Adoption of Integrated Pest Management Technologies: A Case Study of Potato Farmers in Carchi, Ecuador

Maria Mauceri

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Jeff Alwang, Chair
George Norton
Kurt Stephenson

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Abstract

Potato farmers in Ecuador rely on chemical inputs to manage pests and optimize yields. IPM techniques are recommended to lower production costs, reduce exposure to pesticides, and improve the long-term sustainability of the agriculture system. We conducted a survey of 109 potato farmers in Carchi, Ecuador that included 30 Farmer Field School (FFS) participants, 28 farmers who had been exposed to FFS-participants, and 51 randomly selected farmers. Using an ordered probit model, the data were analyzed to identify determinants and constraints of adoption. Access to information through FFS was the main determinant of adoption of IPM, followed by field days, pamphlets, and exposure to FFS-participants. The study looked at the relative cost-effectiveness of information dissemination methods and found that field days and pamphlets have strong impacts on adoption considering their low cost of implementation. The only significant household variable was household size, where larger households adopted less IPM. Per capita land holdings were not significant in the model. There is evidence of farmer-to-farmer diffusion from FFS to non-FFS farmers. Further research is necessary to evaluate the nature and quality of information transfer between farmers. The study was limited by the small sample size and non-random selection of farmer respondents.

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Chapter 1

1.1 Introduction

Agriculture employs much of the rural population in developing countries. These populations make up a large part of the world's poor. Farmers use their livelihood as a means of food security and income generation, and income levels are closely correlated with performance of the agricultural sector. Crop yields are dependent on climate, water availability, soil quality, and pest pressure. Technology is able to ameliorate some pest-related and other production problems through use of irrigation systems, fertilizers, and pesticides. Farmers can expect higher yields from the use of these technologies, but there may be associated costs for both producers and consumers.

Worldwide, insects and diseases cause billions of dollars in damages to crops every year. Farmers depend mainly on chemical technology to manage pests and generate profits in their enterprises. There is evidence of negative effects on local environments and on humans from abuse of pesticides. Animals, plants, and humans are exposed to chemicals in the soil and water. Pesticides and fertilizers effectively increase yields but can diminish water and soil quality. Human populations are exposed to chemical residues on food products and through unsafe handling of pesticide materials. In addition, overuse of chemical inputs can eliminate beneficial insects and encourage resistance among pest populations. More resilient pests can only be controlled by more toxic chemicals, causing further harm. Eventually, the farmer may be unable to manage pests effectively and crop loss or failures can occur. These problems raise concerns about long-term sustainability of chemical-dependent agricultural systems. Chemicals improve yields in the short-term, but adversely affect ecological and human health. Producers need alternative approaches that are feasible, economically sustainable, and effective at controlling pests. Alternative technologies can help to secure the livelihoods of producers and sustain rural farm communities.

In every country, there is the question of how to effectively deal with agricultural pests. Pesticides that are restricted for use in some parts of the world are used regularly in others. International trade for agricultural products implies that it is advantageous for countries to cooperatively design better farm practices, sharing the responsibility to reduce the use of acutely toxic pesticides. One approach is to restrict pesticide use through government policy. However, restrictive policies may adversely affect farmer incomes where no alternatives are available to manage pests and maintain yields. Policy initiatives need to consider alternatives that are economically viable, environmentally sound, and effectively control insects and diseases. Integrated Pest Management (IPM) is one approach that deals with these issues. The goal of IPM is to find (through research) the appropriate set of techniques that will enable farmers to reduce their reliance on pesticides while maintaining or increasing yields, crop quality, and profitability. For example, IPM may use knowledge of life cycles to monitor and target key pests, biological predators, genetically resistant varieties, and various cultural strategies (field rotations, sanitation, early harvest etc.).

1.1.1 POTATO PRODUCTION IN ECUADOR

Agriculture is an important sector in Ecuador. Nearly 1.3 million individuals or 25% of the total labor force are employed in agriculture. Most of the farm labor force lives in rural areas (FAOSTAT, 2002). Consequently, many rural families depend on agriculture as an income-generating and life-sustaining activity. Farming is particularly important for the rural economy, but the national economy is also dependent on it. The agriculture sector accounts for 10% of national GDP and has an annual growth rate of 1.7% (FAOSTAT, 2002).

As Ecuador’s agricultural sector grows, there are concerns about the sustainable use of land resources and the potential health and environmental impacts of conventional agricultural practices. Farmers in Ecuador use large quantities of pesticides and chemical fertilizers. Some of these chemical inputs are restricted for use in the United States because of high toxicity and their ability to persist in the environment. Studies from the early 1990s showed a link between exposure to pesticides and health problems in Ecuadorian farm workers and their families (Crissman et al, 1994). It is important to evaluate whether farmers can both reduce their dependency on pesticides and better protect themselves when pesticides are used.

One crop with relatively high input requirements is the potato. The potato is an economically significant crop in Ecuador. It is a staple in the average diet, particularly among residents in the Andean highlands. In the Andes, potatoes are eaten at every meal. Approximately 90,000 farmers grow potatoes on 60,000 hectares of land. In 2003, Ecuadorian farmers produced 427,149 metric tons of potatoes, the majority of which are marketed within the country. A small percentage ends up in export markets (about 5,000 m.t. in 2001). Average yields are 7 m.t. per hectare but vary widely depending on the region, reaching up to 20 m.t. per hectare in the north. Ecuador's national average is low relative to the worldwide average of about 16 m.t. per hectare (FAO Quarterly Bulletin, 1999).

Around the world, potato farmers face a variety of pest problems. Specific pests vary from country to country and include attacks from both insects and diseases. In Ecuador, three pests are of particular concern to potato farmers. These include late blight (a fungal disease), Andean weevil, and the tuber moth. The most devastating of these pests is late blight, which affects potato yields on a worldwide scale.

It is difficult to estimate the potential damages from each of these pests. Yield losses from late blight depend on the virulence of the fungal strain and whether farmers have the resources to use available fungicides. Studies on lower virulence strains estimate losses at 15%-30% of the crop (Lang, 2001). Without chemical intervention, more lethal strains put farmers at great risk of losing much of their crop. The Andean Weevil can also cause significant damages without proper management. Up to 80% crop damage has been estimated in infested fields in Ecuador (Muñoz and Cruz, 1984). Studies in the 1990s in northern Ecuador reported farmers' perceptions of yield loss from pest problems (see Table 1.1). Nearly 100% of farmers reported being affected by late blight, 80% by Andean Weevil and 6% by tuber moth. The tuber moth, a recently introduced pest, is not yet well-established in potato regions.

TABLE 1.1 - FARMERS' PERCEPTIONS OF YIELD LOSS ASSOCIATED WITH PEST PROBLEMS

	Number of Farmers Affected by Canton				Total for
Pest	Tulcan	Huaca	Montufar	Espejo	**Carchi Province**
Late Blight	20 (100%)	18(100%)	43(93.5%)	16(100%)	97(97%)
Andean Weevil	15(75%)	17(94.4%)	33(71.7%)	14(87.5%)	79(79%)
Tuber Moth	0	0	6(13.04%)	0	6(6%)
	Percent (%) Yield Loss Caused by Pest Damages				
Late Blight	21	33.89	23.84	30.94	26.68
Andean Weevil	26.67	26.18	27.42	38.57	28.99
Tuber Moth	0	0	42.5	0	42.5

Source: INIAP surveys, CIP, IPM-CRSP Virginia Tech, 1998

There are several concerns with pesticide use by Ecuadorian potato farmers. The first problem is the lack of efficient spray regimes. Of all cultivated crops in Carchi, potato production uses the largest quantities of pesticides and fertilizers (see Table 2.6). Spraying is done prophylactically and without knowledge of pest and disease life cycles. Therefore, pesticides are often used in quantities higher than is necessary for effective control. Excessive use leads to contamination of local water supplies and higher than optimal residue levels on potatoes. In some cases, more toxic chemicals are used when safer alternatives exist. Carbofuran and Methamidophos are the main insecticides used for the control of Andean weevil, both of which are restricted for use in North America. In addition, farmers often mix several chemicals at once to reduce the need for multiple spraying. Formulation of these "cocktails" is not recommended because of the unknown effects of mixing several chemicals at once. Mixtures may have different properties than the original chemicals, potentially altering the toxicity levels and usefulness of the pesticide in targeting key pests. Farmers spray, on average, 7 times per cropping cycle with mixtures of 2 to 3 chemicals per spray.

Another concern with pesticide use is the lack of safe handling procedures. Pesticide formulations are often mixed in large plastic buckets in the field. Most pesticides are applied in liquid form using backpack sprayers and few farmers utilize protective equipment while spraying (Crissman et al, 1998). In addition, farmers may eat or smoke without washing, use the same clothing repeatedly, and at most wear rubber boots.

There are several explanations for the lack of caution in applying pesticides. One is lack of knowledge by farmers concerning toxicity levels and effective spray techniques. Another is that the cost of protective equipment is prohibitively high for poor families. Applicators also complain about the discomfort of using equipment. But even with education and sufficient income levels, farmers may still choose not to use protective equipment. Studies have shown that farmers who recognize the potential dangers of improper pesticide handling still continue to put themselves and their families at risk (Crissman et al, 1994). This finding calls into question the impact of education on pesticide safety. It is possible that reducing dependence on toxic chemical inputs would be a more effective way of protecting farmers' health.

Besides negative health and environmental impacts, pesticide use also incurs a significant economic cost for producers. Based on field trials done in Carchi, potato farmers spend between 12% and 20% of production costs on pesticides (Barrera et al, 2003) (see Tables 2.4 and 2.5). Therefore, a reduced reliance on pesticides could benefit farmers in terms of health and household income.

As with agriculture worldwide, in Ecuador there is the need for technologies that reduce pesticide use. Strategies should require a minimal amount of capital up front to attract risk averse producers. The complexity of the technology will also affect eagerness to adopt. Agricultural organizations strive to develop pest control technologies that diminish adverse effects on environment and human health, but maintain or increase profits. IPM uses this type of systems approach.

1.1.2 INTEGRATED PEST MANAGEMENT

IPM provides a strategy for dealing with agricultural pests while minimizing the use of pesticides and maintaining or increasing profitability for farmers. Pesticides are used more strategically based on scientific research. A well-constructed pest management program includes the use of traps to monitor pest populations, awareness of pest life cycles, attention to weather conditions (particularly moisture levels), planting of resistant varieties, use of lower toxicity chemicals, safer pesticide handling, crop rotations, and some other cropping techniques. Many of these IPM practices can be taught to farmers with little or no scientific background.

The Integrated Pest Management Collaborative Research Support project (IPM CRSP), funded by the United States Agency for International Development (USAID), focuses on IPM technologies for developing country agriculture. The specific goals of the IPM CRSP include the development of technologies to reduce crop losses, increase farmer income, reduce pesticide use, reduce residues on exports, improve IPM research and education, improve the ability to monitor pests, and to involve more women in pest management decision-making. Using a participatory approach, the IPM CRSP strives to meets these goals using host country institutions in conjunction with U.S. universities and the U.S.D.A.. Research scientists, extension agents, and graduate students work together to develop and evaluate IPM strategies and to encourage implementation of approved practices in farming communities.

In 1997, five years into the IPM CRSP, Ecuador was added to the list of host countries. The IPM CRSP in Ecuador focuses on three major crops or categories: potato, plantain, and Andean fruits. This study concentrates on the IPM CRSP projects applicable to potato production.

In the first year of the IPM-CRSP potato project, researchers did baseline studies to evaluate current scenarios and problems in Ecuador's potato production system, particularly in relation to pest management practices. They found that farmers were spraying quantities above the recommended amounts and with ineffective timing to manage diseases or insects. This inefficient use of pesticides is not only a hazard to health and long-term ecosystem management, but also costs the farmers a valuable portion of their income to pay for extra and unnecessary inputs. This misuse of pesticides was partially attributed to a lack of knowledge in farmer populations. In 1997, the National Agricultural Research Institute (INIAP) and the International Potato Center (CIP) began to set up Farmer Field Schools to educate farmers about better management practices.

The FFSs worked to educate communities of farmers while agricultural organizations and the IPM-CRSP did the research necessary to develop appropriate technologies. By year 5 of the potato project, FFSs had been established in 16 communities, and about 220 individuals had attended the schools. Multiple workshops were also held to spread information on IPM (see Table 1.2).

TABLE 1.2 - TRAINING EVENTS - 1998-2003
IPM AND PESTICIDE MANAGEMENT

	No. of Participants/Recipients
Workshops	4669
Courses	251
Field Days	1957
Conference	163
Farmer Field Schools	223

Source: Barrera et al., 2003

In Carchi, there are a limited number of agriculture extension agents who mainly work on cattle and milk production issues. For potato production, farmers are dependent on other sources of information to learn about IPM. The IPM CRSP uses FFSs as one method to diffuse IPM information and promote adoption. One question is whether the FFS approach is appropriately meeting this objective. FFSs are a relatively expensive means of transferring knowledge (Quizon et al, 2001a, b; Thiele et al, 2001) and limited funds may prohibit the IPM CRSP from reaching enough farmers. It is important to evaluate the cost-effectiveness of this type of training on adoption rates relative to other methods of information diffusion. Alternative methods include field days, pamphlets, and exposure to other farmers.

Using farmer surveys, this study sets out to evaluate the spread of IPM among potato farmers in Ecuador. Several factors might explain why a technology is not spreading. It may not be appropriate to the problem or needs of the farmers. The farmer's perception of the technology may be negative. The technology may seem risky, overly complex, or prohibitively capital or labor-intensive. In addition, IPM adoption rates could be inhibited by inadequate trainers, lack of access to information, farmer perceptions, or some fault in the technology itself.

1.2 Problem Statement

The overall objective of the IPM CRSP in Ecuador is to improve the well-being of farmers. IPM can help farmers realize economic and health benefits. Current adoption rates of IPM technologies are low, even though most farmers are in need of improved pest management practices. A knowledge gap exists concerning how farmers obtain information on farming practices. This study will help fill this gap. Given the limited resources of the IPM CRSP project, this study seeks to understand how the IPM CRSP can orient itself in terms of development of technologies and appropriate techniques for the diffusion of information in order to maximize adoption and thereby increase net benefits to farmer households and their communities.

1.3 Objectives

The primary global objective of this study is to find mechanisms that effectively spread knowledge and use of IPM technologies among potato farmers in Ecuador.

Several sub-objectives emerge:

1) To understand how farmers obtain information about pest control and in particular to evaluate the cost-effectiveness[1] of FFSs and other dissemination methods (i.e. field days, farmer to farmer diffusion and written media) in conveying IPM information,

2) To describe the extent of adoption of IPM in a sub-region, and

3) To identify the determinants of and constraints to adoption of IPM.

Results will be used to provide perspective on how to improve programs in Ecuador. Are there methods of diffusing information to assure a greater impact on adoption rates? Should resources be diverted from the FFS approach to other methods of diffusion that may be more cost-effective?

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[1] Cost-effectiveness in this study refers to the impacts of information on the spread of IPM. We will look at the costs per farmer for receiving information about IPM and the impact of that information on knowledge and adoption.

1.4 Methods

The investigation takes place in Carchi province in northern Ecuador. A survey of 109 potato farmers was conducted in fall 2003 to analyze farmers' pest-management adoption decisions. The survey asked questions concerning socioeconomic status, production, pesticide usage and handling, IPM knowledge and use, and knowledge of the most significant potato pests (see Appendix A for the complete questionnaire).

Farmers were asked a series of questions concerning the knowledge and use of IPM practices. Each farmer was given an IPM knowledge score. Farmers also indicated how they had obtained information about IPM. Using IPM knowledge scores and adoption rates, we were able to evaluate the effectiveness of various methods of information diffusion including FFSs, field days, pamphlets, and farmer networks.

Survey responses were used to describe the spread of IPM in Carchi. Adoption rates were analyzed and farmers were divided into 5 categories representing levels of adoption intensity from zero to full adoption. Using an ordered probit model, the data were analyzed statistically to identify factors that influence adoption. Marginal impacts were calculated to compare the relative effects of the significant variables. Information on these impacts was compared to per farmer costs for FFSs, field days, and pamphlets to estimate relative cost-effectiveness of these information diffusion mechanisms.

1.5 Data Sources

The primary data source is a survey of potato farmers in Carchi (2003). Of the 109 farmers who were surveyed, 30 were participants of FFS, 28 were non-participants who have had contact with FFS participants and 51 were individual farmers chosen randomly who have not attended FFS or had known contact with FFS participants. Background information was gathered from previous studies done in the first 5 years of the IPM CRSP potato project. This information includes two additional surveys: one baseline survey conducted in 1999, and the other a gender study conducted in 2001.

Additional information was taken from other studies and partial budgets concerning IPM adoption and Farmer Field Schools.

1.6 The Study Site

Potatoes are cultivated primarily in the following provinces of Ecuador: Carchi, Cotopaxi, and Chimborazo. Carchi is located near the border of Colombia, in northern Ecuador, and is the most productive potato region in Ecuador. Of the approximately 60,000 ha of land cultivated in potatoes in Ecuador, 12,600 ha. (21%) are located in Carchi (Barrera et al, 1999). Chimborazo produces 20-25% of the total crop with yields of about 7 metric tons per hectare. In contrast, Carchi produces 40% of the total crop with yields easily above 15 tons/hectare (Barrera et al, 1999). Three major pest problems confront farmers in the Ecuadorian highlands: late blight, Andean Weevil, and the tuber moth. Chemical inputs have made it possible to effectively manage pests and maintain high yields. Yields in this region are also dependent on climatic conditions and the availability of modern and highly productive potato varieties.

Carchi is a useful site of study for several reasons. Potato producers in Carchi have access to many chemical inputs including fertilizers and pesticides. High yields occur because of the ability of farmers to acquire these inputs. Reliance on chemical inputs has raised concerns about unsafe pesticide handling and potential harmful effects on farm workers and consumers. The highest rates of reported pesticide poisonings in the country occur in Carchi (171 per 100,000 rate of pesticide poisoning) (Lang, 2001; Crissman et al,1998). INIAP and the IPM CRSP have focused on promoting IPM and safer pesticide handling methods in Carchi since 1996. Preliminary surveys of potato farmers were done at this time. Nine years later, in 2003, there are 18 FFSs in Carchi. This study can assess whether there has been an impact on potato farmers. For these reasons, Carchi was chosen as the site for this investigation.

1.7 Thesis Layout

The remainder of the thesis is laid out as follows: Chapter 2 provides a description of the study site, the problems of pesticide use, and the three most significant potato pests in Ecuador. The chapter describes the IPM CRSP project and specific recommended IPM strategies. The types of information diffusion are discussed including the FFS approach. Chapter 3 discusses theories behind the adoption of agricultural technologies and potential determinants and constraints of adoption. The chapter also discusses specific methods employed in the study. Chapter 4 reports on the results. This chapter contains qualitative and quantitative observations. Chapter 5 presents conclusions and implications for future research. Copies of the surveys, as well as relevant maps and output from the statistical model, appear in the appendices.

Chapter 2 - Background

This chapter provides background information on the site and context of the study. Section 2.1 provides a description of Carchi, the study site. Section 2.2 discusses potato production in the Andean highlands. Section 2.3 describes the major pest problems for farmers in that region, conventional means of control, and a description of recommended IPM practices. Section 2.4 presents information on pesticide handling and related health concerns. In this section IPM is compared to conventional management practices using budgets from FFS field trials. Section 2.5 discusses how farmers obtain information about IPM and the relationship between information acquisition and adoption of the technology. This section looks at the FFS approach as one potential method for disseminating information about IPM.

