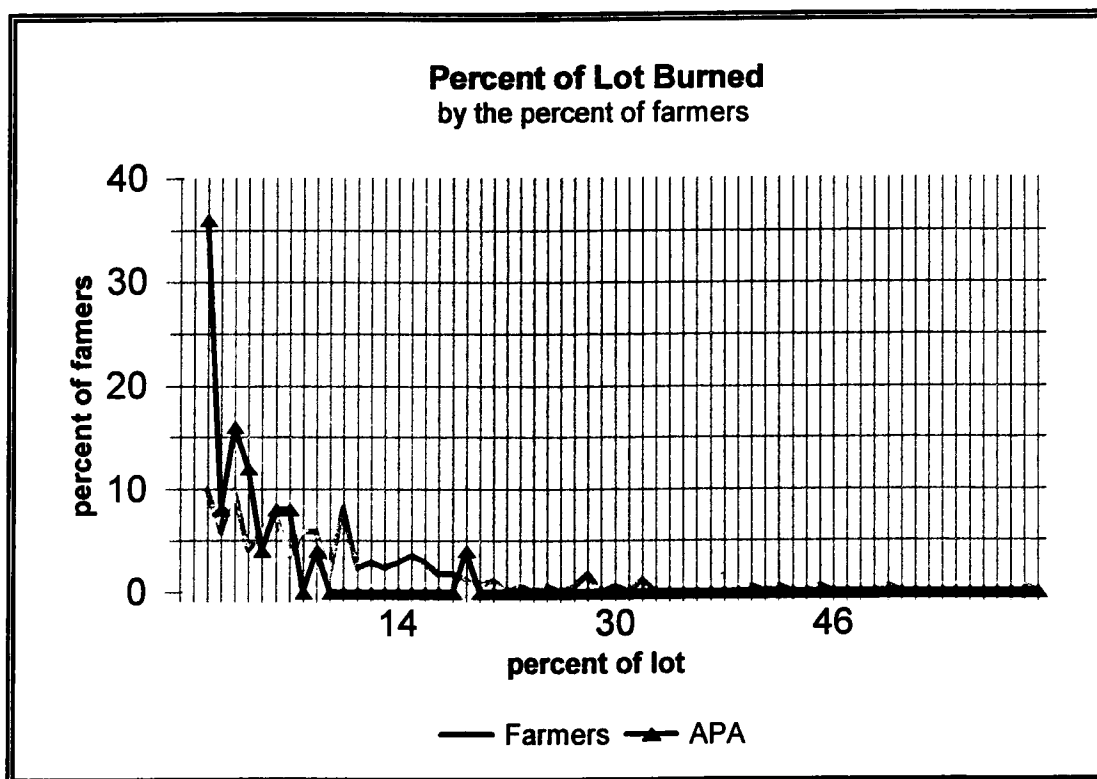


Figure 5.2
Percent of the Lot Burned by Farmer

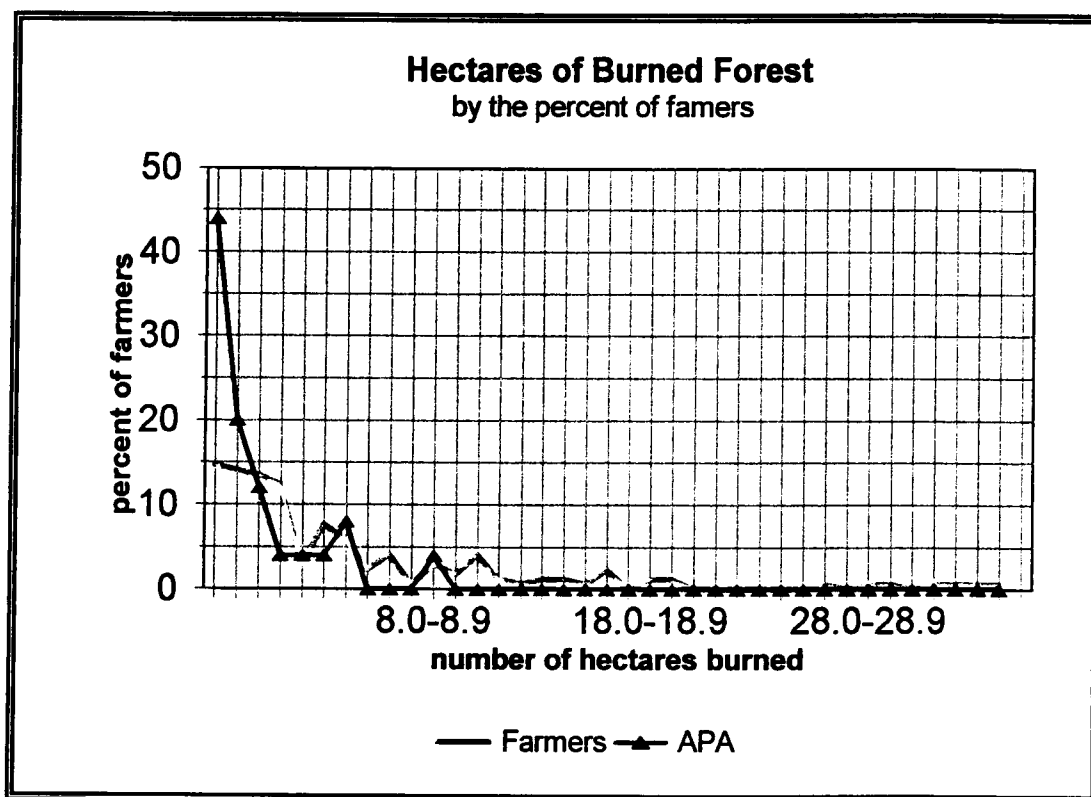


Figure 5.3
Number of Hectares Burned by Farmer

CHAPTER 6

THE ECONOMIC MODEL

6.1 Farm Choices and Decisions

The objective of this study is to test the role that different policy options can make on the farm family's decision to adopt sustainable agriculture. It has been asserted that the adoption of sustainable agriculture by farmers who use slash-and-burn agriculture can reduce deforestation rates considerably if adopted by enough farmers. One of the key issues that must be addressed is why the rate of adoption of sustainable agriculture is low in tropical forests of Rondônia, Brazil. If it can be determined why the diffusion rate is low, policies which address these issues can help to increase the adoption rate.

The choice to use sustainable agriculture is not necessarily a discrete choice, instead, a spectrum of alternatives exist. It is possible for a family to choose to convert a portion of their lots to sustainable agriculture and maintain annual crops, coffee, and pasture on other portions of the land. This option reduces the risk which may be involved in the sole use of sustainable agriculture. Risk is involved with the adoption of sustainable agriculture because the farm family is not familiar with the agricultural technique or the markets where these products can be sold. There is no certainty that the agricultural products that are cultivated in the sustainable agricultural systems can be harvested and

sold or provide the same profit range as annual crops. The markets for these products are not as formally developed as are the markets for annual crops and coffee.

Studies which have addressed local market failure in developing countries by the adoption of new techniques of agriculture have investigated a wide variety of technologies. A common theme throughout these papers is that the adoption of new techniques which increase welfare and/or income often have low diffusion rates (Holden 1993, Kebede *et al.* 1990, Sands 1986, Opare 1977). Many farmers are either not willing to adopt the new technology or are constrained by capital resources and cannot adopt the potentially superior technology. This observation was also made in Ouro Preto do Oeste. Only 10 percent of the farmers from a random sample used sustainable agriculture even though the technique was shown to improve welfare and income of those farmers who used it.

One might expect that sustainable agriculture would be adopted in Ouro Preto do Oeste because it requires less average labor per year for the farmer compared to slash and burn agriculture¹⁹ and also because the use of sustainable agriculture has the potential to

¹⁹ It is difficult to compare the labor required for each dollar of income derived from inter-cropping and sustainable agriculture since income varies greatly by the crop which is harvested. For example one hectare of rice yielded an average \$251 while one hectare of beans averaged \$264, and manioc averaged \$2507 per hectare. Comparing this to inter-cropping plots is also difficult because many of the crops which are produced in the inter-cropping areas are perennials which are native to the area, but are not yet sold in developed markets (as rice, beans, and manioc are). However, one can compare the average labor used per year for each. This can be an appropriate way to compare the two methods of agriculture because it was determined that there was no significant difference between the income before and after using sustainable agriculture, for those farmers who had once used slash and burn agriculture and switched to sustainable agriculture. But, it was found that there was a significant difference in the amount of labor that was required before and after the switch. Therefore, it was concluded that these farmers may be trading labor for leisure by adopting the new agricultural technique. In a sample of 25 farmers, it was determined that the burning of land to plant annual crops, in combination with planting, maintaining, and harvesting annual crops required 55% more hours of work per hectare than the planting, harvesting, and maintaining of one hectare of inter-cropped annuals and perennials. Complicating the comparison is the labor requirement for the harvesting of honey. Honey harvest

increase the profits of the family. Another benefit of adopting sustainable agriculture is that it does not require that the family burn their land each year to plant crops. It was found, in a random sampling of the farmers, that they burned an average of three hectares per year. Although this amount is small compared to a size of a majority of the lots²⁰, each hectare of burned forest means that there is less land available for future generations. Since property rights are now well established in the area, there is an incentive to maintain the production capability of the land since the property is an inter-generational investment. There are also costs which are incurred when sustainable agriculture is adopted. These costs include the initial set up cost (although for many farmers this is zero in Ouro Preto do Oeste since many of the seedlings which are used in inter-cropping have been provided free of charge by local agencies) and the risk which is associated with the adoption of a new technology in terms of production and income capability. Since there are benefits to adoption sustainable agriculture, this study focuses on policies which increase these benefits and make them evident to the farmers in the area.

is included in the definition of sustainable agriculture since this income source is not dependent upon the destruction of the forest. This crop is difficult to compare to the yield from slash and burn agriculture since it cannot be measured in hectares. Since of those farmers who sell honey, it represents a greater portion of income and requires less labor per year, it can be concluded that the farmer who adopts this income source can devote less time per year to the honey harvest than slash and burn agriculture. In a sample of 25 farmers, it was determined that the labor required to harvest the average number of liters of honey (harvested in one year), was 74% lower (in days per year) than the labor required to burn, plant, harvest, and maintain one hectare of annual crops (below the average of 2.5 hectares harvested per year), and 41% lower than labor required to plant, harvest, and maintain one hectare of inter-cropped annuals and perennials. On average, the income from honey represents 18 percent of total income, of those farmers who produce honey (APA members) while annual crops represent 10 percent of total income.

²⁰ A majority of the lots in Ouro Preto do Oeste are 100 hectares in size.

6.2 Family Utility Model

The decision to adopt sustainable agriculture is treated as a dichotomous choice. The farm family decision is made based on the utility which is derived from the chosen agricultural technique. The family chooses between using sustainable agriculture or slash-and-burn agriculture. This choice is not exclusive. When the decision is made to adopt sustainable agriculture the family may continue to cultivate annual crops.²¹ This utility is compared to the utility which the farm derives from slash-and-burn agriculture. In the original conception of this study, the adoption of sustainable agriculture was to be treated as a pure discrete choice decision. The farm family either used slash-and-burn agriculture or sustainable agriculture. However, as the interviewing progressed it was found that a majority of farmers who adopted sustainable agriculture also maintained annual crops on a portion of their lots.²² The choices which face the farmer are therefore represented in this analysis as choosing to use slash-and-burn agriculture or using sustainable agriculture exclusively or in combination with slash-and-burn agriculture. The farmer therefore chooses the combination of farming techniques which delivers the maximum utility. Since the adoption of sustainable agriculture is not a pure discrete choice decision, the extent of

²¹ Sustainable agriculture includes the inter-cropping of perennials with varying perennials and/or annuals, alone, or in combination with income sources, such as bee-keeping and aquaculture, which do not rely on the destruction of the rain forest. A farmer is counted as adopting sustainable agriculture if the family has inter-cropping plots and/or harvests honey. Fish raising is not included in the analysis since only one farmer cultured fish during the interview year, 1996. Eleven additional farmers stated that they began to raise fish in 1996, but would not harvest in that year.

²² The choice to maintain annual crops in addition to adopting sustainable agriculture reduces the risk which is associated with the new technology. It is assumed that once the benefits of sustainable agriculture are realized, the farmers will not need or desire to maintain annual crops.

adoption is also estimated for those farmers who adopt sustainable agriculture.

A utility maximization model is developed based on the supposition that farm families choose a set of agricultural practices based on the resources which are available, knowledge they possess, and constraints which limit these activities. The utility which is derived from the agricultural choices is not directly observable. The non-observable underlying utility function which ranks the preference of the farm family is derived from farm characteristics and characteristics of the specific technology.

The utility model chosen to represent the family decisions of the small scale farmers follows the family utility - family budget constraint model of Killingsworth (1983). Family utility, based on the combined family income and leisure, is utilized in this study instead of individual utility, since this best represents small farm behavior in Amazonia. Given that the individual consumption within the family unit cannot be observed, the family utility is the best measurement of farm activity. Discussions with the families in Ouro Preto do Oeste indicated that families act and make decisions as a single unit. Management decisions on crop production, distribution, inputs and mixes, the timing of operations, and work allocation are made by members of the household according to household goals and needs.

The family utility - family budget constraint model works similarly to the simple labor supply framework with one exception, that Ashenfelter and Heckman (1973) discuss. In this model the individual makes work decisions based on the effect of labor inputs of himself or herself and the labor inputs of all other family members. The most popular version of this model makes the assumption that these two substitution effects are reduced

to a pure income effect (Killingsworth 1983). This same assumption which reduces the demand equation to a simpler utility framework which behaves as a single consumer utility model will be used in this analysis. For other studies which make this same assumption see Bourguignon (1989), Bigston (1988), Bognanno *et al.* (1974) and Cohn *et al.* (1970).

6.3 The Conceptual Framework

Following Adesina and Zinnah (1993) and Rahn and Huffman (1984), the utility maximization of the family utility model is based on the non-observable underlying utility function which ranks the preference of the i th family according to the technology which is chosen. The non-observable underlying utility function is represented by: $U_{it}(M_i, T_i)$, where t represents the technology choice, $t=1$ when sustainable agriculture is used and $t=2$ when slash-and-burn agriculture is used exclusively. The utility is derived from the observable farm and family characteristics, M , (such as lot size, percent of the lot which is primary forest, and the number of hectares of secondary growth), and from the observable technology characteristics, T , (such as yield, income, and the labor and leisure ratio) where the technology refers to the agricultural method of the family. The choice of technology therefore determines the farm yield, family income, and the labor and leisure that the family can afford. The choice of the technology makes this determination since the crops which are harvested and method of planting differ according to the farm technique. Although the utility is unobservable, the relation between the utility derived from a specific technology is a function of the vector of the observed farm and technology characteristics included in the utility measurement. Therefore, although the utility is

unobservable and since its value cannot be calculated directly, the value may be implied by the farmer (firm) specific characteristics, X (e.g. agricultural technique, lot size, and soil productivity). The family chooses between U_{i1} and U_{i2} depending upon which technology yields the greatest utility. The utility of the chose technology is therefore estimated from the vector of observable farm and technology characteristics as follows:

$$U_{it} = \alpha_t F_i(X_i) + e_{it} \quad t = 1, 2; \quad i = 1, \dots, n \quad 6.1$$

where e_{it} is a disturbance term having zero mean.

Equation 1 is not restricted to be linear. The exact distribution of F depends on the distribution of the error term. The i th family will choose to use slash-and-burn agriculture if $U_{i1} < U_{i2}$, or if the latent variable $Y^* = U_{i2} - U_{i1} > 0$ and will choose sustainable agriculture when $U_{i1} > U_{i2}$, or if the non-observable latent variable $Y^* = U_{i1} - U_{i2} > 0$:

$$Y_i = \begin{cases} 1 & \text{if } U_{i1} > U_{i2}, & \text{sustainable agriculture is adopted} \\ 0 & \text{if } U_{i1} \leq U_{i2}, & \text{slash-and-burn agriculture is adopted} \end{cases} \quad 6.2$$

The probability that the farmer adopts sustainable agriculture or that Y_i equals one, is a function of the independent variables:

$$\begin{aligned} P_i &= Pr(Y_i=1) = Pr(U_{i1} > U_{i2}) \\ &= Pr[\alpha_1 F_i(X_i) + e_{i1} > \alpha_2 F_i(X_i) + e_{i2}] \\ &= Pr[(e_{i1} - e_{i2}) > F_i(X_i)(\alpha_2 - \alpha_1)] \\ &= Pr[\mu_i > -F_i(X_i)\beta] \\ &= F_i(X_i\beta) \end{aligned} \quad 6.3$$

where X is an $n \times k$ matrix of explanatory variables, and β is a $k \times 1$ vector of coefficients to be estimated.

$$U_{it} = \alpha_i F_i(M_i, T_i) + e_{it} \quad t = 1, 2; \quad i = 1, \dots, n \quad 6.4$$

where e_{it} is a disturbance term having zero mean.