2.1 Description of the Study Site

There are three distinct regions of Ecuador: the coastal region, the sierra, and the Amazon. Potato production occurs in the sierra, a mountainous region consisting of the Andes and inter-Andean valleys. This region is further divided into three sub-regions: the north, central, and south. Since the 1940s, Carchi has been steadily increasing its share of potato production and currently produces more than any other region (see Table 2.1). Carchi's dominant role comes from the fact that farms in Carchi tend to be larger and yield more potatoes per hectare than in any other region of Ecuador. While average yields for Ecuador hover around 7 tons per hectare, Carchi farmers average between 15 and 20 tons per hectare (Barrera et al, 1999) (see Appendix C for Map of Potato Producing Regions).

TABLE 2.1 - PERCENT OF POTATO PRODUCTION BY REGION AND YEAR

Province	1940	1954	1974	1984	1994
Cotopaxi	39	23.8	27.8	10.5	1.2
Pichincha	22	19.2	11.5	11.9	8.6
Tungurahua	11	14.9	15.3	11.4	17.8
Chimborazo	10	18.4	22.1	20.7	13
Carchi	6	12.2	13.1	18.4	34.5

Source: Crissman and Uquillas, 1989

The climate in Carchi is optimal for potato production during most of the year. Temperatures are consistent from month to month with cool nights and warm days. Changes in season are defined by precipitation which varies by location and altitude. Potatoes are grown at altitudes between 2700 and 3800 meters. The upper highlands typically receive the most annual rainfall, approximately 1,300 mm at 3380 meters.[2] Rain is essential for achieving high yields, as about 70% of farmers do not have irrigation systems (Barrera, conversation). Although the rainy season is from December through March, there is sufficient moisture to grow potatoes any time of the year.

2.2 Potato Production

In the Andes Mountains, potatoes have been grown for thousands of years. The remains of the oldest cultivated potatoes were found in the mountains of Peru (Ochoa, 1991). A diverse selection of old potato varieties still exist, though most are not grown commercially. However, the genetic material from the Andes is valuable. Researchers use this material to find and select potato genes and develop productive, resilient hybrids. Yields for original varieties were relatively low but modern hybrids have increased yield potential considerably. In commercial production, varieties are chosen for their shorter crop cycles, higher yields, and resistance to pests and diseases.

The potato belongs to the plant family Solanaceae. Botanically speaking, the potato is a sibling to the tomato, pepper, eggplant, and tobacco, in addition to over 2000 other species of plants. Members of the same family share common characteristics such as susceptibility to specific diseases and pest problems. Late blight is a particular problem for many plants in this family. Rotations with non-Solanaceous plants helps to reduce the number of late blight spores in a field. For this reason, in rotating one's crops, members of the same family are not chosen for subsequent plantings.

In Ecuador, the crop cycle for potatoes begins with the planting of seed potatoes. Farmers typically save seed potatoes from the previous year's crop, or purchase seed

[2] Examples of annual rainfall fluctuations by altitude are found in Table 5.3 of Crissman, 1998.

from other sources. Because it is important for seed to be "clean" or otherwise free of pests and diseases, farmers may choose to purchase "certified" seed to start their next crop cycle. As the potato plants begin to emerge, soil is brought up around the stems into small hills or mounds. This cultivation practice decreases pest problems and increases yields. The foliage dies back after several months while tubers continue to grow underground. Modern potato varieties are ready to be harvested about 6 months after planting. The ability to harvest varieties earlier increases efficiency of land use and simultaneously helps farmers avoid some pest problems. Specific pest problems will be discussed in further detail later in this chapter.

Throughout the season, farmers struggle to prevent damages from insects and diseases. Pest problems force farmers to be reliant on chemical inputs. During the crop cycle, potatoes are fertilized and sprayed with a combination of insecticides and fungicides. Some cultural methods are also used to manage pest populations. Nematicides and herbicides are not used by Carchi farmers. Nematodes are not a problem in this region and weeding is typically done by hand. After harvest, potatoes are shipped to markets or stored. In storage, potatoes are kept in breathable sacks or in wooden shelters built off the ground. Fields are then replanted with potatoes, rotated with other crops, or left to rest. Most farmers use a crop rotation of two years of potatoes followed by three years of grass. Some farmers substitute one year of barley or wheat (instead of grass) after the two consecutive years of potatoes.

2.3 Description of the Pests

Three main pests significantly impact potato production in Ecuador. They are, in order of economic significance, late blight (*Phytophthora infestans*), Andean Potato Weevil (*Premnotrypes vorax*), and the Central American Tuber Moth (*Tecia solanivora*). In the following section, each pest is discussed in terms of its life cycle, extent of damage, and the control methods employed by farmers. Recommended IPM strategies are also discussed.

2.3.1 LATE BLIGHT (PHYTOPHTHORA INFESTANS)

"Insecticides are more destructive ecologically than fungicides. Nevertheless, what fungicides lack in firepower they make up for in the sheer quantity applied" (Lang 111).

Phytophthora infestans, commonly known as late blight, is a highly damaging fungal disease that attacks potatoes. This disease caused the Irish Potato Famine in the mid 1800s and continues to be a major source of concern for potato farmers worldwide. It is impossible for farmers to avoid exposure to the disease because late blight is present in virtually all soils. The spores are carried by wind between soil and plants, and between fields. According to a conservative estimate, for each 20% increase in severity of late blight, yield losses were estimated at 4t/ha in Ecuador (Ortiz et al, 1999). Another study estimated average yield losses from late blight to be around 6.5t/ha (in Bolivia) (Thiele et al, 1998). Using either estimate, farmers experience a significant loss of income from affected fields.

The prime means of control for late blight is multiple applications of potent fungicides. Systemic sprays can be used to combat diseased plants but like antibiotics in humans, can cause the pathogen to mutate. New more virulent strains of late blight have proven to be resistant to some systemic fungicides. In this case, protectant or contact fungicides are used to prevent late blight from establishing itself by providing a physical barrier to spores. However, the protectant must be present on the plant before the spore makes contact. Therefore, the need for spraying varies depending mainly on weather conditions. Rain washes the pesticide off the plants, thereby requiring repeated sprayings. Additionally, moisture and cool temperatures, as in Carchi, provide the ideal atmosphere for rapid multiplication of late blight spores. Farmers in Carchi spray their fields between 1 and 11 times during a crop cycle, with most farmers spraying 6 times (Barrera et al, 2003; Crissman et al, 1998). Because late blight is particularly difficult to control once the disease has become established, farmers spray as a preventative strategy. Use of resistant varieties can cut spray regimes in half (about 3-5 times per season).

In Ecuador, the most often used fungicide is Mancozeb (see Figure 2.1 for fungicide use by active ingredient). Although Mancozeb's toxicity level is low (color code is green - lowest toxicity), it is sprayed in such high quantities as to be of concern. Fungicides are often mixed with insecticides and are typically sprayed using backpack sprayers. Random mixing of chemicals may increase toxicity to farmers who generally use little protective equipment. Demand for pesticides in the control of late blight is particularly high because of the extent of damage the disease can cause. It is too risky for farmers not to spray.

With conventional late blight management strategies, there is a concern about the development of new, more resilient strains of the fungus. As with insects, fungi can evolve when confronted with high-volume, high-toxicity pesticide applications. This is one reason why conventional spray regimes need to be substituted with alternate strategies. The IPM CRSP project in Ecuador makes recommendations to farmers concerning the control of potato pests and has several strategies for late blight management. The first and most effective strategy is the use of resistant potato varieties. A number of varieties have been developed with varying levels of resistance depending on the virulence of the late blight strain. The IPM CRSP also recommends alternating between systemic and protectant fungicides and using fungicides with different active ingredients. This regime can discourage development of resistant strains of late blight. Even with the use of resistant varieties, late blight can still mutate into more virulent strains. For this reason, durable and horizontal resistance is necessary to prevent new, stronger strains of late blight from developing.

A breeder explains the importance of horizontal resistance in "Taming the Late Blight Dragon," a CIP publication. "Late blight is like a thief with a ring of keys. If the door has just one lock, even a very strong one, it doesn't take long for the thief to find the right key. But if the door has a lot of locks that work in combination, it's going to take much longer" (CIP, 1996). Horizontal resistance works by incorporating several "r" type or minor resistance genes. In recent decades there have been many advances in late blight research. The variety, FRIPAPA, was developed by INIAP with support from

FORTIPAPA[3] and is durably resistant against current strains of late blight in Carchi. FRIPAPA is an andigena-tuberosum hybrid and matures in 5 months. This hybrid is effectively resistant and has been approved by consumers in terms of taste and by producers for food processing potential (Lang, 2001). The IPM CRSP recommends several other varieties with varying levels of resistance and potato characteristics. Superchola is a local variety with some resistance, but is less durable than FRIPAPA (Barrera, conversation). Farmers can choose based on their preferences and the preferences of the consumer market.

INIAP and the IPM CRSP recommend several IPM techniques to accompany the use of resistant varieties. Field sanitation is useful to keep late blight spore populations down. First, diseased plants and volunteers from old crops should be removed and destroyed. Second, foliage should be cut back before harvest, as the disease can spread from infected foliage to exposed tubers. Finally, farmers should periodically rotate potatoes with non-Solanaceous crops. Two consecutive years of potatoes followed by three years of pasture is a typical rotation. Sanitation practices help to reduce the number of spores present in a field, but is not sufficient for complete control of late blight.

Moisture and temperature are key factors in understanding how to control late blight. Late blight spores thrive in moist conditions where they multiply and spread rapidly. Hard frosts kill the spores, but in Carchi temperatures are rarely below freezing. Late blight is ever present though growth is somewhat slowed by the high altitude and cool temperatures. Monitoring of field and weather conditions can alert the farmer when there is the need to apply fungicide to prevent an outbreak. In this manner, pesticides are used more effectively and efficiently.

In sum, prevention of late blight is dependent on a combination of resistance and vigilance. Using resistant varieties, strategic spraying techniques (alternating between systemic and protectant fungicides), and recommended sanitation and cropping practices

[3] FORTIPAPA is a project co-funded by INIAP, CIP, and the Swiss Agency for Development and Cooperation (SDC) and began in 1991 to develop improved varieties of potato seed.

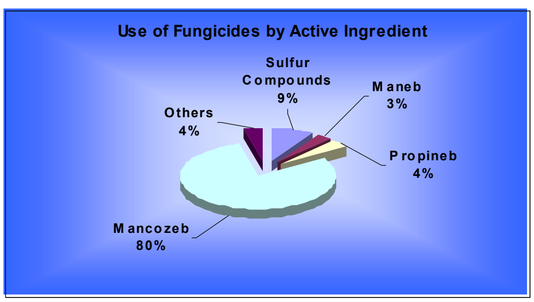
can be successful tools in late blight management. Farmers who follow these recommendations are able to spray about half as much fungicide without compromising yields. (Barrera, conversation) These strategies limit the number of fungicide applications and benefit farmers by simultaneously lowering input costs and reducing exposure to harmful toxins.

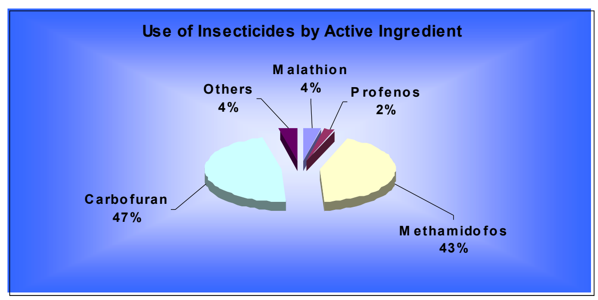
TABLE 2.2 - FREQUENCY OF PESTICIDE APPLICATIONS FOR POTATO PRODUCTION CARCHI, EUCADOR - 1998

	Number of Applications				Total
	Tulcán	Huaca	Montúfar	Espejo	Carchi
Average	7	9	6	5	7
Standard Deviation	4	4	2	2	3
Minimum	2	2	3	1	1
Maximum	15	14	13	9	15

Source: Barrera et al., 1999, Survey 1998 (Carchi)

FIGURES 2.1 and 2.2: PESTICIDE USE IN POTATION PRODUCTION IN CARCHI, ECUADOR





Source: Barrera et al., 2003

2.3.2 ANDEAN WEEVIL (PREMNOTRYPES VORAX)

Known to Ecuadorian farmers as 'gusano blanco,' the Andean potato weevil has the potential to cause significant damage. The insect is adapted to living at high altitudes where the climate is cool and there is sufficient moisture. These conditions are ideal for potato production and Carchi is a prime location for both to thrive. The weevil adult lays its eggs at the base of the potato plant. After about a month, the larvae hatch and tunnel into the soil. They bore into the available potato tubers, live and feed for about 6 weeks, and then tunnel down further where they build cocoons, pupate and develop into adults. If populations are high, weevil larva may damage up to 80% of the total crop (Muñoz and

Cruz, 1984). When the rainy season commences, adults emerge and once again begin their cycle.

Farmers typically use three different strategies against the Andean Weevil. Spraying is the first strategy and Carbofuran and Methamidofos are the chemicals of choice (see Figure 2.2). Both insecticides are restricted for use in the U.S. because of their high toxicity. Farmers saturate the soil in order to target the white larva. Secondly, they use crop rotations to keep populations from increasing year to year. The third method is to use undamaged seed in planting the next crop. Though these strategies help somewhat, there is a need for better pest control. IPM offers several suggestions.

The main mistake in the conventional approach is targeting the larval stage of the insect. Insecticide sprays are more effective when targeting adult populations. IPM recommendations include the use of traps to monitor and target adult populations. Traps consist of foliage from potato plants from other fields that is dipped in two grams of Acefato per liter of water. Acefato is an insecticide with a relatively low toxicity level. The toxicity of the Acefato wears off in 8-10 days, at which point new traps are put out. Baited plants kill off adults before they have a chance to procreate, significantly reducing the potential population explosions of tuber-damaging larva. This method is used until potato plants begin sprouting. When populations reach a specific threshold, farmers are advised to spray at the base of plants.[4] Spraying the whole plant is less efficient since adult weevils tend to remain at soil level, near the plant. At harvest, all tubers should be completely removed from the field.[5] Waiting 30 days before replanting causes larva to die off before the next crop of potatoes is established. The conventional practices: crop rotation and use of 'clean' seed, are both recommended for effective pest management. This combination of practices reduces the number and intensity of spray applications.

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[4] In Table 4.8, see "use insecticides according to recommendations."
[5] This practice is referred to as "dispose of residues in the field" in Table 4.8.

2.3.3 TUBER MOTH (TECIA SOLANIVORA)

A non-native to Ecuador, the tuber moth apparently entered the country from Colombia in 1996. As of 1999, this pest was not a big problem for farmers in Ecuador (Barrera et al, 1999). However, the tuber moth has a particular affinity for temperate valleys like those found in Carchi and significant damages have been witnessed in other regions. Education and use of better management practices can prevent future outbreaks.

The tuber moth is a problem both for pre-harvested tubers, as well as potatoes in storage. The life cycle varies somewhat depending on the species. In general, the female moths tunnel into cracks in dry soil where they lay between 100 and 150 eggs on buried tubers. If she cannot reach the tubers, eggs are laid on plant foliage or otherwise near the potatoes. The larvae hatch within 3 to 5 days and bore into nearby tubers. At this point, the larvae, which are white and highly visible, feed for 10 to 15 days. After feeding they form cocoons. They emerge as adults in 5 to 10 days.

The current methods of control focus on pesticides to target the insect either in storage, or while in the ground. Farmers typically use Carbofuran and Carbosulfan, two highly toxic insecticides. As discussed previously with fungicides, using insecticides can encourage insects to develop resistance. If a strong chemical kills 99% of the population, but leaves 1%, the 1% will re-populate the field with a stronger insect. As farmers then try to control the pest with other chemicals, the insects may mutate and develop more resistance.

A variety of alternatives have been introduced in different parts of the world. A particular strain of Bt (*Bacillus thuringiensis*) has been genetically inserted into potatoes and sold under the name "New Leaf" by Monsanto. Bt has long been used as a bio-insecticide against various types of insects, including most famously the Colorado Potato Beetle. GM crops, however, tend to be an expensive alternative for third world farmers. In Egypt, a Bt strain (*Bacillus thuringirndid kurstaki*) was used against the tuber moth, though applied topically to the plants. Baculovirus, a genetically engineered virus, is also effective against the tuber moth. Although the use of Bt and Baculovirus are less toxic than insecticides typically used for tuber moth, there is still the problem of resistance in future populations.

In Ecuador, the IPM CRSP recommends cultural techniques, not unlike those used for control of the Andean Weevil. Pheromone traps are recommended to monitor and track population dynamics and life cycles of the tuber moth. It is important to target the tuber moth in its adult stage. Traps can be used both in the field and in storage. In storage, farmers are advised to use baculovirus and keep the harvested potatoes covered. When populations are high in the field, Profenos is recommended in low doses. Farmers can use a combination of cultural strategies that include earlier planting and harvests that avoid the dry season (tuber moths prefer dry weather to slip between cracks in the soil, descending toward the tubers), using irrigation through to harvest (if possible), hilling up of soil around plants, and crop rotations with non-solanaceous crops (typically pasture). In addition, seed can be disinfected with low toxicity pesticides such as Carbaryl and Malathion. All of these techniques are plausible, with the exception of irrigation. Only about a third of farmers in Carchi have access to irrigation systems (Barrera, conversation).

2.3.4 COST-BENEFIT ANALYSIS OF IPM VERSES CONVENTIONAL AGRICULTURE

From 1998-2003, 18 FFSs were set up in the Carchi region. One of the basic philosophies of the FFS approach is that farmer participation in field experiments facilitates a better learning environment that improves the ability to retain information and think critically about farm problems. Consequently, as a part of the FFS program, each school conducts experiments to provide hands-on experience to participants. More specifically, each FFS cultivates potatoes on two field plots to illustrate the differences between IPM and conventional methods.

In these field trials, cost-benefit analysis is used to compare conventional to IPM techniques. The analysis from three FFS facilities is shown in Table 2.3. Several items are noteworthy. Yields were higher in two out of three cases for IPM over conventional practices. At San Pedro de Piartal, yields were the same but the costs of production were lower for the IPM plot. Potential factors influencing differences in yield and production costs include changes in fertilization, type of seed and pest management strategies. Fertilizer accounts for approximately 20% of production costs (see Table 2.4). On IPM plots, soil analysis is used to determine fertilization requirements. On conventional plots, farmers typically over-fertilize (see Table 2.3). IPM costs were higher for seed at Santa Martha de Cuba and San Francisco because higher quality seed was used. At San Pedro de Piartal, the high quality seed was used on both the IPM and conventional plots. In all three cases, costs were lower for fertilization and pesticides on IPM plots. Taking into account costs and benefits, net profits were higher in all cases for the FFS/IPM plots. Increased profits ranged from 12% - 56%.