The probability that the i th family adopts sustainable agriculture is the probability that the utility gained from slash-and-burn agriculture is less than the utility gained from sustainable agriculture or the cumulation distribution function of F for μ_i ²³ evaluated at $X_i\beta$. If u_i is normal, F will have a cumulative normal distribution, and if u_i is uniform then F is triangular (Adesina and Zinnah 1993). For the purpose of this analysis, u_i is assumed to be normal, making the estimation of the probability possible using a probit model (see Appendix D for a discussion of discrete choice models).

The second stage of the model involves the estimation of the extent of adoption once the decision is made to adopt sustainable agriculture by the i th family. Evaluating equation 6.4, the functional form of F is specified with a Heckman model where u_i is an independently normal distributed error term with a zero mean and constant variance σ^2 .

$$\begin{aligned} Y_i &= X_i \beta & \text{if } i^* = X_{2i} \beta_2 + \mu_i > H \\ Y_i &= 0 & \text{if } i^* = X_{2i} \beta_2 + \mu_i \leq H \end{aligned} \quad 6.5$$

Y_i is the probability of adopting sustainable agriculture, i^* is a non-observable latent variable, H is a non-observable threshold value, and X_{2i} are the independent variables

²³ Where $u_i = (e_{1i} - e_{2i})$ as is derived in equation 6.3.

which are used to explain the extent of adoption decision. Unlike the tobit model, those variables which determine adoption and the those which determine extent of adoption differ.

After estimating the probability and extent of adoption, estimation of the marginal effects are necessary since probit model coefficients do not represent the expected change in the dependent variable given a one unit change in the explanatory variable. The marginal effect of a variable X_j on the probability of adopting the new technology is:

$$\frac{\partial P_i}{\partial X_{it}} = f(X_i \beta) \beta_i \quad 6.6$$

where $f(X_i \beta)$ is the marginal probability density function of u_i (Adesina and Zinnah 1993). The direction of the marginal effect is, therefore, determined by the sign of β_i . The coefficient β_i represents the coefficient differences ($\alpha_{2i} - \alpha_{1i}$). Thus β_i is expected to have a positive (negative) sign if the coefficient on the slash-and-burn coefficient is larger than (less than, equal to) the coefficient on the sustainable agriculture coefficient.

Farm and farmer characteristics such as lot size, average education of the household, heads (average of the husband and wife) and average age of the household heads are included in X . It is expected that the probability will increase with lot size and the number of years of education, and decrease with age. The probability is expected to increase with lot size and the number of years of education because as lot size and education increase so does human capital and monetary resources and as capital increases it is more likely that a superior technology will be adopted. Also expected is that as age

increases, it is less likely that the farmer will be willing to change habits and therefore adopt the new technology (Adesina and Zinnah 1993, D'Souza et al. 1993, Hussain et al. 1993, Lin 1991, Norris and Batie 1987). Also included are capital variables such as labor available to the family since the labor requirement varies between the two technology choices. It is expected that the probability of adoption will increase as these variables increase.

The technology characteristics which are included in X included income per capita and the labor leisure ratio. Also included in the technology characteristics are variables that indirectly affect the probability of adoption through information. Information about the potential gains in income and leisure from the use of sustainable agriculture can influence the rate of adoption. Union membership, indicated by the number of unions that the family participates in, is therefore included in X.

The economic model suggests that farm and family characteristics such as educational level, information, and union membership may be important determinants of farmer choice. It is important to know if these variables play a significant role in this choice because these factors can clearly be influenced by policy. Other variables such as age, farm size, and labor availability may also play large roles, but these, however, cannot be influenced through policy. If these policy variables do play a significant role in this analysis, the policy recommendations can lead to important results for other parts of Rondônia state, where similar programs have been initiated.

6.4 Data Limitations

The data used in the analysis of farmer behavior in Ouro Preto do Oeste, Rondônia were collected over a five month period and are divided among two different groups. The first group consists of 171 observations which were collected according to stratified random sampling of farm families (including all people living on the lot). The second group consists of 25 observations which were collected from farmers who participate in the local farmer union, the Association of Alternative Producers (APA). This association supports the use of sustainable agriculture.

The degree of transferability of the results of the analysis of these farmers may be limited since the data were collected in a single settlement in a single year. Obviously it would be preferable to gather a broad sample of farmers from different settled areas in the states of Rondônia, Mato Grosso, Para, Acre, and other periphery states. Another limitation of these data is they do not measure changes over time since they have been collected in one time period. A panel data set which tracks the choices of the farmers over time could provide a great deal of information about farm choice. Nevertheless, the results still provide insight to the farm choice and the diffusion of sustainable agriculture in Ouro Preto do Oeste and can help to provide preliminary policy recommendations which aim to increase the rate of adoption of sustainable agriculture across Amazonian states. Even if these policy actions are not applicable to a wide range of farm establishments we may still learn practical lessons about the adoption of sustainable agriculture through this analysis. Other land use policies and manpower development policies do exist, although tailoring them to this problem may be difficult.

6.5 The Empirical Model

The probability of adopting sustainable agriculture and the extent (or intensity) of adoption is estimated using a two-stage Heckman model. This model was chosen over both the probit and logit models, which only estimate the probability of adoption, because the extent of adoption is pertinent to policy implications. Both the Heckman (Heckman 1979) and tobit (Tobin 1958) models estimate adoption and the extent of adoption based on the concept of a threshold value of the dependent variable²⁴ (Pindyck and Rubenfield 1981). The extent of adoption hinges on the adoption decision. Therefore, failure to model the adoption decision can lead to a selection bias. For example, one may find that policy influences the extent of adoption only, where it is possible to ignore the probit stage, such an estimation suffers from a selection bias. Given that the decision to adopt sustainable agriculture is characterized by a dichotomous choice, there is a point where the extent of adoption cannot be measured. But, when the threshold value, which is determined by a vector of observable explanatory variables, is exceeded, adoption occurs and the second decision on the intensity of use is taken. See Appendix D for a detailed discussion of these models.

The Heckman model (Heckman 1979) allows for different variables which determine the adoption choice and then the effort allocated when adoption is chosen. The two equation procedure involves the estimation of a probit model of the adoption decision, calculation of the sample selection control function, and incorporation of that control

²⁴ See section C.5, "The Tobit and Heckman Models Compared" in Appendix D for a detailed comparison of the Heckman and tobit models

function (the inverse Mills ratio) into the model of effort which is estimated with ordinary least squares (OLS)²⁵.

A two-stage Heckman model²⁶ is estimated rather than the more commonly used two-stage tobit model²⁷ since it is expected that different explanatory variables influence the decision to adopt sustainable agriculture and the extent to which it is adopted. The tobit model makes the assumption that the variables which determine both the adoption and extent of adoption are identical. For example, the adoption of sustainable agriculture can be influenced greatly by the knowledge that this method of agriculture exists, but it is unlikely that this knowledge (represented as dummy variable) influences the extent of adoption. And in reverse, variables which may influence the extent of adoption may include the number of years that sustainable agriculture is used and the level of labor which is available to the family. It is unlikely that the knowledge that sustainable agriculture exists will influence the extent of adoption and impossible that the number of years of use will influence the decision to adopt sustainable agriculture.

²⁵ See section C. 4, "Heckman Model Specification" in Appendix D for the mathematical framework of the Heckman model.

²⁶ The Heckman model (Heckman 1979) allows for different variables which determine the adoption choice and then the effort allocated when adoption is chosen. The two equation procedure involves the estimation of a probit model of the adoption decision, calculation of the sample selection control function, and incorporation of that control function (the inverse Mills ratio) into the model of effort which is estimated with ordinary least squares (OLS).

²⁷ Most studies estimate the extent of adoption using the tobit model since the elasticities which are evaluated at the means can be decomposed into the elasticity of adoption and the elasticity of effort given that adoption occurs (Adesina and Zinnah 1992, Gould et al 1989, Norris and Batie 1987). These decomposed elasticities may be interesting for the interpretation of policy since they provide information about the elasticity of adoption and the elasticity of effort, but it is asserted here that the assumption that is necessary to calculate these elasticities is not relevant to this research and therefore the elasticities would not provide any additional information.

This analysis is an addition to the literature on adoption behavior because a model which is rarely used in technology adoption, a Heckman model of estimation, is used. Most studies estimate the extent of adoption using the Tobit model since the elasticities, evaluated at the means, can be decomposed into the elasticity of adoption and the elasticity of effort given that adoption occurs (Adesina and Zinnah 1992, Gould *et al.* 1989, Norris and Batie 1987).²⁸ These decomposed elasticities may be interesting for the interpretation of policy since they provide information and allow the elasticity of adoption and the elasticity of effort, but it is asserted here that the assumption that is necessary to calculate these elasticities is not relevant to this research.

Three series of estimations are preformed in order to examine the probability of adopting sustainable agriculture and the extent of adoption (Figure 6.1). The results from the models are compared in order to determine the role that APA membership can make in the adoption of sustainable agriculture and the variables which play a role in the adoption of sustainable agriculture for non-APA members. The first series of equations which are analyzed are the probability of adopting sustainable agriculture and the extent to which it is adopted using the stratified random sample (non-APA observations). The extent of adoption is measured in two different equations, first in terms of the number of hectares devoted to inter-cropping and second in terms of liters of honey harvested.²⁹

²⁸ See section C.3.1 "Tobit Model Elasticities" for the derivation of the decomposition of the elasticities.

²⁹ Since sustainable agriculture is defined as the use of the inter-cropping of perennials with varying perennials and/or annuals, alone, or in combination with income sources, such as bee-keeping and aquaculture, which do not rely on the destruction of the rain forest, the extent of deforestation is measured in these terms. Fish raising is not measured in the extent equations since only one farmer cultured fish during the interview year, 1996. Eleven additional farmers stated that they began to raise fish in 1996, but would not harvest in that year.

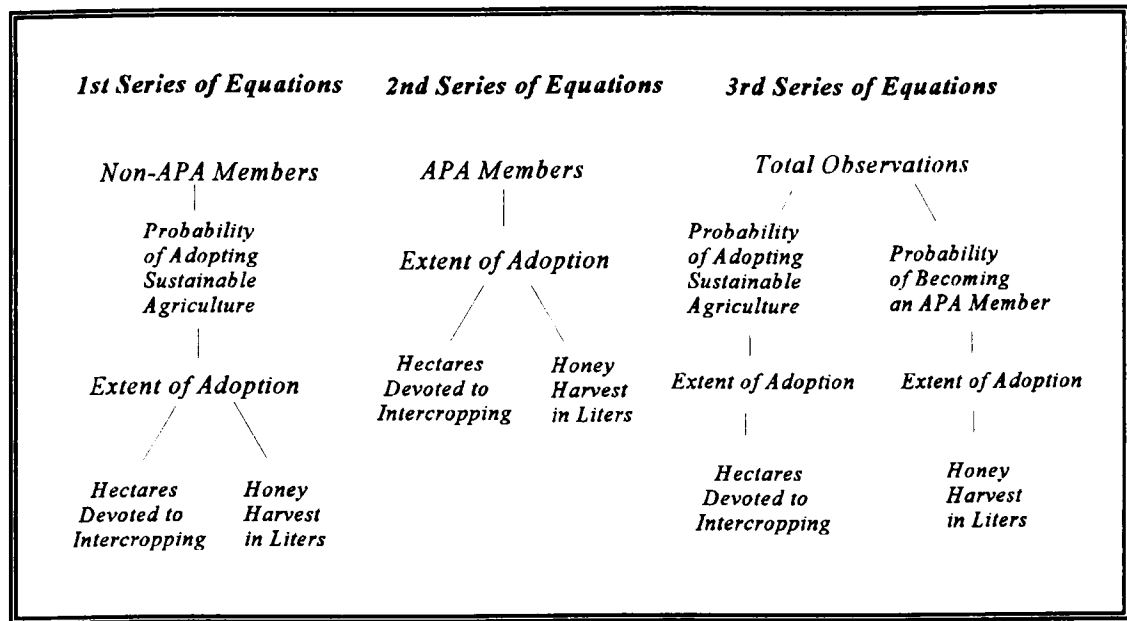


Figure 6.1
Series of Estimated Equations

The second series of equations that are analyzed are the extent of adoption for APA members. Since all APA members participate in sustainable agriculture, a probability of adoption equation was not estimated. The extent of adoption is estimated using the number of hectares devoted to inter-cropping and the liters of honey harvested, as above.

The third series of equations which are estimated include the observations from both data groups. The non-APA and APA members are weighted according to the ratio of the population probability and the sample probability that is applicable to each of the groups of data; non-APA and APA. This weight accounts for the sampling variation in non-APA observations which may exist if the stratified random sample contains a sampling bias and for the selectivity bias of the APA member sample (see section 6.7 for a discussion of the

calculation of the weights and the modeling based on these weights). Two estimations are made using the weighted combined sample. One is the probability of adopting sustainable agriculture and the extent, measured in both number of hectares, and liters of honey. The second estimations are the probability of becoming an APA member and the extent of adoption once a farmer becomes an APA member. The probability of becoming an APA member is compared to the model estimated for the extent of adoption using the 25 APA observations to determine if a selectivity bias exists.

6.6 First Series of Equations - The Probability of Adoption

The first series of equations are estimated based on the stratified random sample³⁰ to determine the probability of adoption and the extent of adoption once the adoption choice is made. Of the 171³¹ farmers which make up this sample, 17 use sustainable agriculture which represents 9.9 percent of the sample. Although the adoption rate is low, this sample can provide insight into the adoption decision and, in turn, help to determine why the adoption rate is low.

The two-stage model is run using dummy variables for each of the counties in the city of Ouro Preto do Oeste, with the exception of Ouro Preto, the county located in the city

³⁰ This sample is stratified in order to ensure that each of the six counties which lie in Ouro Preto do Oeste are represented equally based on the number of farm lots in each county. The percent of the total interviews from each county represents the percent of lots which lie in the county. After the number of interviews to be conducted in each county was determined, a random sample was conducted in each county.

³¹ One observation is dropped in the regression analysis since it was found that the observation was an outlier which dominated the estimation results.

center.³² In addition the model estimates the probability of adoption by using variables for education of the household heads,³³ age of the household heads, knowledge of sustainable agriculture, the number of unions the family participates in, the number of years that the family has resided on the farm, and per capita income. The variables included in this model and the following estimates are defined in Table 6.1.

There have been many attempts to derive goodness of fit measures for discrete choice models (Greene 1997). An analogue to the R-squared used in conventional OLS regression models has been developed and is the most popular of the fit measures for binary choice models. The pseudo-R-squared or the likelihood ratio index (LRI) was developed as a fit measure for probit, logit, and tobit models (Gujarati 1995). This measure has an intuitive appeal in that it is bounded by 0 and 1. There is no way for the LRI to equal 1, but it can come close (Greene 1997). Values between 0 and 1, however, have no natural interpretation (Greene 1997). This value will be presented in the following models, since it is commonly referred to, but it will not be discussed further since it is lacking natural interpretation. The LRI index for this model is 0.33. The coefficient estimates for this model are presented in the Table 6.2.

The model which estimates the probability of adoption predicts 90% of the equations

³² The county Ouro Preto is not included as a dummy to avoid collinearity between the variables and to test for any significant difference between the other five counties and Ouro Preto. Ouro Preto was chosen as the reference county because it is the county which is located in the center of the settlement and is assumed to be average in terms of agriculture, income, and lot size but different in terms of population and development. Since this county was settled first, it is the oldest county with the highest urban population. The urban population is not used in the analysis.

³³ The household heads are the main decision makers on the farm lots.