TABLE 2.3 - COST-BENEFIT ANALYSIS OF IPM OBTAINED IN THREE FFSs IN CARCHI

(Costs and Benefits are per hectare (US Dollars))***

	Santa Martha de Cuba		San Francisco		San Pedro de Piartal	
Variety[a]	**Superchola**		**I-Fripapa99**		**I-Fripapa99**	
	IPM	Conventional	IPM	Conventional	IPM	Conventional
Direct Costs						
Land preparation	96	96	87	87	48	48
Seed**	238	187	225	139	225	225
Fertilization	267	342	272	278	252	397
Labor (cultural)*	123	107	51	83	113	113
Fitosanitary controls	282	370	142	218	136	187
Harvest	315	242	254	232	184	184
Storage	23	23	18	18	23	23
Land rent	82	82	82	82	82	82
Total direct costs	**1425**	**1450**	**1131**	**1138**	**1062**	**1258**
Indirect Costs						
Capital interest	256	261	204	205	191	226
Unforeseen events	72	73	56	57	53	63
Administration	72	73	56	57	53	63
Total Indirect Costs	**399**	**406**	**316**	**319**	**298**	**353**
Total Production Costs	**1824**	**1856**	**1448**	**1457**	**1360**	**1611**
Yield (tons/ha)	25.80	19.79	17.28	15.81	19.84	19.84
Price (USD/kg)	0.24	0.24	0.20	0.20	0.20	0.20
Gross (USD/ha)	5507	4224	3208	2934	3683	3683
Net profits (USD/ha)	**3683**	**2368**	**1761**	**1477**	**2323**	**2072**
benefit/cost ratio	3.09	2.33	2.27	2.06	2.77	2.34
Profitability	**209**	**133**	**127**	**106**	**177**	**134**

Source: Table 9.2 Barrera et al., 2002

a. Varieties were chosen based on the preferences of the local communities and were used on both IPM and conventional plots.

*Regarding the differences in costs for labor (cultural) between the three sites - in the case of Santa Martha de Cuba, labor was more expensive for the IPM plot because of the hiring of outside labor. In other plots, FFS participants were the primary source of labor.

** Regarding the cost of seed, at Santa Marta de Cuba and San Francisco, high quality seed was only used on the IPM plots. At the San Pedro de Piartal site, high quality seed was used on both IPM and conventional plots.

***Note: All monetary terms have been converted to 2003 values.

TABLE 2.4 - COSTS FOR POTATO PRODUCTION PER HECTARE, CARCHI STUDY SITE (1990-1992)

Category	No. of Parcels	Quantity	Cost* (USD/ha)	Percent of Total Cost
VARIABLE COSTS				
Labor:				
Wage labor	320	157 mdy[a]	383	19%
Contract labor	103		74	4%
Harvest labor	270		60	3%
Total Labor			545	27%
Seed	320	1,716 kg	198	10%
Fertilizer:				
Nitrogen, a.i.[b]	320	138 kg	402	20%
Phosphorus, a.i.	320	357 kg		
Potassium, a.i.	317	163 kg		
Foliar fertilizer	207		16	1%
Total Fertilizer			417	20%
Pesticides:				
Fungicides	320		170	8%
Foliar insecticides	314		34	2%
Soil insecticides	268		45	2%
Total Pesticides			250	12%
Supplies and Services:				
Power (oxen and tractor)	153		24	1%
Sprayer	320		15	1%
Harvest supplies	320		71	3%
Hauling	319		141	7%
Total Supplies/Services			250	12%
Total Variable Costs			1631	80%
FIXED COSTS				
Interest			310	15%
Rent			103	5%
Total Fixed Costs			412	20%
TOTAL COSTS			2043	100%

Returns: Average yield = 21.3 metric tons, total revenues = $2582, and net revenue = $538.
[a]mdy = mandays (labor days)
[b]a.i. = active ingredient
Source: Crissman, 1998 - Table 5.6
*Note: All monetary terms have been converted to 2003 values.

Analysis was also done on field data from all 18 FFSs. Yield per dollar of pesticide input was higher in 17/18 cases for IPM over conventional plots. A similar analysis was done for yield per dollar input of pesticides and labor. In this latter case, IPM plots were more productive in 18/18 cases (Table 2.3). (Barrera et al, 2003)

TABLE 2.5 - YIELD PER DOLLAR PESTICIDE INPUT

FFS	IPM	Conventional	IPM	Conventional
	(tons/dollar pesticide input)		(tons/dollar pesticide + labor input)	
1	0.076	0.078	0.064	0.057
2	0.084	0.039	0.060	0.032
3	0.158	0.075	0.112	0.065
4	0.078	0.045	0.063	0.036
5	0.102	0.095	0.085	0.074
6	0.126	0.070	0.110	0.062
7	0.132	0.095	0.116	0.086
8	0.077	0.046	0.069	0.043
9	0.076	0.059	0.066	0.052
10	0.142	0.122	0.120	0.101
11	0.079	0.041	0.064	0.037
12	0.067	0.029	0.054	0.024
13	0.114	0.054	0.092	0.043
14	0.100	0.047	0.075	0.039
15	0.043	0.024	0.036	0.021
16	0.123	0.028	0.092	0.023
17	0.104	0.057	0.092	0.052
18	0.093	0.036	0.065	0.028

Source: Barrera et al, 2003

Looking at the cost-benefit analysis between the two systems, it appears that IPM is a cost-effective choice for farmers and requires little, if any additional capital. Extra labor only appears to be necessary at harvest time. Inputs such as pesticides and fertilizers are used less in IPM plots and offset the increase in costs from purchase of improved seed.

Information is a necessary input that is not accounted for in the partial budget analysis. IPM techniques are relatively complex and therefore require sufficient acquisition of knowledge in order for successful implementation to occur. Acquiring knowledge can be costly to farmers in terms of time and money (travel costs, lost wages) depending on the accessibility of the information. For example, attending FFS requires a time commitment of a minimum of 3-4 hours per week for 3 to 6 months. A day's work for laborers is valued at $5/day. (Barrera, conversation) However, lost wages may be offset by output from FFS experiment plots. Since primarily FFS farmers work on these fields, they are given a share of the yield. Other sources of information such as field days, workshops, or reading pamphlets require less time, but provide different amounts of information. The impact of particular information sources on farmer knowledge will be examined more closely in the statistical model presented in Chapters 3 and 4.

2.4 Pesticide Handling: Effects on Human Populations

2.4.1 HEALTH CONCERNS AND PESTICIDE SAFETY

There is a particular concern about the use of pesticides in developing countries, like Ecuador, where farmers use pesticides that are restricted in other parts of the world. Potatoes are a pesticide-intensive crop and an increase in production is correlated with a significant rise in pesticide use. Pesticides are a necessary input to produce high yields, but can result in adverse effects on both health and environment.

A study by Cole et al looked at the exposure of farmers and families to pesticides in highland potato production (2002). They found that farmers are exposed to pesticides in various ways. Most potato farmers do not use protective equipment when applying pesticides. Workers are exposed to toxins through unprotected skin and the breathing of vapors. Farmers are aware that pesticide exposure can occur and sometimes become sick as a result of exposure. Families are exposed through residues left in clothing or through improper storage or disposal of containers too near the house or water supplies. Runoff from farms causes toxicity to the environment and contaminates water supplies. In addition, communities are exposed through consumption of contaminated potatoes. In Ecuador, residues on potatoes have been found to be above recommended levels for human consumption (Crissman et al, 1998). Including lost wages and medical care, the average cost to the individual was estimated at $17 for each case of pesticide illness (Cole et al, 2000). In our survey, 26% of farmers had been sick from pesticides in the prior year with an average of 4.5 lost days.

IPM offers farmers cost-effective pest control strategies that reduce reliance on pesticide inputs, encourage the use of less toxic chemicals and emphasize safer handling techniques when pesticides are used. It makes recommendations concerning application and storage of pesticides, and proper disposal of pesticide containers. Farmers are most receptive to advice concerning storage or disposal. They are advised to store pesticides and bury empty containers away from their houses and water supplies. Although burial of containers is not ideal environmentally, it is better than the burning of containers typically practiced by many. Other recommendations include not eating, drinking, or smoking while spraying pesticides, and frequent bathing and washing of clothing. Improving conditions such that local populations are less vulnerable to pesticide poisoning will simultaneously improve ecological conditions.

2.5 Information Sources and Knowledge of IPM

2.5.1 HOW DO FARMERS OBTAIN INFORMATION?

Given the importance of potato production in Ecuador and the reliance on pesticides to manage pests and obtain high yields, farmers are in need of alternative pest control strategies. Pesticides are not only a health problem, but also a costly input. Potato farmers spend significantly more on pesticides than on any other crop grown in Carchi (see Table 2.6). IPM offers some alternatives for effective pest management but IPM techniques can be both information and management-intensive. Information must be available to farmers in order for adoption to occur.

TABLE 2.6 - PESTICIDE COSTS (PER HA.): FIELDS THAT RECEIVED PESTICIDES CARCHI STUDY SITE (Costs are in US Dollars*)

Crop	Fungicide	Insecticide	Total
Potato	36	17	53
Wheat	14	1	15
Fava Bean	9	5	15
Barley	13	0	13
Peas	6	3	9
Maize and Beans	4	4	8
Maize	4	4	7
Melloco	0	3	3

Source: Crissman, 1998 - Table 5.8

*Note: All monetary terms have been converted to 2003 values.

Institutions supply information which can reach the farmer in several ways. Information can be presented through written media such as pamphlets or extension bulletins. Some farmers rely on information from pesticide dealers. In some countries, farmers rely on extension agents to recommend better strategies, although Ecuador does not currently have an agricultural extension program. Farmers also become involved in community organizations to exchange information with other farmers.

The complexity of the IPM message can affect which method of diffusion will have the greatest impact. More complex messages include knowledge of the pest life cycle, understanding the use of traps and monitoring of pest populations, systemic verses protectant pesticides and the use of different active ingredients to prevent the buildup of resistance in pests. Other messages can be understood with a minimum amount of explanation, such as: harvesting early, or using crop rotations and resistant varieties.

Depending on the manner in which information is presented, a farmer may be more or less receptive to it. Government agencies and non-profit organizations have been involved in the attempt to disseminate information to farmers around the world. An extension-based method known as T&V (Training and Visit) was promoted by the World Bank and international donors for the past several decades. This approach focused on technology diffusion by frequent visits to groups of farmers who were then encouraged to share the information with local communities. Before T&V, education efforts were more office-based and involved less contact with farmers. T&V was initiated to promote more direct contact between educators and farmers.

Critics of the T&V approach focused on several factors. If farms are dispersed over a large land area, it is difficult and expensive for extension agents to reach enough farmers. T&V also tended to present one technology package which was not flexible enough to meet the diverse needs of individual farmers (Godtland et al, 2003). In Ecuador, the main problem was simply lack of extension.

FFSs were developed to improve upon these earlier approaches. FFSs use a participatory approach that focuses on teaching farmers how to think critically about production problems. The schools provide information on pest plant interactions and possible techniques for managing pest problems. This system allows farmers to evaluate their farm situation and use available technologies according to their needs. Written media is another common method used for getting information to farmers. Success in this case depends upon the literacy of farmers and the complexity of the message. In Ecuador, the main methods of information dissemination are: FFSs, field days, pamphlets, and exposure to other farmers. This study evaluates the relative impacts from each of these information sources to determine the cost-effectiveness of each method of diffusion.

2.5.2 DESCRIPTION OF THE FFS APROACH

Around the world, public programs have long been used to educate farmers. FFSs are a relatively recent approach in the education of developing world farmers. This program was developed in response to deficiencies in other agriculture education programs. Before FFS, information was handed down to farmers in a hierarchical manner. Critics claimed that this previous approach was designed poorly and administered inefficiently (Feder et al, 2003). FFS attempt to improve upon previous methods of educating farmers by using a participatory rather than a top-down approach. Farmers are encouraged to do hands-on field trials to get a feel for IPM techniques. The FFS also relies upon farmer networks to facilitate the spread of information and adoption. Information diffusion from farmer to farmer, if successful, increases the cost-effectiveness of the program.

Some studies have reported on the benefits of this approach. In a Peruvian study, researchers linked FFSs with an increase in farmer knowledge about IPM and consequent increases in productivity (Godtland et al, 2003). An FAO report claimed increases in profits for farmers in Sri Lanka, Thailand, and China (FAO, 2000). A study by Feder, Murgai and Quizon questions the validity of these perceived benefits. They claim that an inherent bias exists in how and where the schools are established and which farmers participate. FFS sites are often selected based on specific characteristics of the community including education levels, interest in innovations, and access to markets. This bias causes researchers to over-estimate the impact of FFS on adoption (Feder et al, 2003). This study looked at FFS impacts in Indonesia on participants in the schools, as well as secondary effects from farmer-to-farmer diffusion, while taking into account non-random placement of schools. They found that FFSs did not have a significant impact on yields and performance of participants. In the same vein, they found no significant impacts on non-participants. They offered the following possible explanations: complexity or method of presenting information, timing of training, large scale problems might limit potential gains from IPM (soil infertility), or movement of pests from field to field where not all farmers are using IPM. In addition, the study focused on rice production where pesticide costs were less than 10% of production costs. In potato production, where pesticide use is between 12% and 20%, IPM offers more of an opportunity to decrease production costs and raise net profits (Barrera et al, 2003).

Disappointment with the FFS approach is due in part to the high cost of implementation of the training programs. The cost per farmer is significantly higher than other mass media approaches to distributing knowledge (Quizon et al, 2001 a,b,; Thiele et al, 2001). There are a range of estimates for per farmer cost of FFS. In Indonesia, costs were estimated at $49/farmer and in Bangladesh at $27/farmer. In Ecuador, FFSs cost approximately $30 per farmer. Estimated costs for other approaches (Ecuador) include: field days ($1.50/farmer) and pamphlets ($.50/farmer) (Barrera, conversation). The question remains whether FFS programs have enough of an effect to justify their costs.

In Ecuador, FFSs were first established in 1996. In Carchi, there are a total of 18 FFSs. The Carchi field schools focus on pest management. As of 2002, 223 students had graduated from the program. This number is small considering that approximately 7000 potato farmers live in Carchi. Participants typically meet for one 3-hour session per week for approximately 3 months. Meetings include discussions as well as participation in field experiments. Each FFS has access to two field plots that are used to instruct participants on the differences between conventional and IPM farming systems. In 2003, fourteen of these schools used FRIPAPA99 for seed, while the other four used Superchola (a local variety with some resistance) (Barrera et al, 2003).

Selection for FFS in Carchi is based on four factors: 1)interest in the program, 2)potatoes are the principle crop on the farmer's land, 3)desire to share/diffuse information with other farmers, and 4)farmers who are creative and innovative. This set of selection criteria illustrates the kind of bias discussed by Feder et al, and raises questions about the true impact of FFS on adoption. FFS may simply be educating only those farmers who would adopt regardless of the information source and those that already strive to use alternative strategies. These concerns, as well as farmer access to information and effects on adoption, will be discussed in further detail in Chapter 4.

Chapter 3 - Methods

The overall objective of this study is to determine effective and efficient mechanisms for promoting adoption of IPM technologies. Under this broad objective, there are three sub-objectives. The first looks at how farmers obtain information concerning pest control and IPM. The second evaluates the extent to which IPM adoption has occurred on potato farms in Carchi, Ecuador. The third looks at what kinds of factors affect adoption including: access to information, economic constraints, farmer characteristics, technology characteristics, and farmer perceptions.

This chapter looks at the specific methods employed to accomplish these tasks. The first section discusses theories behind adoption of agricultural technologies. The second section describes the methods used to answer the objectives mentioned above and defines the variables for the model. The third and final section looks at the statistical model in greater detail.

3.1 Discussion of Theories behind Adoption of Agricultural Technologies

An extensive literature describes and analyzes the determinants of agricultural technology adoption. The literature describes adoption theory and provides possible frameworks for variable definition, models and hypothesis testing. Models are employed to look at determinants of adoption, each with its own set of assumptions and emphasis on particular variables.

Adoption models are generally based on the theory that farmers make decisions in order to maximize their expected utility or profits. Farmers' utility is dependent on optimizing productivity and minimizing costs to achieve the greatest profits. Farmers adopt technologies when they expect a more profitable return on the new technology than what can be gained from current technology (Feder et al, 1985). Expectations concerning profitability are dependent on access to information about the new technology.

Optimizing utility may also include considerations such as health, food security, environmental concerns, and risk.

Pest management is an important aspect of potato production and requires costly inputs. Farmers need reliable, cost-effective technologies in order to maintain yields (and profits). Farmers desire to maximize profits by improving yields and lowering production costs, requiring knowledge of cheaper pest control methods. Agricultural institutions are actively developing new technologies meant to fulfill these farmer needs. In many cases, appropriate technologies exist but not all farmers choose to adopt. For example, disease-resistant potato varieties are available for the management of late blight, but more than half of the farmers surveyed do not use them (see results in Chapter 4).

Various factors affect farmer expectations of profitability, and adoption models, by necessity consider a host of factors potentially affecting willingness to adopt technologies. Access to labor, capital, and information all affect adoption decisions. In adoption studies, access to labor and capital is examined by looking at farmer characteristics such as household size, income, and land holdings. Farmer characteristics such as age and education are also considered for their effect on farmers' willingness to adopt new technologies. Another potential reason for lack of adoption is the perception that technologies are risky. The risk associated with IPM technologies is related to the possibility that pests will damage crops and yields will be reduced if the technology is not effective. Farmers are dependent on these yields for both food and income. Consequently, they use a precautionary approach when choosing pest management technologies.

Most IPM technologies involve use of fewer or less-toxic chemicals. Using pesticides is perceived as a reliable form of pest control and therefore also perceived as less risky. Studies have shown that more complex technologies are perceived as more risky, and this risk constrains adoption (Batz et al, 1999). Populations with higher income and education levels exhibit a willingness to accept more risk and adopt complex technologies (Batz et al, 1999; Fliegel and Kivlin, 1966). Access to information affects farmers' perceptions of risk. Having sufficient knowledge about the technology enables farmers to optimize these decision-making processes (Feder et al, 2003).

The following sections address each of the following factors in greater depth: access to information, economic constraints, farmer characteristics, technology characteristics, and farmer perceptions. Their potential role in affecting adoption behavior is also analyzed.

3.1.1 ACCESS TO INFORMATION AND ECONOMIC CONSTRAINTS

Farmers demand reliable information that enables them to improve production systems. Farmers particularly need information concerning pest control strategies. For example, resistant potato varieties are a key component in the control of late blight and use of such varieties significantly reduces input costs. Adoption is dependent on the availability of information. The development of these varieties is worthless if farmers do not discover and use the varieties.

Institutions supply information that can reach the farmer in several ways. (e.g.. pamphlets, field days, workshops, FFS, and association with other farmers; see Section 2.5 for further details). The complexity of the IPM message affects the impact of different sources of information on farmers. Feder et al found that farmers consider other farmers the most important source of agriculture information, but prefer more specifically trained persons as the complexity of the message increases.

One of the earlier adoption models was described in the work of Rogers in *Diffusion of Innovations* in the 1960s. This model is known as the adoption diffusion model. It makes two basic assumptions. It assumes that the technology is appropriate for the farmer's problem, and that information access is the principle factor that determines adoption. In this model, the acquisition of knowledge leads to a change in farmer perceptions (risk and profitability). Thus, farmers who are knowledgeable about profit-enhancing technologies will choose to adopt (Negatu and Parikh, 1999). Nowak concluded that information is important for the adoption of soil conservation practices because without information, farmers believe that the technologies are unprofitable and risky. He also claimed that inefficiencies in the delivery of information discourage adoption (Nowak, 1987).

The adoption diffusion model does not consider whether other factors may restrict farmers' decision making abilities. Economic barriers may exist that discourage or prevent adoption even when information is adequately received by farmers. This concept led to the development of the economic constraints model. Economic barriers include but are not limited to, access to capital, credit, land, and labor. Hooks et al. studied and compared the results of both models concerning adoption of farm technologies. He found that neither model was adequate in predicting adoption, although the economic constraints model did a better job. He suggested the need for a more complex model that took into account factors from both models (Hooks et al, 1983).

3.1.2 FARMER CHARACTERISTICS

Farmer characteristics often considered in adoption models include: age, gender, human capital (formal or informal education), household size, and wealth (farm size, income). The role of women verses men in decisions to adopt have also been considered in studies. This role has varied depending on the particular agriculture situation. In Uganda, for example, women were more likely to borrow money for technologies requiring capital for inputs and men were more willing to adopt higher-risk technologies (Bonabana, 1998). In this study, female participation in the survey was too low to consider gender in the analysis of adoption determinants.

Human capital can be acquired through formal and informal education and farming experience. Formal education refers to what we typically know as public school education. Informal education refers to other types of training such as workshops, seminars, and field days. It is assumed that formal education increases the farmer's ability to understand and respond to information concerning new technologies (Feder and

Slade, 1984). Human capital increases the ability to think analytically, make practical adoption decisions, and use technology appropriately (Rahm and Huffman, 1984). Studies show that farmers with more formal education tend to adopt more agricultural technologies (Chaves and Riley, 2001; Strauss et al, 1991; Feder et al, 1985). Adoption also occurs from increases in human capital due to FFS participation (Bonabana, 1998), participation in farmer groups (Caviglia-Harris, 2003; Strauss et al, 1991; Adesina et al, 2000), and exposure to extension information (Bonabana, 1998).

Household size is another consideration in determining adoption. Larger households adopt new technologies more often than smaller households, holding other factors constant (Bonabana, 1998; De Souza Filho et al, 1999). Larger households containing members able to participate in on-farm activities enable farmers to adopt labor-intensive technologies (Feder et al, 1985). If technologies are capital-intensive, household members may work off-farm to generate income to purchase farm inputs.

Wealth is a potential determinant of adoption in many adoption studies. Methods of measuring wealth vary depending on the survey sample. It can be measured, for example, by income (cash flow), land holdings (i.e. farm size) or livestock ownership. In general, wealth enables farmers to bear more risk and encourages adoption of new technologies. Farmers with larger farms invest more in information acquisition and accumulate knowledge that leads to adoption (Feder and Slade, 1984).

3.1.3 TECHNOLOGY CHARACTERISTICS AND FARMER PERCEPTIONS

Many adoption studies emphasize technology characteristics as determinants of adoption instead of farmer characteristics (Batz et al, 1999; Adesina and Zinnah, 1993; Fliegel and Kivlin, 1966). In a Kenyan study, Batz et al evaluated the impact of characteristics such as relative complexity, risk, and investment in the technology. They tested the impact of these factors on the rate and speed of adoption of dairy technologies. They found that relatively high complexity and risk had significant negative impacts on the speed of adoption. In a 1966 Pennsylvania study, Fliegel and Kivlin also found that technology attributes affected the rate of adoption. In this case, technologies perceived as "most rewarding and least risky" were adopted most quickly. In contrast to the other study, complexity and initial high costs did not negatively affect adoption rates when all factors were considered. They attributed this apparent inconsistency to the demographic of the farmer population which included higher than average levels of education, income, and exposure to urban society. However, in their 1962 study, low complexity technologies were adopted faster. They concluded that further studies were necessary to understand the patterns of adoption and diffusion.

Measuring how technology characteristics affect adoption can be difficult. Some problems are articulated in an article by Fliegel and Kivlin, *Attributes of Innovations as Factors in Diffusion.* These problems include: (1)separating the farmer characteristics from the technology characteristics as both having potential effects on adoption processes, (2)considering how to measure or categorize the particular characteristics of the technology (3)having enough innovations/technologies considered in the study to be significantly variable (4)every technology is likely to have several characteristics, and so these attributes must be separated out statistically to understand the effects on adoption patterns.

Some studies add perception variables into their models which measure the producer perceptions of the severity of the farm problem or of the technology (Gould, 1989; and Norris and Batie, 1987; Adesina and Zinnah, 1993). They explain that farmer perception of the technology must also be considered when examining the adoption decision. Adesina and Zinnah believed that the farmer's perception of the technology may significantly influence adoption decisions. This variable answers to whether or not the farmer sees the technology as appropriate or inappropriate for solving the particular problem. Using a tobit model, they tested their hypothesis on 124 rice farmers in Sierra Leone. They found that the perception variable was a major determinant of adoption, and that traditionally used variables (adoption-diffusion studies) were not important (Adesina and Zinnah, 1993).

3.1.4 ADOPTION AND THE PRESENT STUDY

The adoption literature shows that many factors should be considered when evaluating adoption determinants. The appropriate model depends upon the circumstances surrounding a particular study including study objectives, time constraints, funding limitations, and available data. In this study, we want to understand how to better promote adoption of IPM technologies. The variables were chosen for the model by taking into account several conceptual models used in adoption studies given the available information from the survey and limited sample size.

The present study focuses on three categories of potential determinants of adoption for IPM potato technologies. These categories include: (i)Farmer Characteristics, (ii)Economic Factors, and (iii)Institutional Factors. Farmer characteristics (age, education, household size, and access to laborers), institutional (access to information from various sources including FFSs, other farmers, field days, and pamphlets), and economic constraints (land holdings and illness from pesticides) are considered to be potential determinants or constraints of IPM adoption for potato farmers. Technology characteristics (complexity and labor requirements) and farmer perceptions (perceived profitability, risk, and preferences) are considered, not as separate variables in the model, but qualitatively to provide feedback in conjunction with model results. The variables include: farmer age, education, household size, household members available as laborers, land holdings, illness from pesticides, and 5 variables representing the sources of information for acquiring knowledge about IPM (see Table 3.1 at the end of Chapter 3). The analysis and results will be enumerated on in Chapter 4.

3.2 Methods

3.2.1 GENERAL METHODS

In Fall 2003, a survey was given to a total of 109 potato farmers. The farmers came from the four potato-producing cantons within Carchi province (Huaca, Montúfar, Tulcán, and Espejo). Thirty had participated in Farmer Field Schools and 79 were non-participants. Of the 79 non-participants, 28 farmers were chosen because of having had some contact with a FFS participant. The 51 remaining farmers were chosen randomly from non-participant potato farmers in Carchi. Surveys were conducted by INIAP technicians from the Santa Catalina and San Gabriel Agricultural Stations (Quito and San Gabriel). Farmers were visited either at their homes, in their potato fields, or while working for other farmers.

Farmers were asked a series of questions that included the following categories of information: socioeconomic, potato production, pesticide usage and handling, IPM knowledge and implemented techniques, and knowledge about the three most significant potato pests, Andean Weevil, Late Blight, and the Central American Tuber Moth. Each farmer was given a score for his or her level of IPM usage. This score was translated into one of five categories: 1=no usage, 2=minimal adoption, 3=moderate adoption, 4=high adoption, and 5=full adoption. Minimal adoption is defined as using between 1 and 25% of recommended IPM activities, moderate between 25% and 50%, high between 50%-75% and full adoption for use of more than 75% of recommended activities. The IPM index value is the dependent variable in the model.

Adoption decisions are based on value of expected net benefits to farmers. Implicitly factored into the expected value are the farmers' perceptions of the technology and potential risks. High-risk technologies are typically those that are relatively new. If a farmer is exposed to technologies, perceptions of risk are assumed to decrease. Other characteristics of technologies include: capital-intensive, labor-intensive, or skill-intensive. Capital-intensive technologies include purchase of quality seed and traps. Labor-intensive technologies refer to the use of trap/monitoring systems (also skill-intensive) and various cropping techniques such as complete removal of post harvest plant debris from the field.

Farmers will choose to adopt if the expected value of benefits from technology use exceeds the expected value of benefits from use of conventional methods. Benefits are used here instead of profitability because of the possibility that farmers base decisions on more than monetary expectations. In addition to profitability, benefits can include improvements in health and to the environment. Profitability is affected by changes in yields and input use. IPM may require an increase in labor demand which if offset by yield increases or reduction in other input costs, can have profitable results. As discussed in Chapter 2, field studies done in FFSs provided evidence that IPM systems are more profitable than conventional systems (see Table 2.3). Recall, however, that these studies did not take into account the cost of acquiring information on IPM.

We can write out this concept as:

[Total Expected net benefits of adoption] = [Expected benefits of adoption - Expected costs of adoption]

IF:

[Expected net benefits of adoption] > 0

Then: we expect farmers to adopt the IPM technology.

When farmers adopt the technologies, it indicates that perception of net benefits is greater than zero. A farmer's perception of total net benefits can be affected by any of the factors discusses above (technology characteristics, access to information, economic constraints, access to labor etc.).

Using survey data, we can determine the current spread of IPM in the Carchi region. At this basic level of analysis, we have not yet recognized what constraints there may be to adoption. Once the level of adoption has been determined, the study attempts to understand the underlying influences that most affect farmers' decision-making processes.

3.2.2 SPECIFIC METHODS

This section will describe in detail the methods of analysis employed to meet each individual objective. Sub-objective (1) is to understand how farmers obtain information about pest control and to evaluate the cost-effectiveness of FFSs and other dissemination methods in conveying IPM information. Survey responses indicate the various methods in which farmers received information concerning IPM. Straightforward analysis will show the distribution of farmer access to information. The econometric model will further analyze the potential relationship between information source and IPM use. The model also examines the relative effectiveness of each information source (including FFS) on farmer knowledge of IPM.

Sub-objective (2) is to identify the spread of IPM and the characteristics of users. We begin with descriptive analysis. The survey responses are used to determine the extent of IPM use. Users are placed into categories by level of usage. The survey asked questions concerning the use of 17 recommended IPM activities for potato production in Ecuador. Categories of use are defined by the percentage of activities in which each farmer participates. Farmers are divided into 5 categories of use - from no adoption to full adoption. Farmer characteristics are evaluated for each category and described in the results in Chapter 4.

Sub-Objective (3) is to identify the determinants and constraints of adoption of IPM. For this objective, the study makes use of an econometric model. The model includes 11 independent variables from the 3 classes described above, and examines their relative impacts on farmer adoption. The complete list and description of independent variables as they appear in the adoption model are discussed in the following section.

3.2.3 DESCRIPTION OF THE VARIABLES IN THE ECONOMETRIC MODEL

i. Category I – Characteristics of Farmers and Farmer Households

FAGE – Age of the chief farmer

Farmer age is often used as a variable in adoption studies. In a study by Adesina and Zinnah (1993), age was found to be negatively correlated with adoption. This relationship is explained by the assumption that as farmers grow older, there is an increase in risk aversion and a decreased interest in long-term investment in the farm. Older farmers tend to have experience in profitable crop technologies and are less likely to experiment with new methods that may seem risky or complicated. Often it is observed that young people are more willing to try new technologies. Younger populations are typically less risk-averse and still in the process of learning the best methods for management of their farms.

EDUC – Farmer has attended secondary school

Education is often considered as a factor in technology adoption studies. It is an indication of the ability to communicate, read pesticide containers and other applicable publications, and synthesize information for optimal decision making. Study results associate higher levels of education with increased adoption (Chaves and Riley, 2001; Strauss et al, 1991). Highly educated farmers are more likely to be aware of IPM methods and associated benefits. In particular for complex technologies, education is positively correlated with adoption. In the case of the study by Chaves and Riley, some technologies required sampling procedures in which mathematical abilities were relevant. In this study, considering the use of traps and monitoring systems, we expect education to be positively correlated with adoption.

FHHS – Total number of members (including the farmer) living in the household

Household size was found to be positively correlated to IPM adoption due to increased availability of labor (Bonabana, 1998; De Souza Filho et al, 1999). Affects on adoption may vary depending on the ages of household members.

HHOLDb – Number of members in the household who are 14 years or older
This age group is of particular interest because of the likelihood that these individuals will participate in on-farm labor activities. Therefore, this variable is used as a measure of labor availability. These individuals may also participate in off-farm work as a supplement for on-farm income. Availability of labor is a potential factor for adoption of sustainable agriculture technologies. Household size has been found to have a positive effect on adoption (Bonabana, 1998; De Souza Filho et al, 1999).

ii. Category II – Economic Factors

LSIZ2 – Land Size
This variable is a per capita measure of the amount of land held by the farmer's household and is one indicator of wealth.[6] There are a variety of conclusions concerning this variable as a determinant of adoption. In some studies farm size has been found to have a positive correlation with adoption (Adesina and Zinnah, 1993) although it was less significant than farmer's perceptions of the technology. In other studies, farm size was negatively correlated with adoption of technologies (De Souza et al, 1999). In a third study, (Bonabana, 1998), farm size had no effect on adoption. A variety of potential explanations exist for differing results. Increased farm size may reflect higher household income and the ability to purchase inputs with greater ease than farmers with smaller landholdings. If the technology is labor-intensive and labor is not plentiful, larger farms may choose to purchase inputs rather than utilize the technology. If however, the technology is input intensive, larger farms may be more able to use the technology than smaller farms with less fluid income. Higher incomes are also associated with an increase in risk-bearing potential, implying a willingness to try new technologies that may or may not be successful. In this study, some IPM technologies are more labor-intensive and others are capital-intensive. For capital-intensive technologies, we expect farmers with

[6] In this study, we used a per capita measure for land holdings as a more accurate measure of household wealth. However, the studies referenced in this section do not use per capita measures. Total income or land variables are useful for looking at relationships between available land and adoption, or for assessing farmers' access to credit. These relationships were not evaluated in the current study, though data were collected for future research.

more land to adopt more IPM. If technologies are labor-intensive, we expect those with more land to adopt less, particularly if there is a labor shortage.

FHEAL – Whether the farmer has been sick in the last year as a result of pesticide use
Several studies have been done in Ecuador concerning health and pesticide use (Crissman et al, 1994; Antle and Capalbo, 1994). Researchers have encountered different responses in terms of knowledge of pesticide toxicity and reaction to that knowledge. Despite toxicity levels and associated dangers of exposure, pesticide safety equipment is rarely used. According to the study by Crissman et al, farmers may be aware of potential for poisoning, but are less aware of long-term health effects. In a study by Bonabana on IPM technology in Uganda, farmers' perception of harm from pesticides was found to have no effect on adoption.

iii. Category III – Institutional Factors

FEXP1-5 – Exposure of farmers to various forms of information.
Researchers strive to understand how information spreads in farming communities and the effect on adoption rates. These 5 variables represent the means by which a farmer has been exposed to information concerning IPM. FEXP1 through 5 represent the following sources of information: (1) attended FFS, (2) heard of IPM from other farmers (FFS participants), (3) heard of IPM from other farmers (non-FFS participants), (4) attended a farmer field day, and (5) read about IPM in a pamphlet.

In this study, 30 of the 109 farmers who were surveyed attended FFSs. In some studies, FFS participation has been shown to have a positive effect on adoption of IPM technologies (Bonabana, 1998). In a West Africa study, FFSs also had positive impacts but there were concerns that FFSs have an inherent bias for literate farmers. FFS tend to be based on 'Western Science' and target or attract farmers who are already somewhat educated or exposed to alternative technological approaches (Owens and Simpson, 2002). An Indonesian study took into account the potential bias and concluded that FFSs did not have a significant impact on participants or associated communities. The study also found that FFS did not have an impact on the reduction of pesticide use or increase in yields (Feder et al, 2003).

Increased exposure to extension agents and participation in farmer groups has been correlated with higher adoption rates (Adesina et al, 2000; Strauss et al, 1991; Bonabana, 1998). In the study by Bonabana, institutional/information factors were found to have the most significant impact on adoption of IPM technologies. These factors included on-farm trials, FFS, training, and extension information. Although we expect varying degrees of impact, all information variables are expected to have some positive effect on adoption.

3.3 Description of the Model

3.3.1 THE EMPIRICAL MODEL

Adoption studies typically use various types of logistic models to analyze survey data. These models recognize adoption as a dependent categorical variable. Linear regression is not an appropriate method for adoption studies for several reasons. Continuous linear regression typically uses the Ordinary Least Squares (OLS) estimator for making predictions. In the case of adoption, where the dependent variable takes on a limited number of values and the error term is not normally distributed, and OLS regression will produce biased results. Particularly, in adoption studies, a significant proportion of the population chooses to adopt 0% of the technologies. The adopters in the population tend to aggregate around a few specific values. In addition, adoption models attempt to predict probabilities of adoption. OLS predictions can lie outside of the [0, 1] range and cannot thus be interpreted as probabilities. Qualitative response models use Maximum Likelihood Estimation (MLE) and account for the discrete nature of the dependent (adoption) variable (Greene, 1993).

Qualitative response models are used particularly for panel, time series, or cross-sectional data in which dependent variable takes on a limited number of discrete values. Binary response models (i.e. probit, logit) are used where adoption is considered as a yes or no decision by farmers. However, farmers often manage risk through diversification, and this diversification may be reflected in partial adoption of technologies. This study looks not only at whether adoption occurs, but also the intensity of adoption. Therefore, the model needs to consider more than two possible responses. We employ a type of probit model (using MLE) to determine the effects of independent variables on the probability of adoption. An ordinary probit model is used when the dependent variable has only two values (0 and 1). Given that there are 5 possible ordered values for Y (described below), a categorical, ordered response model is required. An ordered probit model allows for multiple values for the dependent variable when ordering of the dependt variable is present. It analyzes the effect of each independent variable on the dependent variable. The ordered probit measures the probability that this dependent variable falls in one of 5 discrete categories given the independent X's which correspond to the list of variables in Table 3.1. The general ordered probit[7] model can be written as follows:

$$P(Y=1|X_i) = P(Y=1|x_1, x_2, ..., x_k) = E(Y_i|X_i)$$
$$Y_i^* = X_i\beta + u_i \quad (i = 1, 2, ..., n) \text{ and}$$
$$Y_i = 0 \text{ if } Y_i^* < \gamma_1$$
$$Y_i = 1 \text{ if } \gamma_1 \leq Y_i^* < \gamma_2$$
$$Y_i = 2 \text{ if } \gamma_2 \leq Y_i^* < \gamma_3$$
$$Y_i = 3 \text{ if } \gamma_3 \leq Y_i^* < \gamma_4$$
$$Y_i = 4 \text{ if } \gamma_4 \leq Y_i^* < \gamma_5$$
$$Y_i = 5 \text{ if } \gamma_5 \leq Y_i^*$$

(Y_i = level of adoption of IPM, X_i = explanatory variables, u_i = the residuals or error term and Y_i^* = the unobserved, underlying response variable; γ_i's are the cutoffs or thresholds that define the value of Y_i for given values of Y_i^*)

[7] For more detailed information concerning probit models see the Chapter: Qualitative and Limited Dependent Variables from Greene, 1993: pgs. 511-537.

In this model, Y (the dependent variable) represents the potential level of IPM adoption by farmers. Adoption intensity is defined according to the following five categories:

1 = 0% adoption
2 = $0\% < Y \leq 25\%$ adoption
3 = $25\% < Y \leq 50\%$ adoption
4 = $50\% < Y \leq 75\%$ adoption
5 = $75\% < Y \leq 100\%$ adoption

Adoption percentages were calculated by taking the total number of recommended IPM activities (17) and determining the percentage of activities utilized by each farmer (see Table 4.9) A sixth category could be added to capture farmers who adopted all recommended technologies. However, in this sample, no farmers reached 100% adoption.

Probit model coefficients (β) report on the effect of an independent variable on the probability index. These coefficients give an indication of positive or negative impact, but do not relay information concerning the magnitude of the effect. Marginal effects can be calculated using the linear probability index and provide the magnitude of effect for a change in the independent variables.