Table 6.1
Variable Definitions

OPO	dummy variable for the county Ouro Preto, opo=1 if the family resides in the county and opo=0 if the family does not reside in the county.
NOVA	dummy variable for the county Nova Uniao, nova=1 if the family resides in the county and nova=0 if the family does not reside in the county.
VALE	dummy variable for the county Vale do Pariso, vale=1 if the family resides in the county and vale=0 if the family does not reside in the county.
TEIX	dummy variable for the county Teixeropolis, teix=1 if the family resides in the county and teix=0 if the family does not reside in the county.
MIR	dummy variable for the county Mirante da Serra, mir=1 if the family resides in the county and mir=0 if the family does not reside in the county.
URUPA	dummy variable for the county Urupa, urupa=1 if the family resides in the county and urupa=0 if the family does not reside in the county.
AVEDUHH	average education of the household heads in years
AVEDU2	average education of the household heads squared in years
AVEAGEHH	average age of the household heads in years
AVEAGE2	average age of the household heads squared in years
UNION	number of unions in which the household participates
UNIONAPA	number of unions that a household participates in excluding APA
KNOWSA	knowledge of sustainable agriculture, knowsa=1 if the family knows of or has heard about sustainable agriculture and knowsa=0 if the family does not know of or heard about sustainable agriculture
YEARONFM	number of years on the farm lot
YEARSSA	number of years that the family has used sustainable agriculture
PERBURN	percent of the lot which has been burned
MONEYINC	total income gained in 1996, 1996 reais
PERCAP	total income gained in 1996, 1996 reais per capita
NOHONCAP	income from sources other than honey in 1996, total family income per capita - honey income per capita in 1996 reais
PERFOR	percent of the lot which is virgin forest
PERPAS	percent of the lot which is pasture or secondary growth forest
ADULTMAL	number of males over ten years of age
CATRES	total reais value of total cattle on the lot in 1996 reais

Table 6.2
Coefficient Estimates for the Probability of Adopting Sustainable Agriculture
and the Extent of Adoption

Variable	Probability of Adopting Sustainable Agriculture (n=170)		Extent of Adoption (Hectares) (n=21)	Extent of Adoption (Honey) (n=21)
	Coefficient	Marginal Impacts ^a	Coefficient	Coefficient
Constant	-5.8489 ** (-1.989)	-0.716	-0.181 (-0.117)	707.04 (0.285)
NOVA	-0.43306 (-0.784)	-0.053	-1.9212 ** (-3.844)	-1008.9 (-1.253)
VALE	-0.34414 (-0.609)	-0.042	-0.82478 * (-2.738)	-11.349 (-0.024)
TEIX	0.16804 (0.301)	0.020	-0.22926 (-0.971)	-358.64 (-0.936)
MIR	0.04618 (0.072)	0.006	0.26861 (0.742)	-420.94 (-0.725)
URUPA	-0.45916 (-0.756)	-0.56	-0.67460 ** (-1.845)	-105.93 (-0.181)
AVEDUHH	0.31918 (1.551)	0.039	0.14787 (0.803)	-115.73 (-0.395)
AVEDU2	-0.24152E-01 (-1.107)	0.003	-0.31428E-01 (-1.452)	8.5135 (0.246)
AVEAGEHH	0.099172 (0.949)	0.012	0.43941E-02 (0.091)	-47.245 (-0.609)
AVEAGE2	-0.78696E-03 (-0.773)	-0.000	0.28698E-04 (0.066)	0.38425 (0.550)
UNION	0.40043 ** (2.167)	0.049	0.36906 *** (2.660)	293.11 (1.342)
KNOWSA	1.7685 *** (4.092)	0.216		-0.22519 (-0.028)
YEARONFM	0.046020 * (1.559)	0.006	0.38634E-02 (0.274)	-12.011 (-0.529)
YEARSSA			0.20352 *** (4.454)	64.918 (0.902)
PERCAP	0.22817E-04 (0.338)	0.000	-0.11106E-03 (-1.439)	
PERFOR			0.13561E-01 * (2.701)	

	Probability of Adopting Sustainable Agriculture (n=170)		Extent of Adoption (Hectares) (n=21)	Extent of Adoption (Honey) (n=21)
ADULTMAL			-0.10731 *** (-3.334)	1.6263 (0.032)
NOHONCAP				0.017162 (0.141)
LAMBDA			0.36846 (1.276)	609.68 (1.314)
Probability Model: Likelihood ratio test 42.83*** Pseudo R ² 0.34 Number of Correct predictions 153 (90%) Extent of Adoption (Hectares): F statistic 13.76 *** R squared 0.98 adjusted R-squared 0.91 Extent of Adoption (Honey): F statistic 1.21 R squared 0.82 adjusted R-squared 0.14				
***, **, * indicate significance at the 1%, 5%, and 10% levels, respectively *Marginal impacts are the partial derivatives of $E[y] = \Phi[*]$ with respect to the vector of characteristics. They are computed at the means of the independent variables.				

correctly. The model predicts 92% of the households which do not adopt sustainable agriculture, correctly, and 64% of the households which adopt sustainable agriculture, correctly (Table 6.2). The R-squared is 0.34. A low R-squared is to be expected, since an upper bound R-squared for binary choice models is about 0.33 (Pindyck and Rubinfeld, 1991).³⁴ It is for this reason that R-squared values are not a relevant method of measuring the fit of probit models. The R-squared values will, therefore, not be reported in the remaining probit estimation. Instead the likelihood ratio, a Chi-squared statistic test is interpreted to determine fit of the probit models.

Both the probit and tobit models use maximum likelihood methods (MLE) to estimate the coefficients of the model. The regression coefficients are asymptotically efficient, unbiased, and normally distributed thus with large samples, the ratio of estimated coefficients and its standard error approximates a normal distribution. Therefore, an analogue of the t-test is applied as a test for significance. In the MLE, a log likelihood test replaces the usual F test of OLS regression models to evaluate the significance of all coefficients. The log likelihood ratio test follows a Chi-square distribution with k degrees of freedom. For this model, the Chi-squared value of 43.83 at 13 degrees of freedom is significant at the 1% level implying that the independent factors, taken together, influence

³⁴ There have been many attempts to derive goodness of fit measures for discrete choice models (Greene 1997). An analogue to the R-squared used in conventional OLS regression models has been developed and is the most popular of the fit measures for binary choice models. The pseudo-R-squared or the likelihood ratio index (LRI) was developed as a fit measure for probit, logit, and tobit models (Gujarati 1995). This measure has an intuitive appeal in that it is bounded by 0 and 1. There is no way for the LRI to equal 1, but it can come close (Greene 1997). Values between 0 and 1, however, have no natural interpretation (Greene 1997). This value will be presented in the following models, since it is commonly referred to, but it will not be discussed further since it is lacking natural interpretation. The LRI index for this model is 0.33.

the adoption of sustainable agriculture.

The most significant variable in determining the probability of adopting sustainable agriculture is the knowledge that sustainable agriculture exists. As this knowledge increases, so does the rate of adoption. A positive and significant sign on the union variable indicates that as the number of farm related unions a family participates in increases, so does the likelihood of adoption of sustainable agriculture. Also affecting the adoption positively is the number of years on the farm (YEARONFM). The number of years that a family has resided on the lot can influence the adoption of sustainable agriculture in two ways. One is that as the years increase, so does the access to seedlings and opportunity to plant them since the programs providing the seedlings, free of charge began about 10 years ago and are continuing. The seedlings have been provided free of charge by local unions or government supported agencies. Also, as the number of years increase, so does the permanency of residency of the family and future generations and, therefore, the need to maintain a land use which is sustainable. It is likely that as these families mature, that the families may be concerned about land production for future generations, since property rights are secure in the city and also may simply understand their land better, enhancing their ability and understanding of sustainability.

Unions, networking, and the dissemination of information appear to greatly increase the probability of adoption, but at the same time neighboring effects appear to be insignificant. One might expect that neighbors may be responsible for the dissemination of the information, but the model does not support this since none of the dummy variables which represent counties are significant at the 10% level. Instead unions appear to serve

as the main source of information and the dissemination of information on sustainable agriculture. Knowledge of sustainable agriculture, which is often provided by unions and government sponsored programs greatly increases adoption. These results suggest that increasing this information or increasing the rate at which information is spread, could increase adoption considerably.

Per capita income is not significant. Economic theory would predict that per capita income would play a role in the adoption of new technologies, but it has been shown in various studies of developing countries that income does not play a large role, but rather that information, education, and/or resources are better determinants of the adoption of new technologies in developing countries (Hussain *et al.* 1994, Adesina and Zinnah 1993, Lin 1991, Kebede *et al.* 1990, Shakya and Flinn 1985). And, for this reason, these studies do not include income measurements in their models. This theory is also supported by the results in this analysis. These results also suggest that families having relatively higher educations, and greater number of years on their farm lot are more likely to adopt sustainable agriculture.

The coefficient estimates which are provided in Table 6.2 are not comparable with one another because the magnitudes of the coefficients depend on the unit of measurement and because they are expressed as indices. Unlike OLS coefficients, probit coefficients do not represent the expected change in the dependent variable, given a one unit change in the explanatory variable. Thus, they have little interpretive value unless transformed into marginal values. The marginal impacts of changes in the independent variable are estimated for the significant independent variables. The interpretation of these marginal

impacts are dependent upon the units of measurement of the independent variables (Gould *et al.* 1989). For example, these marginal impacts show that as education increases by one year, the probability of adopted sustainable agriculture increases by 3.9 percent. The direction of the percent change is as would be expected. As the number of years of education increase, the probability of adopting superior technologies increases.

The variables which have important policy implications are knowledge of sustainable agriculture (KNOWSA) and union membership (UNION). The marginal impacts show when farmers become informed about sustainable agriculture that the probability of adoption is expected to increase by 22 percent when this knowledge is obtained. These marginal impacts also show when a family participates in one additional union that the probability of adoption increases by 4.9 percent.

6.6.1 First Series of Equations - Extent of Adoption in Hectares Devoted to Sustainable Agriculture

The extent of adoption is estimated in terms of (1) the number of hectares devoted to sustainable agriculture or inter-cropping and (2) the number of liters of honey harvested in one year (1996). They are both estimated using the Heckman selection bias correction. The extent in terms of hectares devoted to inter-cropping, is estimated first.

The extent of adoption is first estimated in terms of the number of hectares devoted to sustainable agriculture. The model is estimated in order to determine the extent of adoption of sustainable agriculture conditional on the adoption decision. This model includes dummy variables for each of the five counties (as in the first stage). In addition to variables for age, education, union membership, per capita income, and the number of

years that a family has lived on the lot, the number of years that a family has practiced sustainable agriculture is included in the estimation. Also, this model includes variables which represent family capital; the number of adult males (ADULTMAL), and the percent of the lot which is primary forest (PERFOR), indicating how much of the lot may be preserved is sustainable agriculture is used.

The F statistical value is significant at the 1% level, suggesting that the overall significance of the model is high. The R-squared value is 0.98 and the adjusted R-squared value is 0.91, suggesting a high degree of fit for the model (Table 6.2).

Neighboring effects appear to play a more dominant role in the number of hectares which are devoted or converted to inter-cropping, particularly in the counties of Nova Uniao, Urupa, and Vale do Pariso. The negative coefficients signify that compared to Ouro Preto these areas devote less land to inter-cropping. This result is particularly interesting in terms of the characteristics of Urupa and Vale do Pariso. Urupa was the last county to be settled in the area. The soil is relatively fertile and as a result of this and the year of the settlement, the lots are significantly smaller than the other five counties in Ouro Preto do Oeste. The largest lots in Urupa are 50 hectares and the smallest are 10 hectares. In comparison, the majority of the lots in the five remaining counties are 100 hectares. The residents of Urupa therefore devote less land to sustainable agriculture because they have less land. The residents in Vale do Pariso also have less land to devote to sustainable agriculture because of the condition of the land. The majority of the lots in Vale do Pariso have boulders throughout them, making much of the land impossible to farm.

Two variables which are representative of the resources that may be obtained from

outside organizations are the number of unions that the family participates in (UNION) and the number of years that the family has used sustainable agriculture (YEARSSA). UNION and YEARSA are positive and significant at the 1% level indicating that as the number of unions that the family participates in increases and as the number of years that the family has used sustainable agriculture increases, so does the extent of adoption. Since the seedlings which are used in the intercropping plots are provided free of charge by the local unions and local governmental programs, an increase in the number of unions in which a family participates or an increase in the number of years that the family uses sustainable agriculture can increase the availability of these seedlings. As the seedlings become more available, the extent of adoption increases.

The coefficient on one of the measurements of capital resources, adult males (ADULTMAL) is negative and significant at the 1%. This negative relation suggests that the families who adopt inter-cropping do so to take advantage of the less intense labor technique. As stated earlier, intercropping requires less labor per year compared to the slash-and-burn method of farming annual crops. It is those families which do not have the resources that might need to reduce the work load of the family. Those families which do not have a large amount of labor on hand (adult males) are choosing to convert more of their land to inter-cropping compared to those farmers having greater labor and savings options.

The percent of the lot remaining as undisturbed virgin forest (PERFOR) has a positive coefficient and is significant, suggesting that the farmers who have a greater percent of standing forest may be more aware or educated about the value of the standing

forest. These farmers are, therefore, likely to devote more land to this potentially sustainable method of farming and potentially preserve more land in the future.

6.6.2 First Series of Equations - Extent of Adoption in Liters of Honey Harvested

The extent of adoption is secondly estimated in terms of the number of liters of honey harvested. This second model is based on the same Heckman correction technique which is used in the estimation of the extent of adoption in terms of the hectares devoted to inter-cropping. The estimation of the extent of adoption in liters of honey does not appear to be a strong predictor of household decisions. The F statistical value is not significant at the 5% level, suggesting that the overall significance of the model is low. The R-squared value is 0.83 while the adjusted R-squared is 0.14, suggesting that there are factors that have not been represented in the model which may explain the extent of adoption.

Surprisingly, none of the variables are significant. It is expected that the income which is not derived from honey, but income earned outside of the farm and from other farm products would have an influence on the amount of honey harvested. The per capita income which is not derived from honey (NOHONCAP) is expected to have a negative and significant relation, since honey income requires less labor input and, therefore, can supplement other household income, but this is not the case. The coefficient is not significant.

Also interesting is that unions and the resources of the family (ADULTMAL) are not significant. These variables were significant in the determination of the number of hectares which are devoted to sustainable agriculture. The lack of strong estimators suggests that

it may not be possible to estimate honey harvest in terms of the number of liters. Instead, it is likely that factors which cannot be measured such as the availability of flowering plants in the vicinity of the lot may determine the honey production of the bees.

6.7 Second Series of Equations - Extent of Adoption in Hectares Devoted to Sustainable Agriculture

The second series of equations which are estimated are the extent of adoption for APA members. These estimations are made in order to determine how APA farmers respond to the initial adoption of sustainable agriculture. When farmers join APA they are making a commitment to employ sustainable agriculture. A majority of the members produce honey and have intercropping plots, but there are some members who only produce honey. APA members receive free seedlings from the organization but do not receive supplies for honey production. The purpose of these estimations is to determine if there are any specific factors which help to increase the extent of adoption for APA members. These data represent 64 percent of APA membership and are therefore a representative sample of APA members, but represents a non-random sample of the total population. As a result these coefficient estimates may be biased as well which needs to be considered when trying to generalize these results to the population at large.³⁵

The extent of adoption for APA members is measured first by the number of hectares devoted to inter-cropping and second by the total number of liters of honey which are harvested, as is with the stratified random sample. The extent of adoption is estimated for

³⁵ This bias is addressed in the third series of equations where first the probability of becoming an APA member is estimated and then the extent of adoption is estimated using a Heckman correction to adjust for the censored sample.

APA members without first estimating the probability of adopting sustainable agriculture since all APA members harvest honey and/or use inter-cropping on their lots. Both of the extent equations are estimated using ordinary least squares (OLS) regression.

The first model which is estimated is the extent of adoption in terms of the number of hectares devoted to inter-cropping. The R-squared value for this model is 0.41 and the adjusted R-squared value is 0.11, suggesting that only 11 percent of the model can be explained by the variables included in the regression and that too many parameters may be included in the estimation model. The F statistical value is not significant at the 5% level, suggesting that the overall significance of the model is low (Table 6.3).

The coefficients that are significant in the estimation are the number of unions in which a family participates, not including APA (UNIONAPA), and the number of years that a family lives on a lot (YEARONFM). Both of these coefficients are positive and significant suggesting that as the number of unions that the family participates in increases and as the number of years the family spends on the lot increases, so does the number of hectares which are devoted to inter-cropping.

These coefficients suggest that as a farmer becomes more active in the community and a permanent resident of the lot, the extent of adoption increases. As stated earlier, the seedlings used in the intercropping plots are often distributed through unions. The policies which support sustainable agriculture cannot require that farmers join unions or associations but the programs could provide the means for these associations to prosper since the influence of local unions can be critical to the adoption decision for many farmers. This raises the importance of the model which estimates the probability of

Table 6.3
Coefficient Estimates for the Extent of Adoption of APA Members

	Probability of Adoption (Hectares) (n=25)	Extent of Adoption (Honey) ¹ (n=25)	Extent of Adoption (Honey) ² (n=25)
Variable	Coefficient	Coefficient	Coefficient
Constant	-5.3239 (-1.130)	174.31 (0.481)	70.792 (0.367)
OPO	1.1964 (0.881)	-131.95 (-1.060)	
AVEDUHH	0.89694 (0.947)	-10.549 (-0.119)	
AVEDU2	-0.73204E-01 (-0.721)	0.42189 (0.045)	
UNIONAPA	0.89694 * (1.824)	-84.888 (-1.232)	-67.627 (-1.076)
YEARONFM	0.24142 * (2.068)		
YEARSSA	0.26244 (0.494)	69.217 (1.541)	92.384 (2.641) **
PERCAP	-0.15949E-02 (-1.294)		
PERPAS	(-0.542) -0.16944E-01	-2.4507 (-0.888)	
ADULTMAL		10.329 (0.382)	
CATRES		0.89387E-02 (1.114)	
NOHONCAP		0.11520 (0.969)	0.060 (0.672)
Probability of Adoption: F statistic 1.40 R squared 0.41 adjusted R-squared 0.11 Extent of Adoption (Honey) ¹ : Extent of Adoption (Honey) ² : F statistic 1.44 F statistic 2.94 R squared 0.46 R squared 0.30 adjusted R-squared 0.14 adjusted R-squared 0.20			
***, **, * indicate significance at the 1%, 5%, and 10% levels, respectively			

becoming an APA member which is discussed in the following sections.

It is likely that these results and the estimation of the extent of adoption in terms of honey harvest results are biased since this group of farmers is not likely to be a random sample of the Ouro Preto do Oeste population, but rather a homogeneous group of families.

6.7.1 Second Series of Equations - Extent of Adoption in Liters of Honey Harvested

The extent of adoption in terms of honey harvest is estimated using an OLS regression. The R-squared value of 0.46 and the adjusted R-squared value is 0.14 suggesting that only 14 percent of the model can be accounted for by the variables that have been included. The F statistical value is not significant at the 5% level, suggesting that the overall significance of the model is low. Similar to the extent of adoption in terms of the number of hectares, this equation does not provide many significant results (Table 6.3). There are no significant variables. These results may be due to the bias of the sample. This bias is addressed in the following sections.

This model is re-estimated using only three explanatory variables in order to account for the large variance between the R-squared and adjusted R-squared values. The R-squared value of 0.30 and the adjusted R-squared value is 0.20 suggesting that only 20% of the model can be accounted for by the variables which have been included. The F statistic indicates that the model is not significant at the 5% level. The variable which indicates the number of years that the farm family has been using sustainable agriculture (YEARSSA) is significant. The positive sign indicates that as the number of years

increases that the number of liters of honey harvested per year increases. Although the R-squared and adjusted R-squared values are closer in value, this model is still not a good predictor of the extent of adoption in terms of the honey harvested.

As stated earlier, it is likely that the lack of strong estimators may suggest that it may not be possible to estimate honey harvest in terms of the number of liters. Instead, it is likely that factors which cannot be measured such as the availability of flowering plants in the vicinity of the lot may determine the honey production of the bees.

6.8 Third Series of Equations - The Probability of Adoption

The third series of equations is estimated using the combination of data from the stratified random sample and APA members. These data are combined in order to determine the probability of adopting sustainable agriculture and the extent of adoption for the entire data sample. This additional information is obviously an over representation of APA members in comparison to the random sample since 64 percent of the APA members were interviewed compared to only 5 percent of the total lots in the settlement. However, the additional information could provide some insight into the adoption of sustainable agriculture. The observations are therefore weighted in order to account for the over representation. In these regressions the total observations, 196, are weighted according to the ratio of the population and sample probabilities. The weight is calculated as follows. There are 3341 populated lots in Ouro Preto do Oeste. This total can be divided among non-APA (3302) and APA members (39).³⁶ The total number of interviews, 196, is

³⁶ At the time of the interviewing there were 39 active members of APA, however this number has increased since 1996.

divided among non-APA members (171) and APA members (25). The weights are calculated as the total population of the group divided by the total interviews of the group. The weight for non-APA members is therefore: $(39/25)=1.56$ and for APA members is: $(3302/171)=19.31$. These weights insure that the random sample is a representative sample of the total population and that the APA sample is also a representative sample of the total population.

The first two regressions are based on the same estimators of the probability of adopting sustainable agriculture. The second stage of these regressions involves the estimation of the extent of adoption which is measured in the number of hectares devoted to sustainable agriculture and then in honey harvest. The same variables which are used to estimate the probability of adopting sustainable agriculture using the stratified random sample are used to estimate the probability of adopting sustainable using total observations.

The estimation of the probability of adopting sustainable agriculture predicts 90% of the equations correctly. The model correctly predicts 91% of those households that do not adopt sustainable agriculture and correctly predicts 87% of those households which had adopted sustainable agriculture. The Chi-squared value is 115. At 15 degrees of freedom, the Chi-squared value is significant at the 1% level, indicating that the model has good explanatory power (Table 6.4).

The most significant variable in determining the probability of adopting sustainable agriculture according to this model is the knowledge that sustainable agriculture exists (KNOWSA). Also significant is the union membership (UNION). This coefficient is

Table 6.4
Coefficient Estimates for the Probability of Adopting
Sustainable Agriculture and the Extent of Adoption - Total Observations

	Probability of Adopting Sustainable Agriculture (n=196)		Extent of Adoption (Hectares) (n=47)	Extent of Adoption (Honey) (n=47)
Variable	Coefficient	Marginal Impacts ^a	Coefficient	Coefficient
Constant	-6.3926 ** (-2.431)	-0.838	-0.065464 (0.163)	-835.83 * (-1.747)
NOVA	-0.39772 (-0.808)	-0.047	-1.3078 (-1.639)	185.75 * (1.960)
VALE	-0.35700 (-0.697)	-0.052	-1.2341 (-1.593)	-33.771 (-0.367)
TEIX	0.15275 (0.318)	0.020	-0.25599 (-0.844)	-25.803 (-0.701)
MIR	0.33219 (0.615)	0.044	-0.66287 (-0.833)	159.91 (1.680)
URUPA	-0.49940 (-0.911)	-0.066	-1.7256 (-1.449)	390.58 *** (2.797)
AVEDUHH	0.37189 * (1.933)	0.049	0.10072 (0.239)	59.613 (1.195)
AVEDU2	-0.30683E-01 (-1.492)	-0.004	-0.20476E-01 (-0.413)	-5.9946 (-1.065)
AVEAGEHH	0.11142 (1.177)	0.015	-0.26138E-01 (-0.197)	-4.4666 (-0.281)
AVEAGE2	-0.89300E-03 (-0.964)	-0.000	0.73767E-04 (0.055)	0.16360 (1.015)
UNION	0.39662 ** (2.365)	0.052	0.56814 (1.654)	37.965 (0.927)
KNOWSA	1.8963 *** (4.684)	0.249		
YEARONFM	0.53809E-01 ** (1.973)	0.007	0.13112 ** (2.480)	-2.0438 (-0.326)
YEARSSA			0.17219 (1.179)	30.219 * (1.828)
PERCAP	0.30275E-04 (0.474)	0.000	-0.23884E-03 (-0.905)	
PERFOR			0.29022E-01 ** (2.195)	2.1400 (1.365)

	Probability of Adopting Sustainable Agriculture (n=196)		Extent of Adoption (Hectares) (n=47)	Extent of Adoption (Honey) (n=47)
ADULTMAL			-0.25861 ** (-2.622)	25.420 ** (2.220)
APA			0.59694 (0.582)	469.56 *** (3.921)
NOHONCAP				0.06004 * (1.980)
LAMBDA			0.29885 (0.411)	110.43 (1.312)
Probability Model: Likelihood ratio test 115*** Pseudo R ² 0.59 Number of Correct predictions 176 (90%) Extent of Adoption (Hectares): F statistic 1.85 R squared 0.52 adjusted R-squared 0.24 Extent of Adoption (Honey): F statistic R squared adjusted R-squared				
***, **, * indicate significance at the 1%, 5%, and 10% levels, respectively *Marginal impacts are the partial derivatives of $E[y] = \Phi[*]$ with respect to the vector of characteristics. They are computed at the means of the independent variables.				

positive suggesting that as the number of unions that a household participates in increases, the likelihood of adoption increases. The education coefficient is positive and significant at the 10% level, suggesting that as education increases the probability of adoption increases. Also significant is the number of years that the family has been on the farm (YEARONFM). The positive coefficient indicates that as the number of years which the family has been established on the lot increases, the probability of adoption will increase. This relationship suggests that as the family establishes permanent property rights on the lot and realizes that the land must sustain the family for future generations, the likelihood of adopting a more sustainable method of farming increases.

As explained earlier, the coefficient estimates provided in Table 6.4 are not comparable with one another because the magnitudes of the coefficients depend on the unit of measurement and because they are expressed as indices. Therefore, the marginal impacts of changes of the independent variables are estimated for the significant independent variables.

The results of these marginal impacts are similar to the probability of adoption which was estimated using the stratified random sample. For example, these marginal impacts show that if education increases by one year, the probability of adopted sustainable agriculture increases by 4.9 percent, where the probability increase is 3.9 percent in the random sample estimation (although the variable is not significant in the estimation). Also different in magnitude but similar in sign (compared to the marginal impacts which are estimated using the stratified random sample), are UNION, KNOWSA, and YEARONFM. The variables which are important to policy implications are knowledge of

sustainable agriculture (KNOWSA) and union membership (UNION). The marginal impacts show that when farmers become informed about sustainable agriculture that the probability of adoption increases by 25 percent, when the family remains on the land for an additional year that the probability of adopting sustainable agriculture will increase by 0.7 percent, and that when a family participates in one additional union that the probability of adoption increases by 5.2 percent.

6.8.1 Third Series of Equations - Extent of Adoption in Hectares Devoted to Sustainable Agriculture - Based on the Probability of Using Sustainable Agriculture

. The extent of adoption for the combined sample is estimated in terms of (1) the number of hectares devoted to sustainable agriculture or inter-cropping and (2) the number of liters of honey harvested in a one year (1996). They are both estimated using the Heckman selection bias correction.

The extent of hectares devoted to inter-cropping is estimated first. In this model the R-squared value is 0.52 and the adjusted R-squared value is 0.24 suggesting that 24% of the model can be accounted for by the variables which have been included. The F statistical value is not significant at the 5% level, suggesting that the overall significance of the model is low (Table 6.4). This model includes dummy variables for each of the five counties (as in the first stage). In addition to variables for age, education, union membership, per capita income, and the number of years a family has lived on the lot, the number of years a family has practiced sustainable agriculture is included in the estimation. Also, this model includes variables which represent family capital; the number of adult

males (ADULTMAL), and the percent of the lot which is primary forest (PERFOR), indicating how much of the lot may be preserved if sustainable agriculture is adopted.

Neighboring effects do not appear to be relevant to the extent decision, contrary to the same estimation made with the stratified random sample estimation. The inclusion of the APA observations negates the neighboring impacts suggesting that APA members may be spread out throughout Ouro Preto do Oeste, rather than living in the same county or clustering in one area.

Also significant are the coefficients of percent of the lot which is primary forest (PERFOR), the number of years on the farm (YEARONFM), and the number of males on the farm (ADULTMAL). Those families who do not have a lot of labor on hand (adult males) are choosing to convert more of their land to inter-cropping compared to those farmers who have greater labor options. The number of adult males living on the lot has a negative and significant coefficient, suggesting that as the labor available to the family decreases, the likelihood of adopting sustainable agriculture, a less labor intensive method of farming, increases.

Education and age of the household heads are not significant in the determination of the hectares devoted to inter-cropping. It is expected that both of these coefficients would be positive, but in this model they are insignificant.

Interesting is the variable which indicates the number of years the family has used sustainable agriculture (YEARSSA) is not significant. This variable was highly significant in the extent of adoption in terms of hectares which was estimated using the stratified random sample. The inclusion of APA members in the sample has influenced the

significance of this variable greatly. This change in significance could be due to the politics that exist in the APA organization. The role that specific members play in the organization may play a greater role in the number of seedlings that they receive than then the number of years of use of sustainable agriculture.

The role that the APA observations play in the model was analyzed by including a dummy variable to represent APA membership. The variable is not significant suggesting that APA members may not behave differently than other farmers in terms agricultural choices.³⁷ All APA members use sustainable agriculture but if the members do not differ greatly from other farmers it is likely that if non-APA members learn about APA or sustainable agriculture that they would adopt sustainable agriculture as well.

6.8.2 Third Series of Equations - Extent of Adoption in Liters of Honey Harvested - Based on the Probability of Using Sustainable Agriculture

The overall significance of the model used to estimate extent of adoption in terms of honey harvest is low. The F statistical value is not significant at the 5% level. The R-squared value of 0.64 and the adjusted R-squared value is 0.43 suggesting that 43% of the model can be accounted for by the variables included. This model is more significant and better predicts the extent of honey harvest for APA members than the extent of honey based on non-APA members (Table 6.4).

The most significant variable in the estimation is APA membership. APA membership is expected to be highly significant since all APA members sell and harvest

³⁷ The differences between APA members and non-APA members is also addressed in the estimation of the probability of becoming an APA member (section 6.8.3).

honey. Also significant are the dummy variables for Nova Uniao, Mirante da Serra, and Urupa, suggesting that neighboring effects and the spread of information through neighbors is important to honey harvesting.

The variables showing significance are the county dummy variables, the number of years that a family has practiced sustainable agriculture, and APA membership. The coefficients on age of the household heads, education of the household heads, and per capita income (from all sources except honey) are not significant suggesting that honey harvest is influenced greatly by experience. Farming experience can be augmented with APA membership and by increasing the number of years that the family uses sustainable agriculture. This is an important result since experience can be impacted by policy.

6.8.3 Third Series of Equations - Probability of Becoming an APA Member

The estimation of the probability of becoming an APA member is estimated according to variables which indicate county of residence, education of the household heads, age of the household heads, the percent of the lot which is primary forest, the number of unions that the family participates in, and per capita income. This model is used to estimate the value of the Heckman correction used in the extent of adoption equations (in terms of hectares devoted to inter-cropping and liters of honey harvested). This model can account for any sample selection bias that exists for the APA member observations. The purpose of this estimation is to determine the extent to which the estimations in the second series of equations are biased, if any.

The Chi-squared value for the model is 134 which is significant at the 1% level for 13

degrees of freedom, suggesting that the model has high explanatory power. The model predicts 88% of the observations correctly. Of these correct predictions, the model predicts 100% of the non-APA members correctly but only 4% of the APA members correctly. The large difference between predictability of the two groups (non-APA members and APA members) suggests that the predictability of the model is very weak for APA members and raises concern as to whether any of the conclusions from this model are valid since the model has low prediction ability for the group of observations with which we are most concerned (Table 6.5).

None of the variables used in the estimation are significant at the 1%, 5%, or 10% levels. The lack of significant variables suggests that APA members may not be significantly different than non-APA farmers in terms of age, education, per capita income, and county of residence. The farmers are likely to join APA through family and friend networks rather than being selectively chosen based on characterizations such as income, age, or education. APA leaders and founders may have higher levels of education, but this is not true of the remaining members. This result is promising for policy since this suggests that programs which assist in the dissemination of information about sustainable agriculture or provide training in sustainable agriculture are not likely to be adopted by a particular type of farmer (similar to the farmers who joined APA) but rather the average or typical farmer.

Table 6.5
Coefficient Estimates for the Probability of Becoming an APA
Member and the Extent of Adoption

	Probability of Becoming an APA member (n=196)		Extent of Adoption (Hectares) (n=25)	Extent of Adoption (Honey) (n=25)
Variable	Coefficient	Marginal Impacts ^a	Coefficient	Coefficient
Constant	-5.9094 (-0.629)		-4.4655 (-1.066)	271.38 (0.598)
NOVA	0.47007 (0.419)			
VALE	-1.0571 (-0.750)			
TEIX	0.47935 (0.739)			
MIR	0.17700 (0.149)			
URUPA	-1.9450 (-0.956)			
OPO			1.5565 (1.446)	-85.414 (-0.689)
AVEDUHH	0.26724E-01 (0.045)		0.73429 (0.990)	26.727 (0.327)
AVEDU2	-0.16925E-01 (-0.277)		-0.66048E-01 (-0.817)	-0.39793 (-0.044)
AVEAGEHH	0.26264 (0.514)			
AVEAGE2	-0.46442E-02 (-0.650)			
UNIONAPA	0.95201 (1.757)		1.1211 (1.303)	-195.59 * (-1.898)
YEARONFM	-0.32021E-01 (-0.433)		0.22777 * (2.307)	11.663 (1.091)
YEARSSA			0.33909 (0.924)	76.575 * (2.421)
PERCAP	0.70223E-04 (0.410)		-0.17342E-02 (-1.666)	
PERFOR			0.22860E-01 (1.096)	-0.30789 (-0.126)

	Probability of Becoming an APA member (n=196)		Extent of Adoption (Hectares) (n=25)	Extent of Adoption (Honey) (n=25)
ADULTMAL			-0.23778 (-1.347)	21.412 (1.392)
NOHONCAP				0.79397E-01 (0.807)
LAMBDA			-0.22567 (-0.254)	-156.72 (-1.329)
Probability Model: Likelihood ratio test 134.975*** Pseudo R ² 0.90 Number of Correct predictions 172 (88%) Extent of Adoption (Hectares): F statistic 1.19 R squared 0.46 adjusted R-squared 0.07 Extent of Adoption (Honey): F statistic 1.47 R squared 0.51 adjusted R-squared 0.16				
***, **, * indicate significance at the 1%, 5%, and 10% levels, respectively *Marginal impacts are the partial derivatives of $E[y] = \Phi[*]$ with respect to the vector of characteristics. They are computed at the means of the independent variables.				

6.8.4 Third Series of Equations - Extent of Adoption in Hectares Devoted to Sustainable Agriculture - Based on the Probability of Becoming an APA Member

The estimation of the extent of adoption in terms of the number of hectares devoted to inter-cropping by APA members is estimated using variables for education of the household heads, unions that the family participates in besides APA, number of years the family has resided on the lot, the number of adult males on the lot, per capita income, the percent of the lot which is primary forest, and a dummy variable for Ouro Preto county .