Using a transformation function F(X) the model creates a linear index of the probabilities with a cumulative standard normal distribution. The probabilities are evaluated by looking at the linear function $\Phi(X_i\beta)$. Although we do not observe the value of Y_i^*, we observe the sign, and therefore a positive or negative impact on the probability of adoption.[8] The probabilities are written as follows:

$$\Pr(Y_i = 0) = \Pr(Y_i^* < \gamma_1) = \Pr(X_i\beta + u_i < \gamma_1)$$

[8] See Greene, pp. 512-515 (Binary-response models) and 529-531 (Models for more than two discrete responses).

$$Pr(Y_i = 1) = Pr(\gamma_1 \leq Y_i^* < \gamma_2) = Pr(\gamma_1 \leq X_i\beta + u_i < \gamma_2)$$

$$Pr(Y_i = 2) = Pr(\gamma_2 \leq Y_i^* < \gamma_3) = Pr(\gamma_2 \leq X_i\beta + u_i < \gamma_3)$$

$$Pr(Y_i = 3) = Pr(\gamma_3 \leq Y_i^* < \gamma_4) = Pr(\gamma_3 \leq X_i\beta + u_i < \gamma_4)$$

$$Pr(Y_i = 4) = Pr(\gamma_4 \leq Y_i^* < \gamma_5) = Pr(\gamma_4 \leq X_i\beta + u_i < \gamma_5)$$

$$Pr(Y_i = 5) = Pr(Y_i^* \geq \gamma_5) = Pr(X_i\beta + u_i \geq \gamma_5)$$

The independent variables tested in this model are listed in Table 3.1. By analyzing these variables in relation to IPM adoption intensity, we can determine which factors positively or negatively impact adoption (i.e. age, human capital, income, information access, etc...). Results from the statistical model will be discussed in Chapter 4.

TABLE 3.1 - DESCRIPTION OF VARIABLES

Variable Name	Type	Description
Charcteristics of Farmer		
FAGE	Continuous	Farmer age
EDUC	Binary	Attend Secondary School
FHHS	Discrete	Number of members of household including farmer
HHOLDb	Discrete	Number in household 14 and older
Economic Factors		
LSIZ2	Continuous	Land holdings per capita (in household)
FHEAL	Binary	Farmer has been sick from pesticides
Institutional Factors		
FEXP1	Binary	Attended FFS
FEXP2	Binary	Heard of IPM from other farmers (FFS participants)
FEXP3	Binary	Heard of IPM from other farmers (non-FFS participants)
FEXP4	Binary	Heard of IPM from a field day
FEXP5	Binary	Heard of IPM from pamphlets

In this chapter we discussed basic methodological issues concerning IPM adoption. Utilizing studies from adoption literature, we developed the methods for analysis and a layout of the variables for the model. Using these methods, we can proceed to Chapter 4, in which we present the results.

Chapter 4 - Results

This chapter is divided into three sections. Section 4.1 provides a descriptive analysis of results from the survey. This section presents information on how farmers obtain information about IPM technologies, the spread of IPM in Carchi, farmer characteristics, and farmer perceptions. Section 4.2 presents the results from the empirical model. Looking at these results we can determine the role of each variable as a potential determinant of or constraint to adoption. Section 4.3 gives a brief summary of the results.

4.1 Descriptive Analysis

4.1.1 HOW FARMERS LEARN ABOUT IPM

Farmers were asked how they first heard about IPM. Information sources included pamphlets, field days, farmer networks, and participation in FFSs. Six variables were used to represent these sources of IPM information (see key).

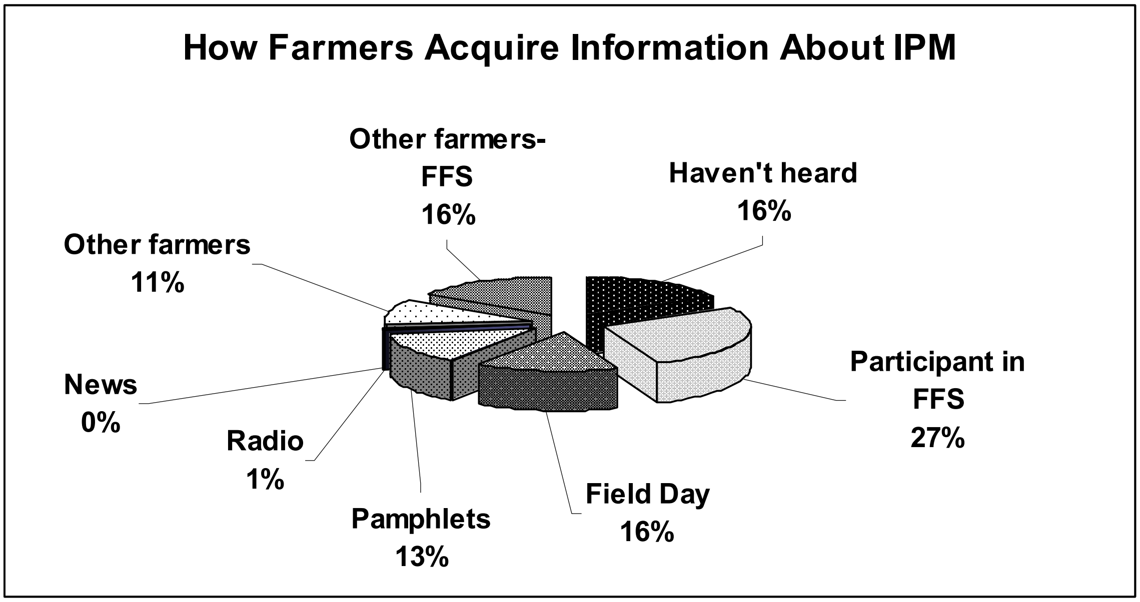
TABLE 4.1 - VARIABLE KEY FOR INFORMATION DIFFUSION MECHANISMS

KEY:	Variable	Source of IPM Information
	FEXP1	Participation in Farmer Field School
	FEXP2	From farmers who participated in FFS
	FEXP3	From farmers who have not participated in FFS
	FEXP4	Participation in Field Days
	FEXP5	Pamphlets
	FEXP0	Haven't heard about IPM

Of 109 farmers, 30 (27%) acquired IPM information through participation in FFS. 29 (27%) farmers heard about IPM through other farmers. 17 (16%) farmers attended field days and 14 (13%) received pamphlets on IPM. 18 (16%) farmers indicated that they had not received information on IPM (see Figure 4.1).

Three distinct populations were included in the survey sample: (1)farmers who attended FFS (FFS), (2)farmers exposed to FFS graduates (Exposed), and (3)farmers randomly selected with no apparent relationship to FFS, either through participation or exposure to graduates (Other). Note that the distribution of farmers is not representative of the farmer population in Carchi. FFS participants were deliberately selected for inclusion in the survey as were the 28 farmers who had contact with FFS participants.

FIGURE 4.1 - HOW FARMERS ACQUIRE INFORMATION ABOUT IPM



Source: Survey Data, Carchi, 2003-2004

Statistically significant differences exist between farmer groups by information source (see Table 4.2). The main sources of information for 'Exposed' farmers were either field days (43%) or other farmers (39%). For the 'Other' group, many farmers claimed they had not received information about IPM (35%). 'Other' farmers who had received information did so mostly through pamphlets (20%) or through interaction with other farmers (35%).

TABLE 4.2 - SOURCE OF INFORMATION ABOUT IPM, BY FARMER GROUP

Information Source	FFS (%)	Exposed (%)	Other (%)	Total (%)
FEXP0 (Haven't heard)	0.0	3.6	35.3	17.4
FEXP1 (Attend FFS)	100.0	0.0	0.0	27.5
FEXP2 (Other farmers-FFS)	0.0	21.4	21.6	15.6
FEXP3 (Other farmers-Non FFS)	0.0	17.9	13.7	11.0
FEXP4 (field days)	0.0	42.9	9.8	15.6
FEXP5 (Pamphlets)	0.0	14.3	19.6	12.8
Total	100	100	100	100

Source: Survey Data, Carchi, 2003-2004
Note: A Pearson chi2 test showed significant differences between farmer groups at the 1% level.

There is evidence that diffusion is occurring between farmers, though we do not know the quality of the information that is being transferred. By looking at the 'Exposed' group, we can see that farmers learn about IPM from multiple sources. Many farmers in this group did not name 'other farmers' as their main source of IPM information. 43% of these farmers attended field days and 14% mentioned pamphlets. This leaves us to wonder how many different sources of information each farmer utilized. The data do not answer this question because of the way the farmers were surveyed. Each farmer only gave one response about their source of IPM information. Additionally, we do not know the quantity of information obtained (i.e. number of field days or pamphlets, amount of exposure to other farmers).

Each farmer was given a knowledge score based on 25 questions in the survey. Questions focused on specific IPM technologies. Farmers were categorized based on the percent of questions answered correctly, from Category I (0% answered correctly) to Category V (76-100% answered correctly). The rest of the category designations can be seen in Tables 4.3 and 4.4, in which we examine farmer knowledge of IPM by information source and farmer group.

Looking at the relationship between information source and IPM knowledge, note that FFSs contribute the most to high knowledge scores (see Table 4.3). Field days and pamphlets also contributed to high knowledge scores. There is some impact on knowledge from farmer-to-farmer diffusion (FEXP2 and FEXP3), but scores are not as high as when other media (field days, pamphlets) are used. Although farmer interactions may not have a strong impact on knowledge, farmers seem to be more likely to acquire additional information on IPM after such interactions.

TABLE 4.3 - DEPTH OF KNOWLEDGE ABOUT IPM BY INFORMATION SOURCE
(Knowledge category was determined by the % of IPM questions answered correctly by farmers)

IPM Knowledge by Category	Information Source					
	FEXP1 (Attend FFS)	FEXP2 (Other farmers-FFS)	FEXP3 (Other farmers--nonFFS)	FEXP4 (field days)	FEXP5 (pamphlets)	FEXP0 (Haven't heard)
Category I (0%)	0.0%	5.9%	16.7%	5.9%	14.3%	44.4%
Category II (1-25%)	0.0%	35.3%	41.7%	11.8%	28.6%	27.8%
Category III (25-50%)	3.3%	41.2%	33.3%	35.3%	21.4%	22.2%
Category IV (51-75%)	23.3%	11.8%	0.0%	41.2%	21.4%	5.6%
Category V (76-100%)	73.3%	5.9%	8.3%	5.9%	14.3%	0.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Survey Data, Carchi, 2003-2004
Note: A Pearson chi2 test showed significant differences between information sources at the 1% level.

There are significant statistical differences in knowledge scores between farmer groups at the 1% level (see Table 4.4). 'Exposed' farmers had significantly higher scores than the 'Other' group, but less than the FFS farmers. If we compare the variable FEXP2 and the 'Exposed' group[9] in Table 4.4, farmers who learned IPM from FFS-participants (FEXP2) had significantly lower knowledge scores than those in the 'Exposed' group. As seen in Table 4.2, 'Exposed' farmers also attended field days and read pamphlets. We can see that although diffusion occurs, farmer-to-farmer interactions, combined with other sources of information, have a greater impact on knowledge scores.

TABLE 4.4 - DEPTH OF KNOWLEDGE ABOUT IPM BY FARMER GROUP
(Knowledge category was determined by the % of IPM questions answered correctly by farmers)

IPM Knowledge by Category	FFS (%)	Exposed (%)	Other (%)	Total (%)
Category I (0%)	0.0	3.6	25.5	12.8
Category II (1-25%)	0.0	7.1	37.3	20.2
Category III (25-50%)	3.3	35.7	29.4	22.9
Category IV (51-75%)	23.3	42.9	3.9	19.3
Category V (76-99%)	73.3	10.7	3.9	24.8
Total	100.0	100.0	100.0	100.0

Source: Survey Data, Carchi, 2003-2004
Note: A Pearson chi2 test showed significant differences between farmer groups at the 1% level.

It is difficult to explain why farmers who claimed to have not been exposed to IPM information (FEXP0), still had knowledge of IPM (see Table 4.3). In Table 4.6, we

[9] The difference between these two groups is subtle. FEXP2 represents farmers who named FFS participants as their primary source of information concerning IPM. The 'Exposed' farmers were individuals named by FFS participants because they had received IPM information from them. The difference is that 'Exposed' farmers also obtained IPM from other sources.

see that these farmers also adopted a number of IPM practices. One explanation is that these farmers did not understand the question or were not aware their methods were considered IPM. (see Table 4.7 for specific IPM practices adopted by this group.)

Surveyees were asked whether they had shared information on IPM with other farmers. Table 4.5 shows to what extent farmers shared information. On average, FFS participants reached out to the most farmers. 'Exposed' farmers spread information to some farmers, though much less than FFS participants. 'Other' farmers hardly shared information with other farmers.

One of the goals of the FFS program is to encourage information diffusion from participants to non-participants. There were 223 farmers in FFSs between 1998 and 2003. In this survey, FFS participants claimed to have shared information with 11 farmers on average. If we assume there is no overlap in these interactions, approximately 2500 farmers were exposed to IPM from FFS farmers (more than one third of potato farmers in Carchi). It is likely that some overlap does occur, though we do not know to what extent.

TABLE 4.5 - FARMER TO FARMER SPREAD OF IPM INFORMATION

	FFS	Exposed	Other	Total
(#) farmers who spread IPM info to other farmers	28/30	25/28	4/51	57/109
How many total # of farmers did they spread info to?	332	61	14	407
On average, how many individual farmers did each farmer talk to about IPM?	11	2.17	0.27	3.73

Source: Survey Data, Carchi, 2003-2004

TABLE 4.6 - DEGREE OF ADOPTION OF IPM BY INFORMATION SOURCE

IPM Use by Category*	Information Source					
	FEXP1 (Attend FFS)	FEXP2 (Other farmers-FFS)	FEXP3 (Other farmers--nonFFS)	FEXP4 (field days)	FEXP5 (pamphlets)	FEXP0 (Haven't heard)
Category I (0%)	3.3%	11.8%	33.3%	5.9%	21.4%	61.1%
Category II (1-25%)	6.7%	29.4%	33.3%	17.6%	21.4%	11.1%
Category III (25-50%)	20.0%	29.4%	16.7%	23.5%	21.4%	5.6%
Category IV (51-75%)	43.3%	23.5%	8.3%	47.1%	35.7%	22.2%
Category V (76-100%)	26.7%	5.9%	8.3%	5.9%	0.0%	0.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Survey Data, Carchi, 2003-2004

Note: A Pearson chi2 test showed significant differences between information sources at the 1% level.

*Use categories are defined by % of IPM techniques adopted, as described in Chapter 3 (Sections 3.2.1 and 3.3.1)

The data were analyzed to look for relationships between acquisition of knowledge by source and degree of adoption (see Table 4.6). In total, 90 farmers had received information about IPM. Category V adoption (76-100%) was mostly observed in farmers who attended FFS. The highest rates of adoption in Categories IV and V were observed with farmers who either attended FFS or a field day. These adoption rates can be partially attributed to the fact that FFS participants and those who attended field days had high knowledge scores. Diffusion of information through farmer networks seemed to be less effective (FEXP2 and FEXP3) as both knowledge scores and adoption rates were lower. However, as discussed previously, farmer-to-farmer interactions encourage pursuit of IPM knowledge through other sources (i.e. field days, pamphlets). The lowest rates of adoption were observed in the farmers who had heard of IPM from non-FFS farmers (FEXP3) or claimed they had not received information on IPM (FEXP0). Non-FFS farmers may lack the expertise to transfer IPM knowledge effectively. In addition, farmers show a preference for more experienced individuals when learning IPM technologies. (Owens and Simpson, 2002) In the statistical model (Section 4.2), all information variables are significant in determining adoption except for FEXP3.

4.1.2 ADOPTION OF IPM TECHNOLOGIES

IPM adopters were defined as those who used any of the recommended practices shown in Tables 4.8-4.9. Adoption intensity ranged from a minimum use of 1/17 practices to a maximum of 16/17 practices. In Table 4.7 we can see that 20% of farmers did not use any IPM (Category I). 42.2% used more than half of the recommended IPM technologies (Categories IV and V). Comparing IPM use between farmer groups, note that 40% of farmers who were randomly selected did not use any IPM. Of the farmers who used more than 50% of IPM practices, the majority had attended FFS (70%). Farmers in the ‘Exposed’ group used less IPM than the FFS participants but more than random farmers.

TABLE 4.7 - FARMER USE OF IPM BY FARMER GROUP

IPM Use by Category*	FFS (%)	Exposed (%)	Other (%)	Total (%)
Category I (0%)	3.3	3.6	39.2	20.2
Category II (1-25%)	6.7	17.8	23.5	17.4
Category III (25-50%)	20.0	50.0	3.9	20.2
Category IV (51-75%)	43.3	21.4	31.4	32.1
Category V (76-100%)	26.7	7.1	2.0	10.1
Total	100	100	100	100

Source: Survey Data, Carchi, 2003-2004
Note: A Pearson chi2 test showed significant differences between information sources at the 1% level.
*Use categories are defined by % of IPM techniques adopted, as described in Chapter 3 (Sections 3.2.1 and 3.3.1)

Looking at adoption rates by activity (Table 4.8), more than half of farmers used some form of insect traps (66%), crop rotations (59%), disinfected seed with insecticides (57%), removed crop residues from fields (50%) and harvested early to control tuber moth (58%). The least popular practices were: the use of recommended storage bins (9%), traps for Andean Weevil (11%) and the use of fungicides with different active ingredients (discouraging the buildup of resistance in the fungus) (13%). There are differences in adoption by activity across farmer groups, however, the patterns of adoption are similar. Further analysis allows us to determine if there are relationships between adoption patterns and technology characteristics.

TABLE 4.8 - ADOPTION OF IPM BY TECHNIQUE AND FARMER GROUP

IPM Technique	FFS	Exposed	Other	Total	Chi^2
Use pest stage in control strategy	83.3%	57.1%	3.9%	39.4%	0.000
Use traps	80.0%	75.0%	52.9%	66.1%	0.023
Use traps (baited)* for Andean Weevil	30.0%	3.6%	3.9%	11.0%	0.000
Dispose of residues in the field	70.0%	60.7%	33.3%	50.5%	0.003
Use insecticides according to recommendations	70.0%	53.6%	33.3%	48.6%	0.005
Use recommended storage	23.3%	7.1%	2.0%	9.2%	0.005
Disinfect seed with insecticides	70.0%	75.0%	39.2%	56.9%	0.002
Use quality seed	56.7%	46.4%	33.3%	43.1%	0.113
Use pheromone traps (Tuber Moth)	33.3%	35.7%	9.8%	22.9%	0.009
Use recommended hilling methods	60.0%	53.6%	2.0%	31.2%	0.000
Use crop rotations	83.3%	75.0%	35.3%	58.7%	0.000
Use early harvest to control tuber moth	73.3%	85.7%	33.3%	57.8%	0.000
Use irrigation	43.3%	17.9%	31.4%	31.2%	0.112
Use yellow traps	56.7%	21.4%	9.8%	25.7%	0.000
Use traps (mobile)	50.0%	14.3%	3.9%	19.3%	0.000
Use resistant varieties	50.0%	14.3%	37.3%	34.9%	0.015
Use fungicides with different active ingredients	26.7%	7.1%	7.8%	12.8%	0.029

Source: Survey Data, Carchi, 2003-2004
*Traps for Andean Weevil are typically baited with Acefato or another low-toxicity insecticide. (Barrera et al, 2003)

There are particular technology characteristics associated with IPM practices. They can be complex, risky, and capital or labor-intensive. Based on available information, we attempted to categorize IPM practices using these four technology characteristics. In general, all IPM technologies require information, but the amount of information required helps determine the level of complexity. Technologies are categorized as higher risk if they require the farmer to use less or different kinds of pesticides (see Table 4.9). Note that technology attributes in Table 4.9 were categorized subjectively and therefore are not strict designations.