The overall significance of the model used to estimate extent of adoption in terms of the number of hectares devoted to intercropping is low. The F statistical value is not significant at the 5% level (Table 6.5). The R-squared value is 0.46 and the adjusted R-squared value is 0.07 suggesting that only 7% of the model can be accounted for by the variables included. The only variable that is significant in this model is the number of years that family has resided on the lot. The coefficient of this variable is positive suggesting, as the number of years that a family has resided in the lot increases, so does the number of hectares which are devoted to sustainable agriculture. This result is also supported by the previous models discussed in this chapter used to estimate the extent of adoption in hectares (Table 6.5).

The R-squared and adjusted R-squared values differ greatly in this model suggesting that too many explanatory variables have been included in the estimation. The model is therefore estimated using only UNIONAPA, YEARONFM, and PERCAP to determine the extent of adoption in terms of the number of hectares that are converted to sustainable

agriculture (Table 6.6). The F statistical value is not significant at the 5% level, suggesting the overall significance of the model is low. The R-squared value of 0.31 and the adjusted R-squared value is 0.18 suggesting that only 18% of the model can be accounted for by the variables which have been included. Although the explanatory power of the model is increased, this increase is small. Again, YEARSSA and UNIONAPA are significant.

The estimation of the probability of becoming an APA member does not improve the second series of equations. This model is estimated in order to correct for the censoring bias which occurs when only the APA members are included. The model does not provide any useful information to analysis due to the censoring which may occur.

6.8.5 Third Series of Equations - Extent of Adoption in Liters of Honey Harvested - Based on the Probability of Becoming an APA Member

The estimation of the extent of adoption in terms of the liters of honey harvested by APA members is estimated using variables for education of the household heads, unions that the family participates in besides APA, number of years the family has resided on the lot, the number of adult males on the lot, per capita income, the percent of the lot which is primary forest, and a dummy variable for Ouro Preto county.

The overall significance of the model used to estimate extent of adoption in terms of the number of liter of honey harvested is low. The F statistical value is not significant at the 5% level. The R-squared value of 0.51 and the adjusted R-squared value is 0.16 suggesting that only 16% of the model can be accounted for by the variables which have been included (Table 6.5). The only variables which are significant in this model are the

Table 6.6
Coefficient Estimates for the Probability of Becoming an APA
Member and the Extent of Adoption - Second Estimation

Variable	Probability of Becoming an APA member (n=196)		Extent of Adoption (Hectares) (n=25)	Extent of Adoption (Honey) (n=25)
	Coefficient	Marginal Impacts ^a	Coefficient	Coefficient
Constant	-5.9094 (-0.629)		-2.6211 (-0.984)	503.78 (1.467)
NOVA	0.47007 (0.419)			
VALE	-1.0571 (-0.750)			
TEIX	0.47935 (0.739)			
MIR	0.17700 (0.149)			
URUPA	-1.9450 (-0.956)			
AVEDUHH	0.26724E-01 (0.045)			
AVEDU2	-0.16925E-01 (-0.277)			
AVEAGEHH	0.26264 (0.514)			
AVEAGE2	-0.46442E-02 (-0.650)			
UNIONAPA	0.95201 (1.757)		1.3972 (1.575)	-160.33 (-1.778) *
YEARONFM	-0.32021E-01 (-0.433)		0.17986 (1.976) *	
YEARSSA				80.320 (2.414) *
PERCAP	0.70223E-04 (0.410)		-0.0006 (-0.698)	
NOHONCAP				0.0754 (0.854)

	Probability of Becoming an APA member (n=196)		Extent of Adoption (Hectares) (n=25)	Extent of Adoption (Honey) (n=25)
LAMBDA			0.0842 (0.099)	-136.70 (-1.372)
Probability Model: Likelihood ratio test 134.975*** Pseudo R ² 0.90 Number of Correct predictions 172 (88%) Extent of Adoption (Hectares): F statistic 2.32 R squared 0.31 adjusted R-squared 0.18 Extent of Adoption (Honey): F statistic 3.19 R squared 0.38 adjusted R-squared 0.26				
***, **, * indicate significance at the 1%, 5%, and 10% levels, respectively ^a Marginal impacts are the partial derivatives of $E[y] = \Phi[*]$ with respect to the vector of characteristics. They are computed at the means of the independent variables.				

number of unions that the family participates in besides APA (UNIONAPA) and the number of years that the family has been using sustainable agriculture (YEARSSA).

The coefficient of UNIONAPA is negative, suggesting that as the number of unions that the family participates in increases honey harvest decreases. This is not as would be expected. Since these unions are the main farm organizations in Ouro Preto, they serve as a vital means of information and communication between farmers. The unions have helped to support government agencies in the establishment of sustainable agricultural systems on farm lots, have disseminated the seedlings which are used in sustainable agriculture free of charge, and have continued to support the use of sustainable agriculture through the sponsorship of annual workshops. It is therefore expected that as participation in these organizations increases, the extent of adoption of sustainable agricultural practices increases.

The coefficient on YEARSSA is positive and significant suggesting that as the number of years a family uses sustainable agriculture increases, the harvesting of honey will increase.

The R-squared and adjusted R-squared values differ greatly in this model suggesting that too many explanatory variables have been included in the estimation as is true for the model of the extent of adoption in terms of hectares of intercropping. The model is therefore estimated using only UNIONAPA, YEARSSA, and NONHONCAP to determine the extent of adoption in terms of the number of hectares which are converted to sustainable agriculture (Table 6.6). The model used to estimate extent of adoption in terms of honey harvest is not significant at the 5% level based on the F statistic 3.19 when

4 explanatory variables are used with 20 degrees of freedom for the numerator. The R-squared value of 0.38 and the adjusted R-squared value is 0.26 suggesting that only 26% of the model can be accounted for by the variables which have been included. Although the explanatory power of the model is increased, this increase is small. Again, the only significant variable is YEARONFM.

The overall results for the estimated involving APA members, including both the probability of becoming an APA member and the extent of adoption, are not significant estimators. The prediction of APA membership is weak and, therefore, not a good means of establishing a bias for the extent equations.

6.9 Summary of the Estimation Results and Policy Implications

Three series of equations have been estimated in this chapter. The first series of equations estimates the probability of adoption of sustainable agriculture and the extent of adoption once the adoption choice is made using the stratified random sample. The first series of equations clearly performs well. Both the adoption and extent of adoption have high explanatory power and many significant variables. The third series of equations makes the same estimation with a combination of data collected from APA (a farmer organization which supports the use of sustainable agriculture) and the random sample. The third series of equations also has high explanatory power and many significant variables. The second series of equations as well as the estimation of the probability of becoming an APA member do not perform as well. The reason that these equations do not perform well is likely the result of the inclusion of the APA member data. Data

gathered from this homogenous group of farmers does not lead to significant regression estimates.

The conclusions from the models involving APA members are; APA members do not significantly differ from non-APA farmers in the characterizations examined in this study. There are not any significant indicators that predict which farmers are more likely to become APA members. Instead, it is concluded that the probability of becoming an APA member is determined by variables which cannot be measured such as the politics which are involved in the recruiting of members. It is likely that the ideology that exist in the organization, which cannot be measured in a regression, play a large role in the extent of adoption.

The impacts that APA has made on adoption and the extent of adoption could be measured best by a larger data sample which includes similar farmer organizations in different settlements of the Amazon. These data do not include observations from areas outside of Ouro Preto do Oeste because of budget and time constraints. A larger data sample would provide the ability to compare the impact of farmer organizations of farm choice in a variety of situations.

Although the different models which have been estimated in this chapter have made different conclusions and have used different data groups, there are some similarities between the results, and these results are important to mention. The probability of adopting sustainable agriculture is highly predictable in the first and third series of estimations and is influenced greatly by the knowledge that sustainable agriculture exists and the number of unions in which a family participates. This result is important to policy

implications since both of these factors may be influenced by economic and social programs.

An important variable in the estimation of the extent of adoption is the number of years that the family has practiced sustainable agriculture indicating that once sustainable agriculture is adopted, farmers are likely to increase the extent to which it is practiced throughout the years. Recognizing this variable is also important to policy because this continued practice of sustainable agriculture by families implies that policies that provide initial assistance and seedlings can lead to multiple effects for each farmer.

Another conclusion that can be made from these models is that as families become permanent residents of their lots, they become more likely to adopt more sustainable means of production. Property rights have become secure over the past ten years in Ouro Preto do Oeste, and these rights have instilled an incentive to maintain farm lots and the productivity of these lots for future generations.

The marginal impacts are calculated for both of the equations which estimate the probability of adoption. The marginal impacts for these models in terms of policy implications are similar. The variables important to policy implications are the knowledge of sustainable agriculture and union membership. The impact that the knowledge of sustainable agriculture makes on the probability of adoption is very large, and implies that policies which can help increase this knowledge can impact the adoption greatly. Programs likely to be most successful are those that concentrate on the dissemination of information about new agricultural methods and provide training for the farmers in the methods of sustainable agriculture.

CHAPTER 7

CONCLUSION

7.1 Model and Methods

Tropical deforestation in Brazil is the result of market failures occurring on global, national, and local levels. Market failure, on all levels, impacts the local farmers who live in the tropical forests and depend on the land for their livelihoods. This study investigates the decisions farmers make in relation to farming technique alternatives and how these decisions impact deforestation.

The adoption of sustainable agriculture is estimated in a technology framework where the choice of using a new farming technique, sustainable agriculture, or using the older technique, slash-and-burn agriculture, is treated as a dichotomous choice. A two-stage Heckman model is estimated to determine first the probability of adoption sustainable agriculture and then the intensity of adoption once sustainable agriculture is used. The results from the analysis are used to make policy suggestions as to the most effective ways to increase the adoption rate of sustainable agriculture. In particular, the roles of farm unions and information dissemination are investigated since these factors may clearly be influenced by policy.

7.2 Results

One important result of the analysis is that information plays a vital role in the adoption of sustainable agriculture by assisting local farmers in the adoption of a superior method of farming. This result is consistent with the results of Hussain *et al.* (1994), D'Souze *et al.* (1993), Feder and Slade (1984), and Opare (1987). Also found to be important is the role of human capital. Similar to Strauss *et al.* (1991), Lin (1991), and Akinola and Young (1985) access to education is found to increase the rate of adoption. The farmers who have a greater number of completed years of education are found to be more likely to adopt sustainable agriculture, although this result is not supported by all of the estimations.

This study adds to this body of literature by investigating the role that farm unions and local farm organizations play in the adoption of a new technology. It is found in the regression analysis that unions and local farm organizations play a critical role in the adoption of sustainable agriculture. This result is important since these organizations can be influenced by policy. For example, financial and educational support of sustainable agriculture could be provided through these organizations.

In addition, this analysis adds to the body of literature because it is a unique look at the influence of capital assets. Previous studies have suggested that as capital assets increase that the adoption of new technologies will increase (Miller and Tolley 1989, Holden 1993, Kebede *et al.* 1990, Jaeger and Matlon 1990, Norris and Batie 1987, Savagado *et al.* 1994, Rahm and Huffman 1984, Shakya and Flinn 1985), but this analysis

finds that the extent of adoption is influenced greatly by a lack of capital assets such as labor available (measured by the number of adult males). The families that have the least capital assets are more likely to adopt the agricultural technique which requires the least labor more intensely, suggesting that more farmers may adopt sustainable agriculture if the smaller labor requirements are learned.

One main issue discussed is that sustainable agriculture is not being adopted by many farmers in Ouro Preto do Oeste despite potential increases in income and welfare. Only one percent of the farmers who live in Ouro Preto do Oeste have adopted sustainable agriculture since it was first introduced to the city in the early 1980's through governmental programs.

It is concluded that the main reason for the low adoption rate of sustainable agriculture in Ouro Preto do Oeste is imperfect information. A majority of farmers interviewed did not have any knowledge of sustainable agriculture. Only 21 percent of the total farmers interviewed knew about or had knowledge of sustainable agriculture. Of the farmers who had knowledge of sustainable agriculture (including APA members) 83 percent chose to adopt sustainable agriculture. In the stratified random sample of 171 farmers (not including APA members), only 10 percent of the farmers knew about sustainable agriculture and of those farmers who knew about sustainable agriculture, 60 percent of them adopted it. These results suggest that the adoption of sustainable agriculture could be increased considerably through programs which support the dissemination of information about sustainable agriculture.

Another important result is, there are few significant variables in the estimation of the

probability of becoming an APA member. The lack of significant variables suggests that APA members may not be significantly different than non-APA farmers in terms of age, education, per capita income, and county of residence. The farmers are likely to join APA through family and friend networks rather than being selectively chosen based on characterizations such as income, age, or education. APA leaders and founders may have higher levels of education, but this is not true of the remaining members. This result is promising for policy since this suggests that programs which assist in the dissemination of information about sustainable agriculture or provide training in sustainable agriculture are not likely to be adopted by a particular type of farmer (similar to the farmers who joined APA) but rather the average or typical farmer.

The overall results of this research are promising. Many farm families have established property rights and have recognized that it is necessary to maintain the nutrient rich soils for future generations. The lots are generally passed on to future generations that depend on productivity of the land in order to survive, and this is a reason why many of the farmers have adopted sustainable agriculture. As the land which can support agriculture is depleted through burning, families have begun to realize the importance of sustainable agriculture. It is therefore important to educate more families about alternative land use methods. Programs supporting the dissemination of information are therefore likely to be successful in encouraging more families to adopt more sustainable methods of farming.

7.3 Future Research

Further research of this area is necessary in order to make implications of the success of sustainable agriculture. Since the adoption of this agricultural method is relatively new to the region there are not many conclusions to the success of sustainable agriculture and whether intercropping can maintain the soil quality necessary to support agricultural crops for extended periods of time. It will therefore be interesting to continue this study and determine the success of these agricultural systems in terms of income and crop yields as Ouro Preto do Oeste becomes more developed, and to investigate the impact that the development makes on deforestation and the decisions by farmers to adopt sustainable agriculture.

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APPENDICES

APPENDIX A
OPERATION AMAZONIA

A.1 Operation Amazonia

The Brazilian government began colonization programs in order to establish settlements in the undeveloped Amazon region in response to the many social and political problems in the populated areas of the northeast and southeast. A major component of the government programs was road development and improvement. Road construction initially began in the states of Goiás, Maranhão, Mato Grosso, and Pará. Responding to infrastructure development and settlement in the tropical forests of Peru, Venezuela, and other adjacent countries, the military government which came to power in 1964 launched "Operation Amazonia" (Southgate 1994, Southgate 1992, Dale and Pedlowski 1992, Hecht and Cockburn 1990, Guppy 1984). Among the first infrastructure projects was the first 1,200 km of the Tranzamazon Highway, which runs west from the northeastern state of Maranhão, and continues across the Amazon region to western Amazonas. It was completed in 1972 (Southgate 1992).

Agriculture colonization was encouraged by the government along the new highways. The primary objective of the completion of the Tranzamazon Highway was to facilitate the resettlement of 70,000 families from poverty in the northeast region. The area was suffering economically and socially from a long drought (Frohn *et al.* 1990, Moran 1990). The colonization objectives were not met because of the low fertility of the soil along the highway. Only about 3% of the land along this highway is suitable for agriculture, resulting in the settlement of only 8,000 families by 1980, which was well below the government's objectives (Browder 1994, Southgate 1992, Hecht and Cockburn 1990).

By contrast, in the areas where conditions were hospitable to agriculture, road construction induced rapid development of agricultural settlements, such as the completion of BR-364 in 1984 in Rondônia and BR-163 in Pará and Mato Grosso. In these areas the deforestation rate became the highest in Brazil only after the completion of the highways (Figure 2.2).

Inappropriate government planning resulted in economic and environmental disasters in the area surrounding the Tranzamazon highway, BR-163, and BR-364. The plans were implemented quickly and recklessly, resulting in a great deal of destruction to both the tropical forests and to the welfare of many people involved. For example, government planners and extension workers based the agricultural and economic development of the settlement areas on annual crops (particularly upland rice) which are generally considered to be environmentally and ecologically unsustainable in areas cleared from tropical rain forests, except under very favorable conditions (Browder 1994, Fearnside 1983, Goodland 1980).

Under the National Integration Program (PIN), which fostered the construction of the Tranzamazon Highway and the settlement of the area, the Tranzamazon settlers found themselves in circumstances that were far from favorable. First, the colonization projects were great distances from major markets for agricultural commodities which put the settlers at a disadvantage compared to other more efficient producers elsewhere in Brazil. Second, largely because of the high cost of transportation due to poor road conditions, fertilizers, pesticides, and herbicides were sold in the region at prices beyond the reach of the farmers. Without these modern inputs, crops often succumbed to pests and diseases

(Hecht and Cockburn 1990, Mahar 1989).

The government integrated the construction of BR-364 in Rondônia, with a World Bank supported settlement program (POLONOROESTE) designed to relocate small scale farmers from other regions of Brazil (Browder 1988). The combination of poor land reform programs in other parts of the country, relatively fertile soils, and an enormously effective government campaign resulted in an explosive growth in the region, unanticipated by the government (Anderson 1993, Mahar 1989). Rondônia's rapid population growth and uncontrolled settlement has had devastating effects on the rain forest. The speed at which this deforestation took place was, in some areas of the state, truly astonishing. Most of the clearing was done for agricultural purposes (Mahar 1989). The government's provision of subsidies to farmers and ranchers continued up until the 1980's (Dale and Pedlowski 1992).