There are some interesting relationships between technology attribute and farmer adoption (see Tables 4.8 and 4.9). In the three farmer groups, adoption patterns were similar. The activities adopted least were recommended storage, use of fungicides with different active ingredients, baited traps for Andean Weevil, irrigation, quality seed, and resistant varieties. Among these activities are the more complex practices as well as those perceived to be most risky and capital-intensive. There is also low adoption on mobile, yellow and pheromone traps which may be attributed to the fact that some pests are not a major problem for farmers (i.e. tuber moth and 'mosca minador,' a pest found only in some areas). Among the most adopted technologies are use of traps (in general), residue disposal, crop rotations, early harvest, disinfection of seeds, and using insecticides as recommended. These technologies tend to be lower risk, low to moderate complexity, and not capital-intensive. Several of these technologies require additional labor, indicating that labor availability may not be a problem for farmers (Table 4.9). Using pest stage as a control strategy has a high adoption rate among FFS farmers, a moderate rate among 'Exposed' farmers and a low rate among 'Other' farmers. Likely, this reflects the high information requirement associated with this more complex technology.

TABLE 4.9 - ATTRIBUTES OF IPM TECHNOLOGIES

IPM Technique	Technology Characteristic			
	Labor	Capital	Complexity	Risk
Use pest stage in control strategy			most	
Use traps	moderate	moderate	moderate	
Use traps (baited)* for Andean Weevil	moderate	moderate	moderate	
Dispose of residues in the field	most			
Use insecticides according to recommendations				
Use recommended storage	moderate	moderate		
Disinfect seeds with insecticides				
Use quality seed		most		most
Use pheromone traps (Tuber Moth)	moderate	moderate	moderate	
Use recommended hilling methods	most		moderate	
Use crop rotations				
Use early harvest to control tuber moth				
Use irrigation		most		
Use yellow traps	moderate	moderate	moderate	
Use traps (mobile)	moderate	moderate	moderate	
Use resistant varieties		most		most
Use fungicides with different active ingredients			moderate	most

*Traps for Andean Weevil are typically baited with Acefato or another low-toxicity insecticide. (Barrera et al, 2003)

4.1.3 CHARACTERISTICS OF FARMERS

Survey respondents were organized into three categories as defined in 4.1.1 (i.e. FFS, Exposed, and Other). All farmers cultivated potatoes in Carchi province. Farmers were predominantly male (93.6%) with a primary school education (81.7%). Only 12% had a secondary school education. Of the 7 female farmers (5 married, 1 widowed, and 1 single), 1 had secondary education. Ages of farmers ranged from 18 to 86 with nearly half between 31 and 50 (see Table 4.11). Mean farming experience was 25.9 years and 40% had been farming for between 21 and 40 years. Household size (FHHS) was distributed over a range from 1 to 9 members with an average of 4.9 members. The average number of members age 14 and older (HHOLDb) was 3.7 and 1.3 for members under the age of 14. Farmer characteristics (i.e. gender, education and age) from this survey were comparable to other surveys conducted in Ecuador in the last 5 years (Barrera et al, 1999).

If we look at the summary statistics in Table 4.10, education and household variables were not significantly different across farmer groups. The only significant differences were gender and how farmers obtained information about IPM. Concerning gender, 5 of the 7 female farmers attended FFS. Recall from Chapter 2, FFS participants in Carchi are chosen based on four factors: 1)Interest in participation, 2)Potatoes are the principle crop on their farm, 3)A desire to share their knowledge with other farmers, and 4)They are creative and innovative. In addition, it is likely that FFSs encourage female farmers to participate since one of the IPM CRSP's goals is to increase the role of women in pest management decisions. As of 2002, 13.9% of farmers in FFSs were women (Barrera et al, 2003). Access to information and differences between farmer groups was discussed in detail in section 4.1.1 - 'How farmers learn about IPM.'

TABLE 4.10 - SUMMARY STATISTICS ACROSS FARMER GROUPS

	FFS Partipants		Exposed Group		Random Sample			
VARIABLE	**Mean** (n=30)	**SD**	**Mean** (n=28)	**SD**	**Mean** (n=51)	**SD**	**F-stat**	**Sig.**
FAGE (farmer age)	41.533	13.508	44.500	12.333	44.216	16.453	0.390	0.676
FGEN (farmer gender)***	1.167	0.379	1.036	0.190	1.020	0.140	3.810	0.025
EDUC (education)	0.100	0.305	0.214	0.418	0.078	0.272	1.670	0.194
FHHS (household size)	5.067	1.530	4.786	1.641	4.961	2.068	0.170	0.840
HHOLDb (# in household >14)	3.633	1.497	3.464	1.347	3.784	1.983	0.320	0.726
FHEAL (sick from pesticides)	0.333	0.479	0.214	0.418	0.196	0.401	1.030	0.360
LSIZ2 (land holdings)	1.460	1.543	1.285	1.138	1.013	1.879	0.760	0.470
FEXP2 (learn from FFS farmers)***	0.000	0.000	0.214	0.418	0.216	0.415	4.000	0.021
FEXP3 (learn IPM from non-FFS)**	0.000	0.000	0.179	0.390	0.137	0.348	2.780	0.067
FEXP4 (attend field day)***	0.000	0.000	0.429	0.504	0.098	0.300	13.900	0.000
FEXP5 (used pamphlets)***	0.000	0.000	0.143	0.356	0.196	0.401	3.390	0.037
IPMKNOW (IPM Knowledge Level)***	83.333	17.167	49.000	24.040	23.216	23.570	69.940	0.000
IPMUSE (rate of adoption)***	58.431	23.828	41.387	20.091	21.915	26.097	22.370	0.000

(**) Indicates significance at the 10% level
(***) Indicates significance at the 5% level

A few items were observed in the 'Other' group. About 10% of the population was over the age of 66, while none of the other groups had members in this age range (see Table 4.11). As discussed in Chapter 3, studies often find that age is negatively correlated with adoption of new agriculture technologies such as IPM. Incomes and land planted in potatoes were also lower in the control group (see Table 4.12). It is difficult to say whether these factors affected adoption, but in other studies age and low incomes are often correlated with lower adoption rates. In this study, the lowest adoption rates were observed in the control group, but this could also be due to the lack of exposure to information on IPM.

TABLE 4.11 - FARMER CHARACTERISTICS

	Farmer Category							
	FFS		Exposed		Other		Total	
	No.	%	No.	%	No.	%	No.	%
Gender								
:male	25	83.3%	27	96.4%	50	98.0%	102	93.6%
:female	5	16.7%	1	3.6%	1	2.0%	7	6.4%
Age								
:18 to 30	7	23.3%	5	17.9%	11	21.6%	23	21.1%
:31 to 50	14	46.7%	13	46.4%	24	47.1%	51	46.8%
:51 to 65	9	30.0%	10	35.7%	11	21.6%	30	27.5%
:66+	0	0.0%	0	0.0%	5	9.8%	5	4.6%
Education								
:None	0	0.0%	0	0.0%	2	3.9%	2	1.8%
:adult educ.	0	0.0%	0	0.0%	2	3.9%	2	1.8%
:pre-primary	0	0.0%	0	0.0%	3	5.9%	3	2.8%
:primary	27	90.0%	22	78.6%	40	78.4%	89	81.7%
:secondary	3	10.0%	6	21.4%	4	7.8%	13	11.9%
Farming Experience (years as potato farmer)								
:up to 5	3	10.0%	1	3.6%	5	9.8%	9	8.3%
:5 to 10	4	13.3%	6	21.4%	9	17.6%	19	17.4%
:11 to 20	6	20.0%	5	17.9%	13	25.5%	24	22.0%
:21 to 40	14	46.7%	12	42.9%	17	33.3%	43	39.4%
:41+	3	10.0%	4	14.3%	7	13.7%	14	12.8%
Farmer has been sick from pesticides in the last year								
:yes	10	33.3%	6	21.4%	10	19.6%	26	23.9%
:no	20	66.7%	22	78.6%	41	80.4%	83	76.1%
Number of days missed from illness								
:one	2	6.7%	1	3.6%	3	5.9%	6	5.5%
:two	0	0.0%	2	7.1%	2	3.9%	4	3.7%
:three	2	6.7%	1	3.6%	0	0.0%	3	2.8%
:four	0	0.0%	0	0.0%	1	2.0%	1	0.9%
:five	1	3.3%	0	0.0%	0	0.0%	1	0.9%
:seven	0	0.0%	0	0.0%	1	2.0%	1	0.9%
:eight	5	16.7%	2	7.1%	1	2.0%	8	7.3%
:fifteen	0	0.0%	0	0.0%	1	2.0%	1	0.9%

Source: Survey Data, Carchi, 2003-2004

TABLE 4.12 - FARMER CHARACTERISTICS - HOUSEHOLDS

	Farmer Category							
	FFS		Exposed		Other		Total	
	No.	%	No.	%	No.	%	No.	%
Households								
:members 14 and over								
0	10	33.3%	8	28.6%	24	47.1%	42	38.5%
1 to 2	15	50.0%	16	57.1%	19	37.3%	50	45.9%
3 to 4	4	13.3%	3	10.7%	7	13.7%	14	12.8%
5 to 6	1	3.3%	1	3.6%	1	2.0%	3	2.8%
:members under 14								
0	0	0.0%	0	0.0%	0	0.0%	0	0.0%
1 to 2	8	26.7%	9	32.1%	17	33.3%	34	31.2%
3 to 4	16	53.3%	13	46.4%	18	35.3%	47	43.1%
5 to 6	5	16.7%	6	21.4%	10	19.6%	21	19.3%
7 to 9	1	3.3%	0	0.0%	6	11.8%	7	6.4%
Household income per capita ($)								
0	1	3.3%	1	3.6%	3	5.9%	5	4.6%
1 to 100	2	6.7%	4	14.3%	6	11.8%	12	11.0%
101 to 300	6	20.0%	6	21.4%	18	35.3%	30	27.5%
301 to 500	9	30.0%	7	25.0%	7	13.7%	23	21.1%
501 to 700	7	23.3%	2	7.1%	6	11.8%	15	13.8%
701 to 1000	2	6.7%	4	14.3%	7	13.7%	13	11.9%
1000+	3	10.0%	4	14.3%	4	7.8%	11	10.1%
Land holdings per capita (ha)								
0	2	6.7%	4	14.3%	12	23.5%	18	16.5%
0.1 to 0.5	8	26.7%	7	25.0%	19	37.3%	34	31.2%
0.6 to 1.0	9	30.0%	3	10.7%	11	21.6%	23	21.1%
1.1 to 1.5	2	6.7%	3	10.7%	0	0.0%	5	4.6%
1.6 to 2	2	6.7%	3	10.7%	4	7.8%	9	8.3%
2.1 to 3	2	6.7%	7	25.0%	2	3.9%	11	10.1%
3.1 to 4	1	3.3%	1	3.6%		0.0%	2	1.8%
4+	4	13.3%	0	0.0%	3	5.9%	7	6.4%
Hectares planted in potatoes								
:none	3	10.0%	2	7.1%	12	23.5%	17	15.6%
:under 1	5	16.7%	3	10.7%	13	25.5%	21	19.3%
:1 to 1.9	11	36.7%	11	39.3%	14	27.5%	36	33.0%
:2 to 2.9	6	20.0%	10	35.7%	6	11.8%	22	20.2%
:3 to 5	4	13.3%	1	3.6%	5	9.8%	10	9.2%
:5+	1	3.3%	1	3.6%	1	2.0%	3	2.8%

Source: Survey Data, Carchi, 2003-2004

Note: In 1999, the poverty line for per capita income was $504 per year. (SIISA, 2003)

4.1.4 FARMER PERCEPTIONS

Farmer perceptions of IPM were generally positive. 82.5% believed that IPM is more profitable than conventional methods. However, it is unclear why more farmers are not using IPM. According to farmers, the prices of pesticides and potatoes impact IPM adoption. 88% of farmers said that an increase in the price of pesticides by 20% would cause them to use more IPM. Nearly 100% of farmers said that a 20% increase in the price of potatoes would increase their use of IPM. There is the question of whether farmers have the available capital to use some IPM technologies. From Table 4.9 and 4.10, we noted that capital-intensive techniques were adopted less across farmer groups. We also notice that, according to income data, at least 64% of farmers are under the poverty line (see Table 4.12). Studies have found that higher income farmers are more willing to take risks with new technologies (Fliegel and Kivlin, 1966). It appears that the combination of low incomes and perceptions of technologies as risky could be limiting factors in adoption. The model will look closer at the relationship between wealth and IPM use.

Concerning labor, about 32% of farmers thought availability was a problem for IPM implementation, 37% said it was not a problem, and 31% gave no response. In the previous section on technology attributes (see Tables 4.9 and 4.10), we observed that higher adoption rates were found for IPM activities requiring extra labor.

In this study, 80.6% of those surveyed claimed that they liked resistant varieties but only 34.9% used resistant varieties. According to Barrera (conversation), resistant varieties are available but farmers consider their seeds to be expensive. The cost of seeds for resistant varieties is about twice as much as other varieties, but cost is not the only factor determining adoption of these varieties. Consumer preferences may also play a role. The data does not provide detailed information on consumers, but we know that several FFSs used 'Superchola' instead of FRIPAPA99 in field plots because of local preferences. Superchola is considered to be less resistant than FRIPAPA99. The point of using either variety is to reduce the farmer's reliance on pesticides to control late blight, therefore, it is likely farmers perceive this technology as high-risk. If the seed fails, the farmer could lose much of their crop. All of these factors may affect farmer adoption of this technology.

Farmers were asked what factors motivated them to use IPM. Fifty percent of farmers indicated that health was their main motivation. Other responses included profitability (22%), environment (14%), better pest control (8%), and consumer preference (7%). Of those farmers who indicated health was the main motivation for IPM use, 45% used more than 50% IPM.

About a quarter of farmers claimed to have been sick from pesticides in the last year. The number of missed labor days ranged from 1 to 15 with an average of 4.7 (Table 4.11). In our study, adoption of IPM was variable within this group of farmers. Of these farmers, 54% used greater than 50% IPM. In the model, we will evaluate whether there is a statistical relationship between farmer health and IPM adoption.

Use of protective gear was significantly different across farmer groups (see Table 4.13) with the exception of masks. FFS participants wore the most protective gear when spraying pesticides. 'Other' farmers used more gear than 'Exposed' farmers, though it is difficult to explain why. In some cases, lack of information may cause farmers to be more cautious concerning pesticide handling. Looking at other information sources in Table 4.14, FFSs are clearly the most effective educators of safe pesticide handling. Educators may need to include more information on pesticide safety in field days and pamphlets.

TABLE 4.13 - PROTECTIVE CLOTHING WORN BY FARMERS (BY FARMER GROUP)

Protective Gear	FFS (%)	Exposed (%)	Other (%)	Total (%)	Chi^2 Sig.
Boots	83.3%	78.6%	94.1%	87.2%	0.001
Mask	50.0%	28.6%	21.6%	31.2%	0.108
Glasses	16.7%	0.0%	5.9%	7.3%	0.027
Jacket	70.0%	21.4%	35.3%	41.3%	0.000
Pants	43.3%	0.0%	15.7%	19.3%	0.000
Gloves	83.3%	25.0%	35.3%	45.9%	0.045

Source: Survey Data, Carchi, 2003-2004

Note: The disproportionate use of boots over other protective clothing is simply because in farmer fields boots are the norm.

TABLE 4.14 - PROTECTIVE CLOTHING WORN BY FARMERS (BY INFORMATION SOURCE)

	Information Source						
Protective Gear	FEXP1 (Attend FFS)	FEXP2 (Other farmers-FFS)	FEXP3 (Other farmers--nonFFS)	FEXP4 (field days)	FEXP5 (pamphlets)	FEXP0 (Haven't heard)	Chi^2 Sig.
Boots	83.3%	88.2%	83.3%	82.4%	85.7%	100.0%	0.008
Mask	50.0%	35.3%	25.0%	17.6%	14.3%	27.8%	0.587
Glasses	16.7%	5.9%	0.0%	5.9%	7.1%	0.0%	0.116
Jacket	70.0%	29.4%	25.0%	23.5%	21.4%	50.0%	0.000
Pants	43.3%	5.9%	8.3%	11.8%	14.3%	11.1%	0.004
Gloves	83.3%	41.2%	16.7%	35.3%	35.7%	38.9%	0.269

Source: Survey Data, Carchi, 2003-2004

4.2 Multivariate Statistical Analysis

The model included the following variables:

TABLE 4.15 - DESCRIPTION OF VARIABLES AND SUMMARY STATISTICS

	VARIABLE	Mean (n=109)	SD	Min	Max
1	FAGE (farmer age)	43.550	14.626	18	86
2	EDUC (education)	0.119	0.326	0	1
3	FHHS (household size)	4.945	1.815	1	9
4	HHOLDb (# in household >14)	3.661	1.701	1	9
5	FHEAL (sick from pesticides)	0.239	0.428	0	1
6	LSIZ2 (land holdings)	1.206	1.623	0	10
7	FEXP1 (attend FFS)	0.275	0.449	0	1
8	FEXP2 (learn from FFS farmers)	0.156	0.364	0	1
9	FEXP3 (learn IPM from non-FFS)	0.110	0.314	0	1
10	FEXP4 (attend field day)	0.156	0.364	0	1
11	FEXP5 (used pamphlets)	0.128	0.336	0	1
12	IPMKNOW (IPM Knowledge Level)	46.385	33.396	0	100

(The variables 7-11 indicate where the farmer received information about IPM and are hereafter referred to as 'information variables.')

RESULTS

Binary-response models are often used in adoption studies where the dependent variable (adoption) has two possible outcomes: adopt or not adopt. In this case, the dependent variable was IPMCAT which represented five levels of adoption from 0% to 100% and so a binary model was not adequate. We chose to use an ordered probit model which allowed us to examine the impacts of independent variables on ordered categories of adoption (see Section 3.3.1 for more details concerning the probit model).

TABLE 4.16 - SUMMARY OF MODEL ITERATIONS

Variables	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	Coefficient	Sig.	Coefficient	Sig.	Coefficient	Sig.	Coefficient	Sig.	Coefficient	Sig.	Coefficient	Sig.
FAGE	-0.0088	(.284)	-0.0091	(.261)	-0.0002	(.981)	0.0039	(.654)	0.0018	(0.842)	-0.0221	(.825)
EDUC	-0.3707	(.104)	-0.4028*	(.094)	-0.3668	(.205)	-0.5016	(.187)	-0.4326	(0.106)	-0.3043	(.319)
FHHS	-0.1176	(.240)	-0.0970	(.327)	-0.2271**	(0.014)	0.1175	(.198)	-0.1310	(0.145)	-0.2753**	(.019)
HHOLDb	-0.0285	(.756)	-0.0208	(.814)	0.0449	(.619)	-0.0702	(.469)	0.0070	(0.937)	0.0544	(.563)
LSIZ2	0.0883	(.407)	0.1127	(.291)	0.0234	(.837)	-0.0206	(.806)	-0.0128	(0.912)	0.0555	(.633)
FHEAL			0.4860*	(.078)	0.4019	(.146)	0.0905	(.742)	0.1354	(0.612)	0.5517*	(.073)
FEXP1					2.041***	(0.00)					3.239**	(.021)
FEXP2					1.005**	(.016)					1.431**	(.032)
FEXP3					0.507	(.245)					0.7983	(.141)
FEXP4					1.521***	(0.00)					2.143***	(.009)
FEXP5					0.9849**	(.016)					1.514**	(.044)
IPMKNOW							.0384***	(0.00)				
predknow									0.5204***	(0.000)	-0.3540	(.374)
Wald chi2	6.86 (.2315)		9.67 (.1395)		74.60 (0.00)		73.53 (0.00)		55.6 (0.00)		76.61 (0.00)	
Pseudo R2	0.0309		0.0422		0.1534		0.2991		0.1308		0.1561	

n=109

*Indicates significance at the 10% level

**Indicates significance at the 5% level

***Indicates significance at the 1% level

Table 4.16 summarizes the process of developing and fine-tuning the ordered probit regression model. Coefficients show whether each variable has a positive or negative impact on adoption. In Model 1, we evaluate only the effects of farmer characteristics on adoption. There are no significant variables in this model. Model 2 adds a variable for farmers who have been ill from pesticides in the prior year. This variable, FHEAL, is significant and shows that farmers who had pesticide-related illnesses adopt more IPM. The only other significant variable is education. The education variable represents whether or not the respondent had attended secondary school. This variable has a negative impact on adoption. Recall that 12% of respondents had a secondary school education, while the majority had only attended primary school. Other household variables (household size, labor availability, and land) did not show any significant impact on adoption.

In Model 3 we look at the role of information in determining adoption. This model is identical to Model 2, but adds 5 information variables. In this model, the effects of education and farmer health are overpowered by impacts from information. Household size is significant at the 5% level with larger households adopting less IPM.[10] Four of five information variables are significant. FFS has the strongest impact followed by field days, exposure to other farmers, and pamphlets.

Model 4 adds the impact of IPM knowledge. This variable was added separately from information so that we could evaluate whether knowledge has an effect apart from information sources. In this model, knowledge is the only significant variable, though the coefficient is relatively small. We realize, however, that IPMKNOW (IPM knowledge) and IPM adoption are jointly determined by information sources. In order to account for this problem, we created a new knowledge variable "predknow."[11] This variable takes into account the effects of information on knowledge and allows us to simultaneously examine the impacts of information and knowledge on adoption (see Models 5 and 6).

In Model 5, we observe that the predicted knowledge variable is strongly significant when information variables are not included. However, when we add the information variables, "predknow" loses its significance (Model 6). While knowledge is an important factor, *how* farmers receive knowledge (through FFS, field days, exposure to farmers or pamphlets) has the most significant effect on adoption. Since knowledge does not impact adoption apart from the effects of information sources, we can remove the knowledge variable and focus on Model 3.

Probit model coefficients provide information concerning direction of impact (positive or negative), but do not tell the magnitude of the impacts on the level of adoption. Using Model 3, we did marginal analysis to compare the relative effects of information dissemination methods.

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[10] Household size did not distinguish between ages of household members. The variable HHOLDb was used to look at household members over age 14 to evaluate labor availability and its affect on adoption. Since the age 14 was chosen arbitrarily, sensitivity analysis was used to look at other ages, but the variable remained insignificant.

[11] The variable "predknow" is created by using an oprobit model that determined the effects of information sources on 5 categories of IPM knowledge. Using predicted probabilities, we factored in these information impacts to create the new knowledge variable.

Marginal effects of the variables were obtained separately for each category of adoption intensity. Table 4.17 summarizes the findings for the two highest categories of adoption (Appendix B contains marginal analysis for all adoption categories). The numbers measure the magnitude of impact on the probability of adoption for a one unit change in the variable.

TABLE 4.17 - MARGINAL EFFECTS OF SIGNIFICANT VARIABLES ON ADOPTION RATES

Information Source	Degree of Adoption	
	Category IV (50-75%)	Category V (75-100%)
FEXP1 (attend FFS)	27.1* (0.000)	41.5* (0.000)
FEXP2 (learn from FFS farmers)	21.1* (0.000)	17.4* (0.114)
FEXP4 (attend field day)	21.7* (0.001)	32.4* (0.009)
FEXP5 (used pamphlets)	20.2* (0.000)	17.4* (0.104)
FHHS (household size)	-6.4* (0.023)	-2.3* (0.024)

*Numbers represent the percent increase in the probability of adopting at the Category IV and V rates
Numbers in parenthesis show significance levels
(FEXP3 omitted because of lack of statistical significance in the model)

For adoption rates between 50 and 75% each additional household member decreased the probability of adoption by 6.4%. At the 75%-100% adoption level, the impact was much less at 2.3%. Of the information variables, FEXP1 (FFS participation) had the strongest impact on Category IV and V adoption rates. Attending FFS increased the probability of adopting at the highest level by 41.5%. At the 50%-75% level, FFS increased the probability by 27.1%. Field days had the second highest impacts on adoption (32.4% and 21.7% increases). Marginal impact on Category V adoption was not significant for exposure to FFS-participants and use of pamphlets. For Category IV adoption, exposure to FFS participants and pamphlets had similar impacts on adoption as field days (21.1% and 20.2% respectively).

Using the marginal analysis from the ordered probit model and cost data we can evaluate the relative cost-effectiveness of information dissemination methods. Estimated costs are $30/farmer for FFS, $1.50/farmer for field days and $.50/farmer for a pamphlet. If we only consider marginal effects on adoption, we find that although FFSs are 20 times the cost of field days, they have only about 1.25 times the impact (see Table 4.18). We can compare the relative cost-effectiveness of pamphlets and FFSs in a similar manner and find again that pamphlets have more effect considering their low costs. If we take into account diffusion between farmers, (assuming there is no overlap in terms of which farmers are receiving information), we see that the cost differential between FFS, field days, and pamphlets is reduced since FFS participants share information to the most farmers. Another relevant factor is the number of field days the average farmer attends or whether a farmer is using several dissemination methods simultaneously. From Table 4.2, we saw that farmers exposed to FFS participants were more likely to attend field days and read pamphlets. These factors make it difficult to quantify effects on adoption and do an accurate cost analysis. To be able to calculate to do this analysis, further research is necessary. However, we can see that other methods (i.e. field days and pamphlets) appear to be equally or more cost-effective than FFSs

TABLE 4.18 - RELATIVE COST-EFFECTIVENESS OF INFORMATION DISSEMINATION METHODS

	FEXP1	FEXP4	FEXP5	Cost Ratios		Relative Impacts	
	(Attend FFS)	(field days)	(pamphlets)	FFS/field days	FFS/pamphlets	FFS/field days	FFS/pamphlets
Implementation Costs (per farmer)	$30	$1.50	$0.50	20:1	60:1		
Farmer-to-farmer diffusion							
(On average, no. of other farmers they shared IPM information with)	11	2.7	0.33				
Marginal Effects on Adoption							
Category IV (51-75% Adoption)	27.1	21.7	20.2			1.25:1	1.34:1
Category V (76-100% Adoption)	41.5	32.4	not sig.			1.28:1	
Taking into account diffusion (Cost/Total no. of farmers affected)	($30/12) $2.50	($1.50/2.7) $0.56	($.50/.33) $1.52	4.46:1	1.64:1		

4.3 Summary

We have established that FFSs, field days, and pamphlets are effective mechanisms for transferring information to farmers and promoting adoption. Field days and pamphlets are relatively inexpensive and effectively impact farmer knowledge and adoption of IPM. FFSs are expensive, but have some distinct benefits. FFSs seem to have the most influence on farmer knowledge of pests and pest management practices. They are most likely to use safe handling practices and also share information most readily with other farmers. In addition, FFS-farmers participate in field experiments that compare IPM to conventional methods throughout the entire crop cycle. With the combination of first-hand experience and general knowledge about IPM, FFS-participants have a more complete perspective than other farmers. Farmers exposed to FFS-participants often go on to learn more about IPM through other dissemination methods. It is safe to say that each of these dissemination mechanisms has a role to play in increasing farmer knowledge and promoting adoption. An approach that integrates all of these mechanisms would be recommended.

Chapter 5 - Discussion

In the previous chapter, the data were analyzed and results were given. In this chapter, the results are further synthesized and discussed in order to make conclusive remarks and suggestions for the direction of future research. Section 5.1 sums up the findings. Section 5.2 discusses the problems or limiting factors with the design and implementation of the study. Section 5.3 wraps up the study and discusses implications and recommendations for future research.

5.1 Summary of the Results

This study had several key objectives. We evaluated how IPM technologies are spread among potato farmers in a region of northern Ecuador. We attempted to understand how farmers learn about pest control and IPM and the cost-effectiveness of the FFSs relative to other disseminations methods. We also looked at the extent of IPM use in that region and the determinants and constraints of adoption. We attempted to answer these questions based on survey responses from 109 potato farmers in Carchi, Ecuador.

Looking briefly at the current spread of IPM in Carchi, there are marked differences between the three farmer groups. In the control group ('Other'), about 40% of farmers were not using any IPM. Of the FFS participants and the 'Exposed' farmers, only 3-4% did not use any IPM. Average adoption rates were as follows: FFS participants adopted 58.4%, 'Exposed' farmers adopted 41.4% and the control group adopted 22% (see Table 4.10). These differences were attributed to differences in exposure to information and consequent levels of knowledge concerning IPM techniques.

IPM technologies are spread in several ways. Farmers are educated through FFSs or field days, exposed to information via interaction with other farmers, or obtain and read pamphlets (written materials). These information sources have a positive effect on farmer knowledge of IPM. FFSs had the greatest impact on high knowledge scores, followed by field days, pamphlets, and exposure to FFS-participants. Exposure to non-FFS participants had the least effect on farmer knowledge.

Knowledge is critical for successful implementation of IPM technologies which can be complex depending on the practice. According to the statistical model, the source of information jointly determines knowledge and adoption rates. Certain information sources have more effect on adoption than others. Participants from FFSs had the highest adoption rates, followed again by field days, pamphlets, and exposure to FFS-participants.

According to the model, farmer characteristics (socio-economic factors) did not play a significant role in affecting adoption rates. Apart from information effects, the only other significant variable in the model was household size where larger households adopted less IPM. Lack of effects from household variables may be due to limitations in the survey sample (see Section 5.2).

The variable land holdings was included in the model to evaluate whether there was a relationship between income level and adoption. Although the variable was not significant, there is evidence that capital or income may be a constraint for adopters. In Chapter 4, we looked at technology attributes of specific IPM activities and the patterns of adoption. We found that activities perceived as risky and/or were capital-intensive, were adopted least in all farmer groups. These activities included buying quality seed, resistant varieties, irrigation, use of recommended storage, and use of fungicides with different active ingredients. In addition, most farmers claimed that an increase in pesticide prices or potato prices would cause them to use more IPM. Future studies should look more closely at the role of income and wealth in adoption.

Marginal effects and cost data were used to determine the relative cost-effectiveness of information dissemination mechanisms. In terms of quality of information, FFS participants have the most thorough understanding of IPM and the highest adoption rates. Particularly concerning pesticide safety, FFSs have had the most effect on farmers in terms of safe pesticide handling. However, it is possible to improve the quality of information presented through field days and pamphlets. Factoring in costs, field days and pamphlets are possibly more cost-effective as diffusion mechanisms. Although these farmers have slightly lower knowledge scores and adoption rates, the benefits are high relative to the costs of implementation. FFS cost 20 times as much as a field days and 60 times as much as a pamphlet. They provide valuable information but only a small percentage of farmers can attend the limited number of schools. Through exposure to FFS participants, other farmers choose to learn about IPM through field days and pamphlets. By combining these information diffusion mechanisms (FFS, field days, farmer interactions and pamphlets), large populations of farmers are able to access important IPM messages. Based on our survey results, we expect that access to information will lead to higher rates of adoption.

5.2 Limitations

The validity of model results is dependent on quality of survey design, data collection, and accuracy of farmer responses. There were several concerns about the design and implementation of the farmer survey. Problems with this survey included: limited sample size (109 farmers), non-random sample selection, potential bias in data collection and lack of data in some areas.

Two considerable limitations in the survey were sample size and non-random sample selection. The sample was not an accurate representation of the Carchi population of potato farmers. In particular, nearly a third of the sample attended FFS. There is an inherent bias in the selection of FFS participants since they are chosen based on specific farmer characteristics (interest in IPM, desire to share information, and innovativeness). A large random sample of farmers would enable us to look more closely at household demographics, economic factors, access to information and farmer perceptions.

In this survey, there was a need for more accurate data on incomes, land holdings, consumer preferences, labor availability, farmer perceptions, motivations for use of IPM, and a more thorough understanding of how farmers obtained information about IPM. Not all survey questions were effective in soliciting clear responses from farmers. For example, some farmers use IPM techniques (including insect traps, resistant varieties and cultural techniques), but they do not necessarily identify them as IPM. This makes it difficult to know how they obtained their knowledge. Concerning sources of IPM knowledge, farmers were only able to give one response when, in reality they may have received IPM information from multiple sources. It would be useful to pre-test questions and evaluate them for potentially biased or unclear responses. Future survey work should also explore farmer-to-farmer diffusion and whether it occurs only in casual contexts or via farmer organizations. Location of FFSs may also play a role in how information is diffused as participants are more likely to interact with other farmers within their communities. It would be helpful to understand these networks so that farmers (in FFSs, for example) could be prompted to diffuse information more effectively. In addition, field days should focus some attention on communities that have been thus far under-exposed to IPM.

Given these various concerns about the quality and size of the data set, further investigations and survey work are necessary to supplement the results of this study.

5.3 Recommendations and Implications for the Direction of Future Research

One of the goals of this study was to determine if current methods of information dissemination are effective and what kind of improvements can be made. FFS are expensive relative to other means of transferring IPM information to farmers. However, FFSs are a valuable tool for providing information to farmers. This study supports continuation of the FFS program to be used in conjunction with other information diffusion methods. Therefore, we look towards ways of improving the current program.

There are two main concerns with the FFS approach. The problems included: 1)Program costs and 2)Bias towards particular groups of farmers. Thiele (2001) and Feder (2004) give some suggestions based on experiences with FFSs programs in other countries. Feder suggests that FFSs can lower program costs by limiting the number of sessions and using better quality trainers to focus on the most significant IPM messages. However, in Ecuador, because the IPM message for potatoes is complex, one must be careful not to oversimplify the message. A more feasible approach may be, as Thiele suggests, that added profitability from adoption of IPM would enable farmers to contribute to the expense of running the FFS programs. Participants could even be trained as facilitators to lead field days and improve the flow of information from FFS to non-FFS farmers. Whether or not farmers would be receptive to these changes would have to be explored. Owens and Simpson refer to a FFS program in Tanzania that was able to finance itself and another program in Ghana which reduced their costs to $8-10/ farmer by using a decentralized approach. It is possible that some of these recommendations could be incorporated into the FFS program in Ecuador. Further investigations are necessary to determine actual feasibility.

The other concern with FFSs is that there is a bias towards more literate and wealthy farmers, encouraging an education and income gap. Less motivated and illiterate farmers will continue to know very little about IPM while motivated and literate farmers will learn and adopt these technologies. Consequently, it is important to have other means of transferring information to farmers who are not likely to attend these schools. Information dissemination mechanisms can supplement each other to reach a larger and more diverse population of farmers.

CLOSING COMMENTS

If cost per farmer were reduced significantly, it would be tempting to increase the number of FFSs in Carchi. However, even if funding were not an issue, there are reasons to exercise caution in efforts to up-scale current programs. Studies have found that FFS programs are problematic because of inherent biases toward literate and wealthier farmers. In addition, Feder (2004) found that quality of FFSs tend to diminish with large up-scaling. Not to say that no additional FFSs should be built. FFSs should be strategically dispersed throughout the region. Analysis needs to be done to identify communities that have not been exposed to IPM and evaluate what is the best approach for that area.

Although FFSs are useful for educating farmers, it works well to supplement FFS education with other dissemination strategies. It is important to improve diffusion from FFS-participants to non-participants so that a diverse farmer population is reached. In terms of cost-effectiveness, field days and pamphlets seem to be equally if not more cost-effective, can educate large populations of farmers and significantly impact knowledge and adoption rates.

Site-specific studies are necessary in order to understand particular circumstances including: crop characteristics, severity of pest problems, current use of pesticides, flexibility and adequacy of IPM packages and the availability of labor and capital. Care should be taken in the study design and implementation of surveys. This study is most useful as a resource for continued research on IPM in Ecuador. Future work can build on these findings; testing and refining the methods of disseminating information and improving the potential for IPM adoption in Ecuador.

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Appendix A

FARMER SURVEY

INIAP–IPMCRSP
MODULO 1: CONDICIONES SOCIO-ECONÓMICAS
Respuesta de agricultores entrevistados en Octubre 2003

V0. Número de encuesta (numérico)

V1. Nombre (carácter)

V2. Edad en años (numérico)

V3. Sexo (carácter):

1= Masculino
2= Femenino

V4. Estado Civil (carácter):

1= Soltero
2= Casado
3= Separado
4= Divorciado
5= Viudo

V5. Educación (carácter):

1= Sin educación
2= Alfabetización
3= Pre-primaria
4= Primaria
5= Secundaria
6= Superior
7= Otra (especifique)

V6. ¿Número de años que Usted ha trabajado como agricultor?(numérica)

V7. Tenencia de la tierra (carácter):

1= Propiedad con título
2= Propiedad sin título
3= Arriendo
4= Cedido, prestado
5= Al partir
6= Propiedad con título y al partir

V8. Tiempo que le toma (en minutos) para viajar de la casa a la finca (numérica)

V9. Tiempo que le toma (en minutos) para viajar de la casa a la oficina de extensión agrícola más cercana (numérica)

V10. Tiempo que le toma (en minutos) para viajar de la casa al mercado donde vende sus papas (numérica)

V11. Tamaño de la propiedad en hectáreas (numérica)

V12. Número de hectáreas con cultivo de papa (numérica)

V13. Durante cuántos años ha estado cultivando papa (numérica)

V14. Ingreso anual total en dólares que su familia recibe de los recursos de la finca (numérica)

V15. Ingreso anual total en dólares que su familia recibe de otras fuentes (numérica)

V16. ¿Usted o cualquiera de sus empleados ha tenido problemas de salud durante el último año como resultado del uso de pesticidas? (carácter)

1= Si
2= No

V17. ¿Cuántos días de trabajo ha perdido durante el último año como resultado de la enfermedad causada por los pesticidas? (numérica)

V18. ¿Cómo escuchó hablar Usted acerca del MIP?

1= No ha escuchado hablar del MIP
2= Participó en las ECAs
3= Día de campo
4= Cursos, talleres,
5= Radio
6= Noticias
7= De otros agricultores (no-ECA)
8= De otros agricultores (ECA)
9= Otras (especifique)

V19. ¿La disponibilidad de mano de obra es un problema para implementar el MIP? (carácter)

1= Si
2= No

V20. ¿Cuántos miembros de la familia trabajan en la finca (no se incluya Usted)? (numérica)

V21. ¿Usted, durante cuántos años ha estado implementando el MIP? (numérica)

V22. ¿De las siguientes respuestas, indique cuál han influido en Usted para el uso del MIP? (carácter)

Anote en orden de importancia: 1= muy importante….10= no importante.