A.2 Migration to the Amazon

The combination of government programs, diverging land prices, and the poverty in urban areas of the country resulted in a massive migration movement in the 1970's and 1980's into the Amazon Basin of Brazil. Deforestation has increased as roads have made the region more accessible to settlers, farmers, loggers, miners, and ranchers.

In 1960 much of the Brazilian Amazon could only be reached by small aircraft or river boats. The tropical forests were largely undisturbed. In the late 1960's a large number of colonists from the south, southwest, and northeast began to move to the Amazon Basin responding to government incentives. Many settlers were attracted to the

frontier by the prospect of owning land; lots up to 100 hectares were supplied by the government (Baer 1995). The new settlers then cleared the forest for their settlements, farms, and ranches (Dale *et al.* 1993, Pedlowski and Dale 1992, Hecht and Cockburn 1990).

Human migration to the Amazon greatly increased the deforestation rate, but unlike tropical forests in other parts of the world, population pressure, by itself, has probably not been a major factor. Instead incentives provided by the government through Operation Amazonia have led to most of the deforestation in the area. In Brazil most rural poor have been much more likely to emigrate to the large cities on the eastern coast of the country rather than to the Amazon. In the 1970's at the start of Operation Amazonia, 16 million rural inhabitants migrated to cities compared to only 770,000 to the Amazon frontier (Mahar and Schneider 1994) resulting in high rates of urbanization.

A.3 Subsidies

Road construction is the most visible aspect of Operation Amazonia, but the creation of the Superintendency for the Development of Amazonia (SUDAM), established to provide subsidies for agricultural development, also indirectly added to deforestation in the area. The Bank of Amazonia (BASA) was founded to provide and distribute the funds for Operation Amazonia (Southgate 1992). In 1963 legislation was passed which induced Brazilian firms to invest in the Amazon Basin by reducing their tax payments by half if they invested the money in that region.

The Brazilian government generally promoted cattle ranching with the subsidy

program. The subsidies administered to the settlers were often as great as 75 percent of the cost of starting a ranch (Holloway 1993). By late 1985 SUDAM had approved 950 projects in the Amazon, 631 of which were cattle ranches mostly located in the eastern Amazonian states of Maranhão and Pará. Between 1974 and 1980 the volume of subsidized rural credit committed to Amazonia increased almost tenfold in real terms. Many of these projects would not have been profitable in the absence of subsidies (Mahar 1989). On the other hand, the impact of subsidies should not be exaggerated, since Mahar (1989) found that these projects were responsible for no more than 10 percent of the total land clearing.

A.4 Divergence of Land Values

Land prices in the southern regions of Brazil began to increase rapidly relative to the north in the 1970's. In 1970 a farmer (or anyone) in the south could purchase about twice the amount of land in the north as in the south for the same price (Southgate 1992). In 1975 one hectare of land in the Southeast could be traded for 13 hectares in the Amazon. Within ten years land in the south was worth up to ten times the price of land in the north (Southgate 1992). Although increased production in the south can explain some of the increase in land value, this increase combined with government incentives which provided many lots in the settlement programs free of charge (through Operation Amazonia) resulted in many farmers moving north.

A.5 Land Tax System

The rural land tax in Brazil, administered by the national government is currently assessed at a maximum of 3.5 percent of the market value of the land, and 50 percent of the total land owned is exempt from taxation (Mahar and Schneider 1994). Reductions of up to 90 percent of the basic rate are given according to the degree of utilization of land (the proportion cleared and efficiency indicators such as crop yields and cattle stocking rates). This tax system provides the incentive to clear land for pasture and agriculture. Fortunately the tax structure has had little influence on the rate of deforestation mainly because the landowners declare the value and efficiency of its use themselves. For example, in 1996 only half of the farmers in Rondônia paid any land tax and of the 50 percent who did, the average payment was only equal to \$5 (Mahar and Schneider 1994) which is rarely paid anyway (Moran 1993). In 1997 it was estimated by the labor union of rural workers (STR) that only approximately 40% of farmers pay their land taxes in Ouro Preto do Oeste.

A.6 Agricultural Income Tax

The agricultural income tax system supplies another incentive to deforest. Corporation and individuals can exclude up to 80 percent and 90 percent, respectively, of agricultural profits from their taxable income. Corporate agricultural profits are taxed at a rate of only 6 percent. Combined with the depreciation provision the tax can be as low as 1.2 percent. Comparatively, corporate income taxes from other sources are subject to a rate of 35-45 percent (Binswanger 1991). The incentives of this tax structure are to entice

corporations to invest in agriculture.

This tax structure may seem irrelevant to the small farmer who does not have to pay income taxes, but since poor individuals cannot benefit from the tax breaks, as corporations can, the tax benefits affect small farmers indirectly. Since agricultural income is taxed at a lower rate than other forms of income, agriculture is treated as a tax shelter, which leads the market price of land to contain a component capitalizing on these profits, which increases the relative price of land (Binswanger 1991). The corporations therefore drive up the price of land as they invest in this relatively cheaper capital asset making land more expensive for the small farmer.

APPENDIX B
ENGLISH SURVEY

English Version of Survey

Number _____

Date: _____

I. General Information

1.1 City _____ 1.2 Gleba _____

1.3a Linha _____ 1.3b Lot Number _____

1.4a Area _____

1.4b distance to city _____

1.4c distance of paved road _____

1.4d distance of unpaved road _____

Plots _____ Rural _____ Urban _____ Total _____ APA members _____

1.8 How old are you? _____

1.9a Did you go to school? Yes No

1.19b How many years did you study? _____

1.10 How many years have you been a farmer? _____

1.11 How many years have you lived on this lot? _____

1.12 Are you the owner of the lot? Yes No

1.13a What is the size of your lot (in hectares)? _____

1.13b How much of your lot is being used for:

1. Agriculture _____

2. Pasture _____

3. Forest _____

4. Sustainable Agriculture _____

1.14a How did you acquire this lot?

a. Occupied the land

b. Land was given to you through INCRA

c. Payed with a loan from the bank

d. Bought with your own money

e. Occupied the land and then bought it

1.14b How are the roads to your lot during the rainy season?

1. Good

2. Passable

3. Unpassable

1.15a Did you participate in any unions or associations for farmers? Yes No

1.15b How many? _____ which?

1.16 What state were you born in? _____

1.17 What state were your parents born in? _____

1.18 Were (Are) your parents farmers? Yes No

II. Family Characteristics

2.1 Who lives on this farm? How many people? _____

	number
a. men $\geq$ 10	
b. men $<$ 10	
c. women $\geq$ 10	
d. women $<$ 10	

How old is the woman of the house? _____

For how many years did she go to school? _____

2.2 How many of the following items does your family own?

a. Horses _____

b. Chickens _____

c. Cattle _____

d. Pigs _____

e. Televisions _____

f. Sheep _____

g. Satellite Dish _____

h. Goats _____

i. Tractors _____

j. Equipment for use with animals _____

k. Cars _____

l. Trucks _____

m. Motorcycles _____

n. Wheel Barrel _____

- o. Telephones _____ p. Refrigerators _____
- q. Bicycles _____ r. Other lots _____
- s. Other houses _____ city houses _____ t. Workers _____ pay labor _____
- u. Chain Saws _____ v. Garden (size) _____
- w. Other types of equipment _____

2.3 Why did your family migrate to Rondônia?

- a. The land was free
- b. For work
- c. Because other members of your family migrated to Rondônia
- d. Land
- e. Other (specify)

2.4 What year did your family migrate to Rondônia? _____

III Methods of Cultivation

3.1a With what frequency do you slash-and-burn your lot to plant crops?

- a. One time
- b. Every two years or more
- c. Every year
- d. Never

3.1b What land?

- a. Primary forest
- b. Secondary forest

3.2a With what frequency do you slash-and-burn your lot to create a fire line?

- a. One time
- b. Every two years or more
- c. Every year
- d. Never

3.2b What land?

- a. Primary forest
- b. Secondary forest

3.3a With what frequency do you slash-and-burn your lot to create pasture?

- a. One time
- b. Every two years or more
- c. Every year
- d. Never

3.1b What land?

- a. Primary forest
- b. Secondary forest

3.4a How much of your land did you burn this year? _____

3.4b Last year? _____

3.5 What type of equipment do you use to clear and burn your land? _____

3.6 How many people help to clear and burn your lot? _____

3.7 How many days do you need to clear and burn your lot? _____

IV. Production

4.1 The following questions are about your harvest of annual crops

- a. How much _____ did you plant this year (in hectares)?
- b. Last year?
- c. How much _____ did you harvest last year?
- d. How much _____ did you sell last year?
- e. At what price?

Annuals	1. Area Planted 1996	2. Area Planted 1995	3. Unit	4. Harvest 1995	5. Unit	6. Sell Y/N	7. How much	8. Price
a. Rice								
b. Corn								
c. Beans								
d. Manioc								

4.2 a. Do you use chemical fertilizers? Yes No For which crops?

b. Do you use organic fertilizers? Yes No For which crops?

c. Do you use pesticides? Yes No For which crops?

d. Do you use herbicides? Yes No For which crops?

	Rice	Corn	Beans	Manioc	Coffee	Garden	
Chemical Fertilizers							
Organic Fertilizers							
Pesticides							
Herbicides							

4.3 The following questions are about your harvest of fruits and trees.

- a. How much _____ did you plant his year?
- b. Last year?
- c. How much _____ did you harvest this year?
- d. How much _____ did you sell this year?
- e. At what price?

Perennial Crops	1. Area Planted 1996	2. Area Planted 1995	3. Unit	4. Harvest 1995	5. Unit	6. Sell Y/N	7. How much	8. Price
a. Coffee								
b. Coco								
c. Banana								
d. Citrus								
f. Cupuaçu								
g. Pupunha								
h. Açaí								
I. Acerola								
j. Mahogany								
k. Valuable wood								
l. Mango								
m. Coco								
o. Jake friut								
abacati								
other								
other								
other								
other								

4.4 Where do you sell your crops? _____

V. Cattle and Pasture

5.1 About your cattle, how many of these produce milk? _____

5.2 Does anyone pick up your milk to sell at a market?

5.3 What is the importance of milk to your income?

1. Very important
2. Important
3. Not very important
4. Not important

5.4 How much milk do you produce each day?

5.4a in the dry season _____

5.4b in the rainy season _____

5.5 How much do you sell your milk for? _____

VI. Sustainable Techniques of Agriculture

6.1 Do you know about sustainable techniques of agriculture? Yes No

“Sustainable agriculture contributes to the production of agricultural products at the same time as it conserves the tropical rain forest. Sustainable agricultural methods include the use of various perennials planted together and the use of perennials with annual crops such as corn, rice, beans, and coffee. This agricultural method uses the forest while reducing the need to burn. In addition, the farmers which use these methods do not depend totally on the income raised from cattle (in the form of meat or milk), but instead have various other forms of income like beekeeping and fish raising. Therefore the majority of income of these farmers is derived from perennial crops, bee-keeping, and fish raising, all of which are sustainable uses of the forest and are dependent upon the standing forest.”

6.2 Do you use any of these techniques? Yes No If yes, which? If no, question 6.8

- 6.3
- a. Planting perennials
 - b. Leaving trees standing
 - c. Inter-cropping (only perennials) Which trees?
 - d. Inter-cropping (perennials and annuals) Which trees and annuals?
 - e. Using other forms of income

6.4 When did you begin using these new techniques? _____

6.5 How much of your lot do you use for the following?

- a. Planting perennials _____
- b. Leaving standing trees _____
- c. Inter-cropping (perennials) _____
- d. Inter-cropping (perennial and annuals) _____
- e. Using other forms of income _____

6.60 What other forms of income do you have?

- a. Bee-keeping
- b. Fish raising
- c. Other (specify)

6.61a How much honey did you harvest last year? _____ 6.61b Sell? _____

6.61c At what price did you sell? _____

6.62a How much fish did you harvest last year? _____ 6.62b Sell? _____

6.62c At what price did you sell? _____

6.7 What is the importance of _____ for your income?

a. Bee-keeping

1. Very important 2. Important 3. Not very important 4. Not important

b. Fish raising

1. Very important 2. Important 3. Not very important 4. Not important

c. Other (specify)

1. Very important 2. Important 3. Not very important 4. Not important

Do other people who live on this farm work outside or have other forms of income?

6.8a How many people? _____ 6.8b What do they do? _____

6.9 Why do you use these new techniques of farming?

- a. It is more profitable
- b. Seed was provided
- c. Money was provided
- d. It's better for future generations
- e. It is better for the forest and the region

- f. My parents use these methods
- g. My neighbors use these methods
- h. Other (specify)

VII. The Cost of Sustainable Agriculture (for those farmers who use it)

7.1a Do these new techniques require more or less work? Yes No

7.1b If yes, how much more or less?

7.2a Are these new techniques more expensive? Yes No

7.2b If yes, how much more?

7.3 Do you use the same area of your lot for these new techniques? Yes No

7.4 How much did you harvest before you began using these new techniques (6.4) _____
years ago?

Crop	Old Harvest	Unit
a. Rice		
b. Corn		
c. Beans		
d. Manioc		
f. Coffee		
g. Coco		
h. Banana		
I. Citrus		
j. Cupuaçu		
k. Pupunha		
l. Açai		
m. Acerola		
n. Mango		
o. Coconut		
p. Jake fruit		
q. Abacati		
r. Passion fruit		
other		
other		
other		
other		

VIII. Methods of Agriculture

8.1 The following items influence you, and in what degree, as to your choice of agricultural methods on this farm? What types of things effect your choice of crops and methods of cultivating them?

- a. Your neighbors
 - 1. A lot of influence 2. Some influence 3. No influence
- b. An association, union, or cooperative
 - 1. A lot of influence 2. Some influence 3. No influence
- c. Free Seed
 - 1. A lot of influence 2. Some influence 3. No influence
- d. Free trees
 - 1. A lot of influence 2. Some influence 3. No influence
- e. Bank Loans
 - 1. A lot of influence 2. Some influence 3. No influence
- f. A market to sell your annual crops
 - 1. A lot of influence 2. Some influence 3. No influence
- g. A market to sell your perennial crops
 - 1. A lot of influence 2. Some influence 3. No influence
- h. The soil and soil quality
 - 1. A lot of influence 2. Some influence 3. No influence
- i. Precious Wood
 - 1. A lot of influence 2. Some influence 3. No influence
- j. The cultivation methods of people in Ouro Preto do Oeste
 - 1. A lot of influence 2. Some influence 3. No influence
- k. The cultivation methods of your parents
 - 1. A lot of influence 2. Some influence 3. No influence

Surveyors Comments:

APPENDIX C
PORTUGUESE SURVEY

Data: _____

I. Informação Geral

1.1 Cidade _____ 1.2 Gleba _____

1.3a Linha _____ 1.3b Lote _____

1.4a Area _____

1.4b distância _____

1.4c rua de pavimento _____

1.4d rua não de pavimento _____

1.5 Número de lotes _____ 1.6 Populacao _____ 1.7 Número de APA _____

1.8 Quantos anos o Sr. tem? _____

1.9a O senhor estudou na escola? Sim Não

1.19b Quantos anos o senhor estudou? _____ E que grou estudou? _____

1.10 Há quantos anos você trabalha como agricultor? _____

1.11 Há quantos anos você trabalha nesta propriedade? _____

1.12 O senhor é o proprietário do lote? Sim Não

1.13a Qual o tamanho do seu lote (em hectares)? _____

1.13b Quanto de seu lote está sendo usado para

1. Agricultura _____

2. Pasto _____

3. Floresta _____

Outro _____

1.14a Como adquiriu este lote?

a. Ocupou a terra

b. Terra foi daoda pelo INCRA

c. Pegou financiamento do banco

d. Comprou com o seu próprio dinheiro

e. Ocupou a terra e depois comprou

1.14b Como são as estradas para o seu lote na época de chuva?

1. Bom

2. Mais ou menos

3. Ruim

1.15 O senhor pertence a alguma associação ou sindicato ou cooperativa? Sim Não
Caso sim, quais são?

1.16 O senhor nasceu em que estado? _____

1.17 Seus pais nasceram em que estado? _____

1.18 Seus pais eram agricultores? Sim Não

II. Características da Família

2.1 Quem mora nesta (na sua) propriedade rural? Quantas pessoas? _____

Quantos anos a senora na casa tem? _____

A senhora estudou por quantos anos? _____ E que grou estudou? _____

	numero
a. homens ≥ 10	
b. homens < 10	
c. mulhers ≥ 10	
d. mulhers < 10	

2.2 Que bens a sua família possui?

a. Cavalos _____

b. Frangos _____

c. Gados _____

d. Porcos _____

e. Televisões _____

f. Carneiros _____

g. Antenas parabólicas _____

h. cabras _____

i. Tratores _____

j. Equipamento para tração animal _____

k. Carros _____

l. Caminhões _____

- m. motocicletas _____
- n. Carrinhos-de-mão _____
- o. Telefones _____
- p. Geladeiras _____
- q. Bicicletas _____
- r. Outra lotes _____
- s. outra casas _____
- t. trabalhadores _____
- u. motoserras _____
- v. horta (tomanho) _____
- w. Outros tipos de equipamento _____

2.3 Por que sua família veio em Rondônia?

- a. O lote foi grátis.
- b. Para trabalhar
- c. Porque outros membros de sua família vieram à Rondônia
- d. Terra
- e. Outro (qual)

2.4 Quando a sua família chegou em Rondônia? _____

III Métodos de Lavoura

3.1a Com qual frequência você roça e queima para plantar?

- a. Um vez
- b. A cada dois anos ou mais
- c. Cado ano
- d. Nunca

3.1b Qual terra?

- a. floresta primeira (mato)
- b. floresta secundária (capueira)

3.2a Com qual frequência você faz acero?

- a. Um vez
- b. A cada dois anos ou mais
- c. Cado ano
- d. Nunca

3.2b Qual terra?

- a. floresta primeira (mato)
- b. floresta secundária (capueira)

3.3a Com qual frequência você roça e queima para plantar pasto?

- a. Um vez
- b. A cada dois anos ou mais
- c. Cada ano
- d. Nunca

3.3b Qual terra?

- a. floresta primeira (mato)
- b. floresta secundária (capueira)

3.4a Quanto de área do seu lote você queimou este ano? _____

3.4b Ano passado? _____

3.5 Que equipamento você usa para roça e queimar o seu lote? _____

3.6 Quantas pessoas fazem a preparação para a queima no seu lote? _____

3.7 Quantos dias você leva para preparar o seu lote para a queima? _____

IV. Produção

4.1 As seguintes perguntas estão sobre suas colheitas.

- a. Quanto do seu lote você usou para _____ (cultivo) este ano?
- b. Ano passado?
- c. Quanto _____ (cultivo) você colheu no ano passado?
- d. Quanto _____ (cultivo) você vendeu no ano passado?
- e. A que custo?

Anuais (lavoura branca)	1. Área Plantada 1996	2. Área Plantada 1995	3. Unidade	4. Colheita 1995	5. Unidade	6. Vende u S/N	7. Quant o	8. Preço
a. Arroz								
b. Milho								
c. Feijão								
d. Mandioca								

- 4.2a. Você usou fertilizantes químicos? Sim Não Em quais lavouras?
- b. Você usou fertilizantes orgânicos (como estrume)? Sim Não Em quais lavouras?
- c. Você usou pesticidas? Sim Não Em quais lavouras?
- d. Você usou herbicidas? Sim Não Em quais lavouras?

	Arroz	Milho	Feijão	Mandioca	Café	Horta	
Fertilizantes Químicos							
Fertilizantes Orgânicos							
Pesticidas							
Herbicidas							

4.3 As seguintes perguntas estão sobre a sua colheita de arvores e frutas.

- a. Quanto do seu lote você usou para _____ (cultivo) este ano?
- b. Ano passado?
- c. Quanto _____ (cultivo) você colheu no ano passado?
- d. Quanto _____ (cultivo) você vendeu no ano passado?
- e. A que custo?

Culturas Perenes (Permanentes)	1. Área Plantada 1996	2. Área Plantada 1995	3. Unidade	4. Colheita 1995	5. Unidade	6. Vendeu S/N	7. Quanto	8. Preço
a. Cáfe								
b. Cacau								
c. Banana								
d. Citrus								
f. Cupuaçu								
g. Pupunha								
h. Açaí								
i. Acerola								
j. Magno								
k. Madeira de lei								
l. Outro arvores								

4.4 Onde você vendeu a sua colheita? _____

V. Gado e Pastagens

5.1 Sobre as suas cabeças do gado, quantas destas produzindo leite?

Quantas Vacas? _____

5.2 Alguém apanha o seu leite para vender no mercado?

5.3 Qual é importância de leite para sua renda?

1. Muito importante
2. Importante
3. Pouco importante
4. Não importante

5.4 Quanto de leite você produz à cada dia?

5.4a na época de seca _____

5.4b na época de chuva _____

5.5 Por quanto você vende o leite? _____

VI. Novas Técnicas de Cultivo

6.1 Você sabe quais são as novas técnicas de cultivo? Sim Não

Novas técnicas agrícolas podem contribuir para produção agrícola e ao mesmo tempo, conservar as florestas desta região. As novas técnicas incluem as combinações das culturas perenes com as culturas anuais como: milho, arroz, feijão e mandioca. Esta lavoura usa a floresta, a qual não é brocada, derrubada nem queimada, em combinação com a lavoura como: consórcio e cultura casada. Além disso, você não depende totalmente da renda do gado (leite ou carne), mas de várias fontes de renda, como a maioria da renda derivada de culturas perenes ou da criação de abelhas e de peixe.

6.2 Você utiliza algumas das novas técnicas? Sim Não Se sim, quais? Se não, 6.8

6.3 a. Cultivando culturas perenes

b. Deixando as árvores

c. Consórcio (misturando as colheitas juntos) Qual colheitas?

d. Cultura casada (usando árvores com lavouras brancas)

Qual árvores e quais lavouras brancas?

e. Usando fontes alternativas de renda

6.4 Quando você começou a usar algumas destas técnicas? _____

6.5 Quanto do seu lote você usa para?

- a. Cultivar culturas perenes _____
- b. Deixar as árvores _____
- c. Consórcio _____
- d. Cultura casada _____
- e. Usando fontes alternativas de renda

6.6a Quais são as fontes alternativas de renda que você tem?

- a. criação de abelhas
- b. criação de peixe
- c. Outro (qual)

6.6b Quanto colheu no ano passado? _____

6.6c A que preço vendeu isto? _____

6.7 Qual é importância de _____ para a sua renda?

- a. criação de abelhas
 - 1. Muito importante
 - 2. Importante
 - 3. Pouco importante
 - 4. Não importante

- b. criação de peixe
 - 1. Muito importante
 - 2. Importante
 - 3. Pouco importante
 - 4. Não importante

- c. Outro (qual)
 - 1. Muito importante
 - 2. Importante
 - 3. Pouco importante
 - 4. Não importante

6.8a As outras pessoas que moram nesta propriedade rural têm outras fontes de renda além da lavoura? 6.4b Quantas pessoas? 6.4c Quais são as fontes de renda?

6.9 (Se o agricultor usa as novas técnicas) Por que você usa as novas técnicas?

- a. É mais proveitoso
- b. Semente foi fornecida.
- c. Dinheiro foi fornecido.
- d. É melhor para as gerações futuras.
- e. É melhor para a terra e a floresta.
- f. Os meus pais usam esses métodos
- g. Os meus vizinhos usam esses métodos
- h. Outro (qual)

VII. O custo das novas técnicas (para os agricultores que as usam)

7.1a As novas técnicas requerem mais ou menos trabalhadores? Sim Não

7.1b Caso sim, quantos mais ou quantos menos?

7.2a As novas técnicas são mais caras do que as velhas técnicas? Sim Não

7.2b Caso sim, quantos?

7.3 Você usou a mesma área do seu lote para a lavoura depois de que começou a adotar as novas técnicas? Sim Não

7.4 Quanto colheu antes de adotar as novas técnicas (6.4) _____ anos passado?

Culturas	Colheita Antes	Unidade
a. Arroz		
b. Milho		
c. Feijão		
d. Mandioca		
f. Café		
g. Cacau		
h. Banana		
i. Citrus		
j. Cupuaçu		
k. Pupunha		
l. Açaí		
m. Acerola		
n.		
o.		

VIII. Métodos Agrícolas

8.1 Estes itens tiveram algum efeito nos seus hábitos de cultivar?

- a. Os seus vizinhos
 - 1. muito efeito 2. algum efeito 3. nenhum efeito
- b. Uma associação, um sindicato, ou uma cooperativa
 - 1. muito efeito 2. algum efeito 3. nenhum efeito
- c. Semente grátis
 - 1. muito efeito 2. algum efeito 3. nenhum efeito
- d. Árvores grátis
 - 1. muito efeito 2. algum efeito 3. nenhum efeito
- e. Empréstimos
 - 1. muito efeito 2. algum efeito 3. nenhum efeito
- f. Um mercado para vender as suas culturas anuais
 - 1. muito efeito 2. algum efeito 3. nenhum efeito
- g. Um mercado para vender as suas culturas perenes
 - 1. muito efeito 2. algum efeito 3. nenhum efeito
- h. As condições de terra (sabe sobre o solo de seu lote)
 - 1. muito efeito 2. algum efeito 3. nenhum efeito
- i. As árvores eram de alto valor para derrubar
 - 1. muito efeito 2. algum efeito 3. nenhum efeito
- j. As maneiras de cultivo de região
 - 1. muito efeito 2. algum efeito 3. nenhum efeito
- k. As maneiras de cultivo dos seus pais
 - 1. muito efeito 2. algum efeito 3. nenhum efeito

Surveyors Comments:

APPENDIX D

DISCRETE CHOICE MODELS AND TECHNOLOGY ADOPTION

D.1 Discrete Choice Models

Discrete choice models also known as: probability, multivariate, or limited dependent variable models are frequently used in the study of technology adoption in developing countries (Hussain *et al.* 1994, Adesina and Zinnah 1993, Lin 1991, Kebede *et al.* 1990, Shakya and Flinn 1985, Akinola and Young 1985). These include probit, logit, tobit and Heckman regression techniques. Discrete choice models are applicable in a wide variety of fields and are used extensively in survey or census type data (Gujarati 1995). In the literature review of diffusion and adoption studies in Chapter 4 many of the papers used discrete choice analysis in order to determine the probability of adopting a new technology. The probability of adoption is used in these studies because it is an excellent indicator of adoption trends and therefore can indicate how the adoption of new technologies can be increased. For example, if the probability of adopting a new agricultural technology is low the model may show that financial support or incentives can increase the adoption rate.

This appendix provides a review of discrete choice models are used in the regression analysis in Chapter 6. In particular the appendix discusses the tobit and Heckman techniques. These are discrete choice models which estimate first the probability of adoption and secondly the extent of adoption.

D.2 Choosing a Probability Model

Studies which use linear, log-linear, or semi-logarithmic regression equations to measure the adoption rate and the intensity of the use of an innovation often estimate the

parameters using ordinary least squares (OLS). Such applications fail to capture the complexity of the decision making process when truncated or censored data are used and produce misleading if not erroneous influences. Non-adopters for whom expenditure on the innovation is zero are excluded from the sample, creating a sample selection bias. This bias leads to heteroskedastic error structure and inefficient regression parameters leading to biased and inconsistent parameter estimates (Maddala 1985). The exclusion of non-adopters implies a zero demand. A more appropriate assumption, which is made in multivariate models such as probit, logit, and Heckman estimations, is that non-adopters display market behavior by choosing not to adopt the technology. A comparison of these two groups could also serve to indicate any significant difference between the characteristics of the adopters and non-adopters.

Attempting to correct for the sample selection bias by including non-adopters in linear, log-linear, and semi-logarithmic regression equations still results in a bias. As non-adopters, for whom the dependent variable is zero, are excluded from the sample, a sample selection bias is created and hence the regression coefficients are likely to be biased. The clustering of observations at zero, when correcting for the sample error, would violate the OLS assumption of a continuous dependent variable (Goldberger 1964, Pindyck and Rubinfeld 1983). Feder *et al.* (1985) review the range of bivariate and multivariate statistical models used to analysis adoption behavior, criticize bivariate OLS models and conclude that they provide no insight into the relationship between adoption and the determinants of adoption. The authors recommend the use of probit or logit models to avoid most of these difficulties. Since the publication of that paper, there have

been many studies which have used probit and logit models to study the adoption of new technologies in farming (Savagado *et al.* 1994, D' Souza *et al.* 1993, Kebede *et al.* 1990, Feder and Slade 1984).

Feder *et al.* (1985) review the adoption literature of developing countries and determine that the best economic models which investigate the adoption decision to be probit and logit models. According to this review, the probit-logit methodology is preferable to discriminate analysis for analyzing the adoption decision since any form of linear regression results used to determine a discrete choice results in a bias. They also point out that few studies adopted procedures that explicitly account for the qualitative nature of the dependent variable and the intensity of adoption.

Since the Feder *et al.* (1985) study, multivariate statistical models have become common in the adoption decision literature with growing support for the tobit model (Tobin 1958). The tobit model measures not only the probability of adoption but also the intensity of use of the technology once it is adopted. Therefore, when the intensity of adoption is desired, the tobit model of estimation has been shown to be superior to both the logit and probit methods of estimation. (Saha *et al.* 1994, Adesina and Zinnah 1993, Lin 1991, Gould *et al.* 1989, Norris and Batie 1987, Akinola and Young 1985, Shakya and Flinn 1985).

D.3 Tobit Model Specification

The tobit model (Tobin 1958) has been used by economists extensively since it was first developed in order to estimate the determinants of demand for a variety of consumer

goods. Tobin measured the demand for luxury goods. These goods are unique in that they measure a zero demand in those years that consumers do not buy them. The zero demand becomes a problem when linear models of estimation are used. Instead, a censored probability model such as the tobit, assumes that non-adopters are displaying market behavior by choosing not to purchase the good (Akinola and Young 1985). For example, the expenditures on cars may be used to derive a demand for cars, but the price that a consumer is willing to pay may be below the market price, and therefore the consumer will not purchase the car. The demand price would therefore be estimated to be zero, instead of the price below the market price. The OLS estimates of the parameter obtained from the subset of consumers (those that do purchase the car) will be biased as well as inconsistent as a result of this approach.¹

The tobit model assumes that many variables have a lower (or upper) limit and take on this limiting value for a substantial number of respondents. For the remaining respondents, the variables take on a wide range of values above or below the limit. An explanatory variable in such a situation may influence both the probability of limit responses and the size of non-limit responses (Akinola and Young 1985).

The theoretical framework of the tobit model can be explained by the concept of a threshold value of the dependent variable. Given that the decision to adopt sustainable agriculture is characterized by a dichotomous choice between two mutually exclusive alternatives, (slash-and-burn agriculture and sustainable agriculture) there is a break-point

¹ The bias arises from the fact that if we only consider those observations from consumers who purchase the car, there is no guarantee that the expected value of the error term $E(\mu_i)$ is zero. And without $E(\mu_i) = 0$ there is no guarantee that the OLS estimates will be unbiased.

in the dimension of explanatory variables such as farmer characteristics, capital assets, and information variables. There is a point below which a stimulus elicits no observable response. The independent variables which determine the extent of adoption of sustainable agriculture are only measured once the decision to use the new agricultural technique is made. Only when the strength of the stimulus exceeds that threshold level does adoption occur and the second decision on the intensity of its use is taken. In other words, an underlying continuous choice model on adoption exists but is only observed if sustainable agriculture is adopted.

For example, let Y denote the probability of adopting sustainable agriculture is the dependent variable and X a vector of explanatory variables. The Y variable can be defined in the context of a limited variable which takes on two values, $Y = Y^*$ if the decision results in the adoption of sustainable agriculture and $Y=0$ if adoption does not occur. The dichotomous nature and intensity of this decision is represented in Figure D.1. Point T represents the break-point or the threshold. At values of X greater than T there is a probability of 1 of adoption and the intensity of adoption, represented by Y^* is continuous, shown by the line TC . At values of X below T , the probability of adoption is zero and the intensity of adoption is, of course, zero. In Figure D.1, the portion of the x -axis from 0 through to T , represents the observation of those farmers who choose not to adopt sustainable agriculture, while the portion of the curve from T to C represents the extent of adoption for those farmers who do choose to use sustainable agriculture.

In the example just described, the dependent variable is censored. Information is missing for the dependent variable when the choice is made to adopt slash-and-burn

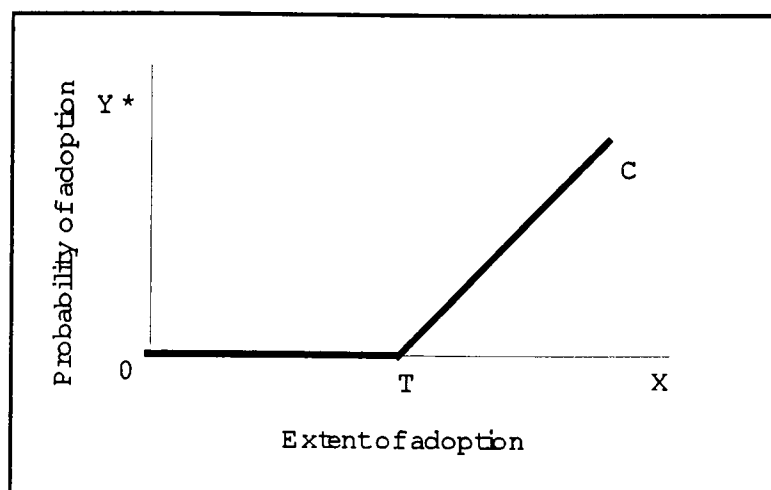


Figure D.1
The Tobit Threshold

agriculture (not to adopt sustainable agriculture), pertaining to the extent of adoption.

But the corresponding information for the independent variables is present² (Pindyck and Rubinfeld 1991).

The tobit model, like all limited dependent variable or discrete choice models, interprets the dependent variable as the probability of adoption and therefore limits the value of the dependent variable to be between 0 and 1. A transformation is, therefore, used to keep the values of the estimated dependent variables in the 0 to 1 range. The requirement of such a process is that it translates the values of the attributes X_i , which may range in value over the entire real line, into a probability which ranges in value from 0 to 1. It is desirable that the transformation should maintain the property that increases in X_i are

² When both types of data are missing (the data responding to both the dependent variable and the independent variables), the dependent variable is considered to be truncated.

consistently associated with increases or decreases in the dependent variable for all values of X_i , making a monotonic transformation necessary. The cumulative probability function (defined as one having as its values the probability that an observed value of the variable X_i) will be less than or greater than the threshold value, provides the necessary transformation for this operation. The range of the cumulative probability function is the interval (0,1) since all probabilities lie within these values. The standard cumulative normal distribution of $X_i\beta$ (the cumulative distribution function, CDF)³ is given by:

³ The standardized normal CDF can be determined as follows. The decision of whether to use sustainable agriculture or not by the i th farmer depends on the unobservable utility index, Y_i^* (which is determined by the explanatory variable X_i) in such a way that the larger the value of the index Y_i^* , the greater the probability of adoption. The index is expressed as $Y_i^* = X_i\beta$. For each farmer there is assumed to be a critical value, Y_i^{**} , such that if Y_i^* exceeds Y_i^{**} , the farmer will adopt sustainable agriculture. The threshold, Y_i^{**} , like Y_i^* is not observable, but if it is assumed to be normally distributed, with the same mean and variance as Y_i^* , it is possible to estimate the parameters of the index and to obtain information about the observable index. The probability that Y_i^{**} is less than or equal to Y_i^* can be computed as follows:

$$Y_i = Pr(Y=1) = Pr(Y_i^{**} \leq Y_i^*) = F(Y_i^*) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{Y_i^*} e^{-s^2/2} ds = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{X_i\beta} e^{-s^2/2} ds$$

which comes from the probability density function:

$$f(z) = \int_{-\infty}^{X_i\beta} \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}s^2}$$

where s is the variable X (a normally distributed variable with mean μ and variance σ^2) converted into a standardized normal variable, s by the following transformation: $s = (x - \mu) / \sigma$ (Gujarati, 1995).

$$F(X_i \beta)' = \int_{-\infty}^{X_i \beta'} \frac{1}{\sqrt{2\pi}} e^{-s^2/2} ds \quad \text{D.1}$$

where s is a random variable which is normally distributed with mean zero and unit variance (Pindyck and Rubinfeld 1981). To estimate the parameters, β , a maximum likelihood method is applied.

The expected functional relationship of the adoption decision resembles a sigmoid curve for the tobit model. Since a probit estimation of the probability of adoption is first estimated, the sigmoid curve is based on the assumption that the cumulative distribution of the error term is normal (the logit model assumes that this distribution is logistic⁴). The main characteristic of a normal sigmoid curve is the existence of a lower limit (zero, for probability models) and an upper limit (one, for probability models) which bind the possible outcomes. A response in the decision variable can be observed only in the segment between the two extremes (Akinola and Young 1985). It may be assumed that the decisions of a population of potential adopters would follow an 'S'-shaped curve of this type, when the values of the explanatory variable exceed the threshold point. The 'S'-shaped curve follows the adoption diffusion theory discussed in Chapter 4. As Mansfield (1971) first showed when an innovation is first introduced, a firm may be uncertain regarding its profitability and success, should the firm adopt the innovation. This uncertainty can be reduced over time as the information about the innovation accumulates.

⁴ Since the cumulative normal distribution and the logistic distribution are very close to each other, with the exception of the tails, the two methods produce very similar results, with the exception of very large samples where there are many observations at the tails (Maddala 1983).

As the information increases, the probability that the innovation will be adopted will increase, resulting in an S-shape diffusion curve or a logistic (learning) curve. The rationale for this diffusion pattern through time is that the adaptation of an innovation accelerates initially as it becomes more widely known and competitive pressure compels its adoption. Eventually the rate of adoption slows as the number of firms not employing the innovation declines. The implication of this relationship is that when values of explanatory variables are close to the threshold point, policies that would increase the values of X are likely to encourage adoption.

The stochastic model of analysis of a simultaneous innovation decision making process of potential adopters may be expressed as follows:

$$\begin{array}{lll} Y_i = X_i\beta + \mu_i & \text{if } Y^* = X_i\beta + \mu_i > T \\ Y_i = 0 & \text{if } Y^* = X_i\beta + \mu_i \leq T \end{array} \quad i = 1, 2, \dots, n \quad \mathbf{D.2}$$

where n is the number of observations, Y_i is the limited dependent variable, Y_i^* is the continuous dependent variable when adoption occurs (in practice Y^* is unobservable, instead we observe the dummy variable, Y_i), X_i is a vector of explanatory variables, β is a vector of unknown coefficients, T is the threshold point, and μ_i is an independently distributed error term assumed to be normally distributed with a constant mean and constant variance, σ^2 (like the probit model).

Equation D.1 is a simultaneous and stochastic decision model. The tobit model estimates the probability, using probit estimation, and the intensity of adoption, under the maximum likelihood method, simultaneously. It is for this reason that the determinants of

both the adoption and intensity decisions are assumed to be the same. When the unobserved variable Y^* is less than T , the observed qualitative variable Y_i that indexes adoption is zero. And, when the unobserved variable Y^* is greater than T , the observed qualitative variable Y_i that indexes adoption is a continuous function of the explanatory variables. In cases where substantially large number of decision makers (at least more than 50%) have completely adopted the new technology, a variant of the one-limit tobit model in equation D.1 (such as the 2-limit tobit) could be used (Adesina and Zinnah 1993, Gould *et al.* 1989, Akinola and Young 1985).

D.3.1 Tobit Model Elasticities

In addition to measuring both the probability and intensity of adoption, the tobit model has the advantage that it gives information about the elasticity of the predicted probability. McDonald and Moffitt (1980) have shown that elasticities calculated at the means of the variables can be decomposed into two parts: the elasticity of the probability of being above the limit (elasticity of adoption) and the elasticity of the conditional expected value (elasticity of effort) given adoption occurs. The two elasticities sum to equal the total elasticity or the percent change in the dependent variable given a one percent change in the independent variable.

D.3.2 Tobit Estimation

Both the probit and tobit models use maximum likelihood methods to estimate the coefficients. The maximum likelihood method has a number of desirable statistical

properties. The regression coefficients are asymptotically efficient, unbiased, and consistent. In addition all parameter estimators are asymptotically normal so that an analog of the t test is applied as a test for significance of the individual coefficients (Pindyck and Rubinfeld 1991). In the maximum likelihood model a log likelihood ratio test replaces the usual F test of the OLS regression models to evaluate the significance of all or a subset of coefficients. The goodness of fit of the model is inferred from an analogy of the coefficient of determination of OLS models. This pseudo- R^2 is calculated and interpreted in a similar manner as is R^2 in OLS regression models. However, the pseudo- R^2 should be used with caution as its sampling distribution is not known (Shakya and Flinn 1985).

The underlying tobit stochastic model may be expressed by the following relationship:

$$\begin{array}{lll} Y_i = X_i\beta + \mu_i & \text{if } Y^* = X_i\beta + \mu_i > 0 \\ Y_i = 0 & \text{if } Y^* = X_i\beta + \mu_i \leq 0 \end{array} \quad i = 1, 2, \dots, n \quad \text{D.3}$$

which is the same relationship as in equation D.1 with a defined threshold value, T , of 0.

D.3.3 Influences of the Dependent Variable

The number of zero and non-zero responses can influence the impact that a change in the independent variables can make on the extent of adoption decision. In a study on the decision to purchase durable goods by Tobin (1958), 75% of the observations had nonzero expenditures on durable goods. McDonald and Moffitt (1980) evaluated Tobin's

results and found that 54% of the total change in durable goods expenditure resulting from a change in the independent variables would be generated by marginal changes in the value of expenditures. (The value of expenditures is estimated secondly as the extent of adoption once the adoption decision is made). Therefore, McDonald and Moffitt determine that 46% of the total change in durable goods expenditure resulting from a change in the independent variables would be generated by marginal changes in the probability of purchasing a durable good at all.

In the same paper, McDonald and Moffitt also evaluate data from a paper concerned with the demand for durable goods (Dagenais 1975). Dagenais' (1975) data contain fewer nonzero purchases. Only 21% gave nonzero responses. Evaluating at this point, McDonald and Moffitt find a lower percentage (23%) of any total change that was due to marginal consumption changes. Most of the response, 87%, is due to changes in the probability of purchasing the durable good. Therefore, the smaller (larger) the number of non-zero responses, the larger (smaller) the percentage of the total change in the extent of adoption decision will be generated by marginal changes in the extent decision, rather than the decision to adopt the new technology.

D.4 Heckman Model Specification

The underlying assumption of the tobit model is that the same set of determinants which influence the adoption decision also influence the choice of the intensity of effort (Maddala 1983). The Heckman model (Heckman 1979) offers an alternative model to deal with censored samples which allows for different variables which determine the

adoption choice and then the effort allocated when adoption is chosen. The two equation procedure involves the estimation of a probit model of the adoption decision, calculation of the sample selection control function, and incorporation of that control function (the inverse Mills ratio) into the model of effort which is estimated with ordinary least squares (OLS). While the Heckman model does allow for different determinants between the adoption choice and the intensity of use, it does not allow for the decomposition of the elasticity afforded by the tobit procedure.

The Heckman model determines both the probability of adoption as well as the intensity of use, like the tobit model but the assumption of the tobit model, that the same variables influence both decisions is dropped. The two equation procedure involves the estimation of a probit equation of adoption, and incorporation of that bias into a model of effort estimated using OLS.

The two step procedure can be illustrated by the following equations:

$$\begin{array}{lll} Y_i = X_i\beta + \mu_i & \text{if } Y^* = X_i\beta + \mu_i > 0 & \\ Y_i = 0 & \text{if } Y^* = X_i\beta + \mu_i \leq 0 & \end{array} \quad i = 1, 2, \dots, n \quad \text{D.4}$$

Since the likelihood function for the probit model is well behaved the dummy variable is defined:

$$\begin{array}{ll} I_2 = 1 & \text{if } Y_i > 0 \\ I_2 = 0 & \text{otherwise} \end{array} \quad \text{D.5}$$

Using the probit model, consistent variables of β/σ are calculated, using these estimates.

values of ϕ_i and Φ_i are calculated (where $\phi_i = \sigma f_i$ and $\Phi_i = F_i$, refer to equation D.1 and the footnote attached to the equation for further explanation). For each observation λ is calculated as:

$$\lambda = \phi(\alpha'/w) / \Phi(\alpha'/w) \quad \text{D.6}$$

Equation D.5 is known as the inverse Mills ratio. After calculating λ , equation D.3 is estimated using OLS (Maddala 1983).

The inverse Mills ratio, sometimes referred to as the hazard rate, is based on the probability density function of the censored error term. The cumulative distribution function is then derived from the probability density function. The calculation of this ratio can best be explained in terms of the figure below. Figure D.2 shows the probability function of a normal random variable.

The shaded area in Figure D.2 represents the cumulative density function. Dividing by this area normalizes the density function so that the total area under the probability density function is equal to one. The inverse Mills ratio can therefore be used to normalize the mean of the error terms to zero, and consistent estimators are then calculated for α and β , according to the normalization of the error terms. From the estimated parameters $\hat{\alpha}$ and $\hat{\beta}$ of the probit model, it is easy to calculate $\hat{\lambda}$.

Because $\hat{\lambda}$ approaches λ as the sample size gets large, and λ normalizes the mean of the error terms, ordinary least squares estimation of equation D.6 yields consistent estimators of α and β :

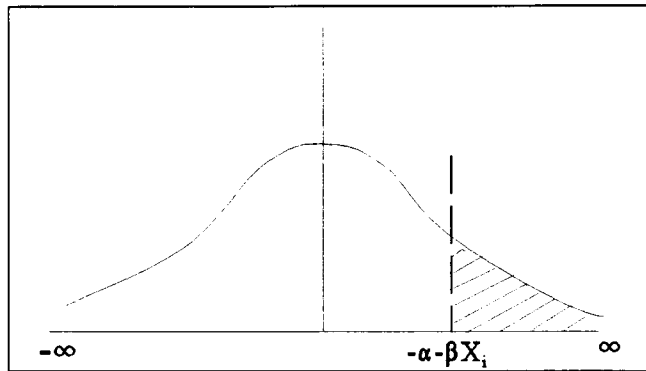


Figure D.2
The Probability Function of a Normal Random Variable

$$Y_i = \alpha + \beta X_i + \sigma \hat{\lambda}_i + \mu_i \quad \text{D.7}$$

In this equation λ is added as an explanatory variable. The two stage estimator yields heteroskedastic errors (the error variance depends on X_i as well as whether $Y=0$, or not) so that the usual t-statistics are biased. In addition, the OLS method is not as efficient as the maximum likelihood method, and therefore the maximum likelihood method is preferred for this type of calculation.

D.5 The Tobit and Heckman Models Compared

The tobit model can be explained as a special case of the Heckman model. Following Heckman's derivation (1979), consider a random sample of I observations. Equations for individual i are:

$$\begin{aligned} Y_{1i} &= X_{1i}\beta_1 + U_{1i} \\ Y_{2i} &= X_{2i}\beta_2 + U_{2i} \end{aligned} \quad i = 1, 2, \dots, I \quad \text{D.8}$$

where X_{ji} is a $1 \times K_j$ vector of exogenous regressors, β_j is $K_j \times 1$ vectors and

$$\begin{aligned} E(U_{ji}) &= 0 \quad E(U_{ji}, U_{j'i'}) = \sigma_{jj'} \quad i = i' \\ &= 0 \quad i \neq i' \end{aligned} \quad \text{D.9}$$

the final assumption is a consequence of a random sampling scheme. The joint density of U_{1i}, U_{2i} is $h(U_{1i}, U_{2i})$. Suppose that data are missing on Y_1 for certain observations. (The Heckman model is used for censored samples). The population regression equation, for Y_{1i} in equation C.7, can be written as:

$$E(Y_{1i} | X_{1i}) = X_{1i}\beta_1 \quad \text{D.10}$$

If the conditional expectation of U_{1i} is zero, the regression function for the selected subsample is the same for as the general data. In the general case:

$$\begin{aligned} E(U_{1i} | X_{1i}) &= E(U_{1i} | X_{1i}, Y_{2i} \geq 0) \\ &= E(U_{1i} | X_{1i}, U_{2i} \geq X_{2i}\beta_2) \end{aligned} \quad \text{D.11}$$

The model outlined contains a variety of models as special cases, one of which is the tobit model. If $h(U_{1i}, U_{2i})$ is assumed to be singular and to have a normal density ($U_{1i} \equiv U_{2i}$)

and $x_{2i} = x_{1i}$, $\beta_1 = \beta_2$, the tobit models takes shape. When U_{1i} and U_{2i} are independent the data on X_{1i} are missing randomly, the conditional mean of U_{1i} is zero. In the general case, it is nonzero and the sub-sample regression function is:

$$E(U_{1i} | X_{1i}, Y_{2i} \geq 0) = X_{1i} \beta_1 + E(U_{1i} | U_{2i} \geq X_{2i} \beta_2) \quad \text{D.12}$$

D.6 The Use of Tobit and Heckman Models in the Dissertation

This study uses a combination of probit, tobit, and Heckman techniques. Estimations of the probability of becoming an APA (Association of Alternative Producers) member, adopting sustainable agriculture, and the extent to which sustainable agriculture is adopted are estimated using the techniques discussed in this chapter. These models as well as the data which is used in the analysis are presented in the following chapters. The data is presented in Chapter 5 and analyzed in Chapter 6.

VITA

VITA

Jill L. Caviglia was born in Bethpage, New York on January 16, 1970. She attended the public school system in Centereach, New York, where she graduated from Centereach High School in June 1988. Jill then enrolled in college at the University of Binghamton (formally SUNY Binghamton) in August 1988. She graduated in May 1992 with a Bachelor of Science in Economics and Bachelor of Arts in English Literature. In August 1992, she enrolled in the Ph.D. program at the University of Tennessee in Economics. She received her Master of Arts in Economics from the University of Tennessee in May 1996.

As part of her doctoral research, Jill received four international grants to conduct research in Brazil. These grants were provided by the *Institute for the Study of World Politics*, the *Organization of American States*, the *National Security Education Program*, and the *McClure Fund Foundation*. The Ph.D. was received in May 1998.

Jill's teaching experience includes appointments at the University of Tennessee, Western Carolina University, and Carson Newman College. Her research experience includes a four year appointment at Oak Ridge National Laboratory and the research which was conducted as part of this dissertation. She hopes to continue with an appointment which supports both research and teaching.