V22.1= Motivos de salud _____
V22. 2= Motivos ambientales _____
V22. 3= Rentabilidad _____
V22. 4= Preferencia del consumidor _____
V22. 5= Mejor control de enfermedades _____
V22. 6= Otras (especifique) _____

V23. ¿Cree Usted que el MIP es más aprovechable que otros métodos? (carácter)

1= Si
2= No

V24. ¿Si el precio de las papas aumentara 20%, sería probable que Usted aplicara más MIP? (carácter)

1= Si
2= No

V25. ¿Si el precio de los pesticidas aumentara 20%, sería probable que Usted aplicara más MIP? (carácter)

1= Si
2= No

V26. ¿Le gusta la calidad de las variedades de papa con resistencia al tizón tardío o lancha? (carácter)

1= Si
2= No

INIAP–IPMCRSP

MODULO 2: COMPOSICIÓN FAMILIAR
Respuesta de agricultores entrevistados en Octubre 2003

V0. Número de encuesta (numérica)

V1. Parentesco (carácter)

1=	Jefe/a	2=	Esposo/a	3=	Hijo
4=	Hija	5=	Yerno	6=	Nuera
7=	Nieto	8=	Nieta	9=	Padres/suegros
10=	Hermano/a	11=	Sobrino	12=	Sobrina
13=	Abuelos	14=	Tío/a		

V2. Sexo (carácter)

1= Hombre
2= Mujer

V3= Edad en años (numérica)

En caso de menor de un año, poner 0

V4. Nivel educativo (carácter)

1= Ninguno	2= Alfabetización	7= No aplica < 5 años
3= Pre – primaria	4= Primaria	
5= Secundaria	6= Superior	

V5. Toma de decisiones (carácter)

1= Si
2= No

LISTADO DE RESPUESTAS DEL ESTUDIO DE IMPACTOS PARA PARTICIPANTES DE ECAS EN PAPA DE CARCHI

BASE DE DATOS: ARCHIVO "MODULO1.DBF"

SUPERFICIE Y PRODUCCIÓN DEL CULTIVO DE PAPA

V0= Número de encuesta (numérica)

V1= Nombre de la ECA (carácter)

1= San Francisco 2000
2= Santa Martha de Cuba 2000
3= San Pedro 2000
4= Santa Martha de Cuba 2001
5= San Pedro 2001
6= San Francisco 2001
7= Pioter
8= San Isidro
9= Monteverde
10= Shanshipamba
11= Yuracruz
12= Fernández Salvador
13= Pueblo viejo
14= San Francisco 2002
15= San Pedro 2002
16= Colegio Santa Martha de Cuba 2002
17= Eloy Alfaro
18= Las Lajas
19= El Rosal
20= Minas

V2= Superficie Total del predio en ha (numérica)

V3= Variedad de papa cultivada (carácter)

1= Superchola
2= INIAP-Fripapa
3= Capiro
4= Chaquira
5= Uva
6= Papa INIAP-PAN
7= Esperanza
8= Maria
9= Roja
10= Gabriela

11= Sabanera

V4= Superficie cultivada de papa en ha (numérica)

V5= Cantidad de semilla utilizada en la siembra kg (numérica)

V6= Cantidad semilla guardada en kg (numérica)

V7= Cantidad gruesa vendida en kg (numérica)

V8= Precio del Kg de gruesa en $(numérica)

V9= Subtotal venta de gruesa en $(numérica)

V10= Cantidad segunda vendida en kg (numérica)

V11= Precio del Kg de segunda en $(numérica)

V12= Subtotal venta de segunda en $(numérica)

V13= Cantidad de cuchi vendida en kg (numérica)

V14= Precio del Kg de cuchi en $(numérica)

V15= Subtotal venta de cuchi en $(numérica)

V16= Producción total cosechada en kg (numérica)

V17= Total venta en $ del lote (numérica)

V18= Costo Total por semilla en $

LISTADO DE RESPUESTAS DEL ESTUDIO DE IMPACTOS PARA PARTICIPANTES DE ECAS EN PAPA DE CARCHI

BASE DE DATOS: ARCHIVO "MODULO2DBF"

PROCESO TECNOLÓGICO DEL CULTIVO DE PAPA

V0= Número de encuesta (numérica)

V1= Nombre de la ECA (carácter)

1= San Francisco 2000
2= Santa Martha de Cuba 2000
3= San Pedro 2000
4= Santa Martha de Cuba 2001
5= San Pedro 2001
6= San Francisco 2001
7= Pioter
8= San Isidro
9= Monteverde
10= Shanshipamba
11= Yuracruz
12= Fernández Salvador
13= Pueblo viejo
14= San Francisco 2002
15= San Pedro 2002
16= Santa Martha de Cuba 2002
17= Eloy Alfaro
18= Las Lajas
19= El Rosal
20= Minas

V2= Preparación de terreno(carácter)

1= Tractor
2= Jornal
3= Yunta

V3= Días que utilizo para arar (numérica)

V4= Costo unitario por día de arado en $(numérica)

V5= Subtotal por arado en $(numérica)

V6= Días que utilizo para rastra (numérica)

V7= **Costo unitario por día de rastra en $(numérica)**

V8= **Subtotal por rastra en $(numérica)**

V9= **Número de jornales utilizados en la melga (numérica)**

V10= **Costo unitario de jornal en $ (numérica)**

V11= **Subtotal de melga en $(numérica)**

V12= **Número de jornales utilizados en la surcada (numérica)**

V13= **Subtotal de surcado en $(numérica)**

V14= **Numero de trampas para gusano blanco (numérica)**

V15= **Costo por trampa para gusano blanco en $(numérica)**

V16= **Numero de jornales para colocar trampas de gusano blanco (numérica)**

V17= **Subtotal por trampeo de gusano blanco en $(numérica)**

V18= **Total preparación de terreno en $(numérica)**

V19= **Cantidad en kg de semilla (numérica)**

V20= **Uso de silo verdeador en $ (numérica)**

V21= **Precio por Kg de semilla en $(numérica)**

V22= **Jornales utilizados para la siembra (numérica)**

V23= **Valor ciclo del terreno en $(numérica)**

V24= **Total siembra en $(numérica)**

V25= **Tipo de fertilizante (carácter)**

1= 10-30-10
2= 18-46-0 + 8-20-20
3= 8-20-20 + 15-15-15
4= 18-46-0 + 10-30-10 + 8-20-20
5= 18-46-0 + 15-15-15 + 0-0-60
6= 18-46-0
7= 18-46-0 + 8-20-20 + 0-0-60 + 46-0-00
8= 18-46-0 + 10-30-10 + 15-15-15 + 46-0-00

9= 18-46-0 + 10-20-20 + 13-26-06 + Fertisamag + 8-20-20 +15-15-15
10= 18-46-0 + 8-20-20 + Fertisamag

V26= Cantidad de fertilizante en kg (numérica)

V27= Costo unitario por kg de fertilizante(numérica)

V28= Jornales utilizados para la fertilización (numérica)

V29= Transporte de insumos en $(numérica)

V30= Total de fertilización en $(numérica)

V31= Jornales utilizados en el retape (numérica)

V32= Jornales utilizados en el medio aporque (numérica)

V33= Jornales utilizados en el aporque (numérica)

V34= Total labores culturales en $(numérica)

V35= Sacos para la cosecha (numérica)

V36= Costo unitario de saco en $(numérica)

V37= Costo por piola en $(numérica)

V38= Jornales para la cosecha (numérica)

V39= Transporte de producto al mercado en $(numérica)

V40= Total cosecha en $(numérica)

V41= Total costo de producción en $(numérica)

V49= Época del cultivo (carácter)

1= Invierno
2= Verano

LISTADO DE RESPUESTAS DEL ESTUDIO DE IMPACTOS PARA PARTICIPANTES DE ECAS EN PAPA DE CARCHI

BASE DE DATOS: ARCHIVO "MODULO3.DBF" CONTROLES FITOSANITARIOS

V0= Número de encuesta (numérica)

V1= Nombre de la ECA (carácter)

1= San Francisco 2000
2= Santa Martha de Cuba 2000
3= San Pedro 2000
4= Santa Martha de Cuba 2001
5= San Pedro 2001
6= San Francisco 2001
7= Pioter
8= San Isidro
9= Monteverde
10= Shanshipamba
11= Yuracruz
12= Fernández Salvador
13= Pueblo viejo
14= San Francisco 2002
15= San Pedro 2002
16= Santa Martha de Cuba 2002
17= Eloy Alfaro
18= Las Lajas
19= El Rosal
20= Minas

V2= Número de control fitosanitario (carácter)

V3= Clase de producto (carácter)

1= Insecticida
2= Fungicida
3= Fertilizante foliar
4= Herbicida
5= Fijador
6= Bio estimulante
7= Regulador pH

V4= Nombre comercial del producto (carácter)

V5= Nombre del ingrediente activo del producto (carácter)

V6= **Cantidad de i.a. en kg (numérica)**

V7= **Costo unitario $/kg (numérica)**

V8= **Costo total de pesticidas en $ (numérica)**

V9= **Superficie del lote ha (numérica)**

V10= **Número Total de jornales (numérica)**

V11= **Costo por jornal día en $ (numérica)**

V12= **Costo total de pesticidas mas mano de obra $ (numérica)**

LISTADO DE RESPUESTAS DEL ESTUDIO DE IMPACTOS PARA PARTICIPANTES DE ECAS EN PAPA DE CARCHI

BASE DE DATOS: ARCHIVO "MODULO4.DBF"
CONOCIMIENTO DEL MIP

V0= Número de encuesta (numérica)

V1= Nombre de la ECA (carácter)

1= San Francisco 2000
2= Santa Martha de Cuba 2000
3= San Pedro 2000
4= Santa Martha de Cuba 2001
5= San Pedro 2001
6= San Francisco 2001
7= Pioter
8= San Isidro
9= Monteverde
10= Shanshipamba
11= Yuracruz
12= Fernández Salvador
13= Pueblo viejo
14= San Francisco 2002
15= San Pedro 2002
16= Santa Martha de Cuba 2002
17= Eloy Alfaro
18= Las Lajas
19= El Rosal
20= Minas

V2= Beneficios de las ECA´s (carácter) (Different than NO ECA survey)

0= No observan beneficios
1= Controla gusano blanco
2= Bajar costos y disminuye uso de químicos
3= Conocimientos sobre uso de químicos
4= Mejor sabor de la papa
5= No se desgasta el suelo
6= No se mata insectos benéficos

V3= Problemas del MIP (carácter)

0= No existen problemas
1= No controla bien las plagas
2= Variedades nuevas susceptibles

3= Es muy laborioso
4= Falta difusión a otros agricultores
5= Disminuye producción
6= Técnicos no conocen sobre el tema

V4= Seguirá utilizando el MIP (carácter)

1= sí
2= no

V5= Porque seguirá utilizando (carácter)

0= No responde
1= Buenos resultados y disminuye uso de químicos
2= Beneficios buenos

V6= Porque no utilizara (carácter)

0= No responde
1= No hay resultados

V7= La capacitación recibida en MIP ha sido suficiente (carácter)

1= sí
2= no

V8= Temas en que desearía capacitarse (carácter)

0= No aplica
1= Manejo orgánico
2= Mas capacitación
3= Semilla de calidad
4= Análisis de suelos

V9= Ha enseñado a otras personas sobre MIP (carácter)

1= sí
2= no

V10= A cuantas personas ha enseñado (numérica)

V11= Razones porque no ha enseñado sobre MIP (carácter)

0= No aplica
1= No dispone de tiempo

LISTADO DE RESPUESTAS DEL ESTUDIO DE IMPACTOS PARA PARTICIPANTES DE ECAS EN PAPA DE CARCHI

BASE DE DATOS: ARCHIVO "MODULO5.DBF" CONOCIMIENTO Y UTILIZACIÓN DEL MIP

V0= Número de encuesta (numérica)

V1= Nombre de la ECA (carácter)

1= San Francisco 2000
2= Santa Martha de Cuba 2000
3= San Pedro 2000
4= Santa Martha de Cuba 2001
5= San Pedro 2001
6= San Francisco 2001
7= Pioter
8= San Isidro
9= Monteverde
10= Shanshipamba
11= Yuracruz
12= Fernández Salvador
13= Pueblo viejo
14= San Francisco 2002
15= San Pedro 2002
16= Santa Martha de Cuba 2002
17= Eloy Alfaro
18= Las Lajas
19= El Rosal
20= Minas

V2= Conoce sobre el ciclo de vida del gusano blanco (carácter)

1= sí
2= no

V3= Conoce el estado de la plaga en que se lo puede controlar (carácter)

1= sí
2= no

V4= Utiliza el estado de la plaga en que se lo puede controlar (carácter)

1= sí
2= no

V5= **Conoce las trampas para control de gusano blanco (carácter)**

1= sí
2= no

V6= **Utiliza las trampas para control (carácter)**

1= sí
2= no

V7= **Conoce las trampas cebo para el control de gusano blanco (carácter)**

1= sí
2= no

V8= **Utiliza las trampas cebo para el control de gusano blanco (carácter)**

1= sí
2= no

V9= **Conoce sobre la eliminación de residuos de cosechas anteriores (carácter)**

1= sí
2= no

V10= **Utiliza la eliminación de residuos de cosechas anteriores (carácter)**

1= sí
2= no

V11= **Conoce la aplicación de insecticidas en forma dirigida (carácter)**

1= sí
2= no

V12= **Utiliza la aplicación de insecticidas en forma dirigida (carácter)**

1= sí
2= no

V13= **Conoce los silos verdeadores de semilla (carácter)**

1= sí
2= no

V14= **Utiliza los silos verdeadores de semilla (carácter)**

1= sí
2= no

V15= Conoce la desinfección de semilla con insecticidas (carácter)

1= sí
2= no

V16= Utiliza la desinfección de semilla con insecticidas (carácter)

1= sí
2= no

V17= Conoce sobre semillas de calidad (carácter)

1= sí
2= no

V18= Utiliza semilla de calidad (carácter)

1= sí
2= no

V19= Conoce el ciclo de vida de la polilla (carácter)

1= sí
2= no

V20= Conoce el estado de la plaga en que se lo puede controlar (carácter)

1= sí
2= no

V21= Conoce las trampas de feromona (carácter)

1= sí
2= no

V22= Utiliza las trampas de feromona (carácter)

1= sí
2= no

V23= Conoce los aporques altos (carácter)

1= sí
2= no

V24= Utiliza los aporques altos (carácter)

1= sí
2= no

V25= Conoce la rotación de cultivos (carácter)

1= sí
2= no

V26= Utiliza la rotación de cultivos (carácter)

1= sí
2= no

V27= Conoce la cosecha temprana para control de polilla (carácter)

1= sí
2= no

V28= Utiliza la cosecha temprana para control de polilla (carácter)

1= sí
2= no

V29= Conoce el riego por aspersión para en control de polilla (carácter)

1= sí
2= no

V30= Utiliza el riego por aspersión para en control de polilla (carácter)

1= sí
2= no

V31= Conoce el ciclo de vida de la mosca minadora (carácter)

1= sí
2= no

V32= Conoce el estado de la mosca minadora en que se la puede controlar (carácter)

1= sí
2= no

V33= Conoce las trampas amarillas fijas (carácter)

1= sí
2= no

V34= Utiliza las trampas amarillas fijas (carácter)

1= sí
2= no

V35= Conoce las trampas móviles (carácter)

1= sí
2= no

V36= Utiliza las trampas móviles (carácter)

1= sí
2= no

V37= Conoce los signos de presencia de lancha (carácter)

1= sí
2= no

V38= Conoce la agresividad de la lancha (carácter)

1= sí
2= no

V39= Conoce el porcentaje de ataque en que se debe controlar la lancha (carácter)

1= sí
2= no

V40= Conoce variedades resistentes para la lancha (carácter)

1= sí
2= no

V41= Utiliza variedades resistentes a la lancha (carácter)

1= sí
2= no

V42= Conoce los ingredientes activos de los funguicidas (carácter)

1= sí
2= no

V43= Utiliza funguicidas con ingredientes activos diferentes (carácter)

1= sí
2= no

LISTADO DE RESPUESTAS DEL ESTUDIO DE IMPACTOS PARA PARTICIPANTES DE ECAS EN PAPA DE CARCHI

BASE DE DATOS: ARCHIVO "MODULO6.DBF"
USO DE PRÁCTICAS MIP

V0= Número de encuesta (numérica)

V1= Nombre de la ECA (carácter)

1= San Francisco 2000
2= Santa Martha de Cuba 2000
3= San Pedro 2000
4= Santa Martha de Cuba 2001
5= San Pedro 2001
6= San Francisco 2001
7= Pioter
8= San Isidro
9= Monteverde
10= Shanshipamba
11= Yuracruz
12= Fernández Salvador
13= Pueblo viejo
14= San Francisco 2002
15= San Pedro 2002
16= Santa Martha de Cuba 2002
17= Eloy Alfaro
18= Las Lajas
19= El Rosal
20= Minas

V2= Estado del cultivo en que se deben colocar las trampas para el control de gusano blanco (carácter)

1= antes de la siembre
2= antes de la emergencia

V3= Cada qué tiempo renueva las ramas utilizadas en las trampas (carácter)

1= Semanalmente
2= Quincenalmente
3= Tres semanas

V4= En qué parte de la planta aplica usted los insecticidas, para el control de gusano blanco (carácter)

1= Toda la planta
2= Cuello de la planta

V5= Qué práctica utiliza usted, para el almacenamiento de la semilla (carácter)

1= Silos verdeadores
2= Asolación
3= Ambos
4= Sacos ralos (second best and more common)

V6= En qué casos utiliza sistémicos, para el control de la lancha (carácter)

1= Sistémico para control
2= Sistémico para prevención
3= No conoce

V7= En qué casos utiliza protectantes, para el control de la lancha (carácter)

1= Protectante para prevención
2= Protectante para control
3= No conoce

V8= En qué estado del gusano blanco, se lo debe controlar (carácter)

1= Larva
2= Adulto

V9= En qué estado de la polilla, se lo debe controlar (carácter)

1= Larva
2= Adulto

V10= En qué estado de la mosca minadora, se lo debe controlar (carácter)

1= Larva
2= Adulto

V11= A partir de qué porcentaje de ataque de lancha, se debe efectuar su control (carácter)

1= Menos del 1%
2= Sobre el 1%
3= Sobre el 2%

V12= **Cuando compra los plaguicidas como los solicita en la casa comercial (carácter)**

1= Ingrediente Activo
2= Nombre comercial
3= Por el síntoma

V13= **Qué ha observado, luego de disminuir el uso de los plaguicidas (carácter)**

1= Reducción de costos
2= Mejor control de plagas (it will depend here)
3= Mejora la salud humana

V14= **En cuánto a su salud y de familiares, que ha observado con la disminución de los plaguicidas (carácter)**

1= Han disminuido los dolores de cabeza
2= Presentan un mejor estado de ánimo
3= Trabajan con mayor agilidad
4= 1 y 2
5= No hubo cambios

V15= **Conoce usted sobre el significado del color de las etiquetas de los productos químicos (carácter)**

1= Si
2= No

V16= **Prepara su equipo para aplicar los productos químicos (carácter)**

1= Si
2= No

V17= **Utiliza usted medidas de protección, para la aplicación de plaguicidas (carácter)**

1= Si
2= No

V18= **Utiliza botas para la aplicación (carácter)**

1= Si
2= No

V19= Utiliza mascara para la aplicación (carácter)

1= Si
2= No

V20= Utiliza guantes para la aplicación (carácter)

1= Si
2= No

V21= Utiliza chompa para la aplicación (carácter)

1= Si
2= No

V22= Utiliza gafas para la aplicación (carácter)

1= Si
2= No

V23= Utiliza pantalón para la aplicación (carácter)

1= Si
2= No

V24= Mientras aplica los remedios, usted come, fuma o toma agua (carácter)

1= Si
2= No

V25= En dónde almacena los productos químicos (carácter)

1= Bodega
2= En una caja cerrada
3= Dentro de la casa

V26= Luego de aplicar los remedios, donde lava la bomba de fumigar (carácter)

1= En la casa
2= En el lote
3= En la acequia

V27= Luego de aplicar los remedios, qué hace con los envases utilizados (carácter)

1= Entierra las fundas en el lote
2= Quema las fundas en el lote

Appendix B

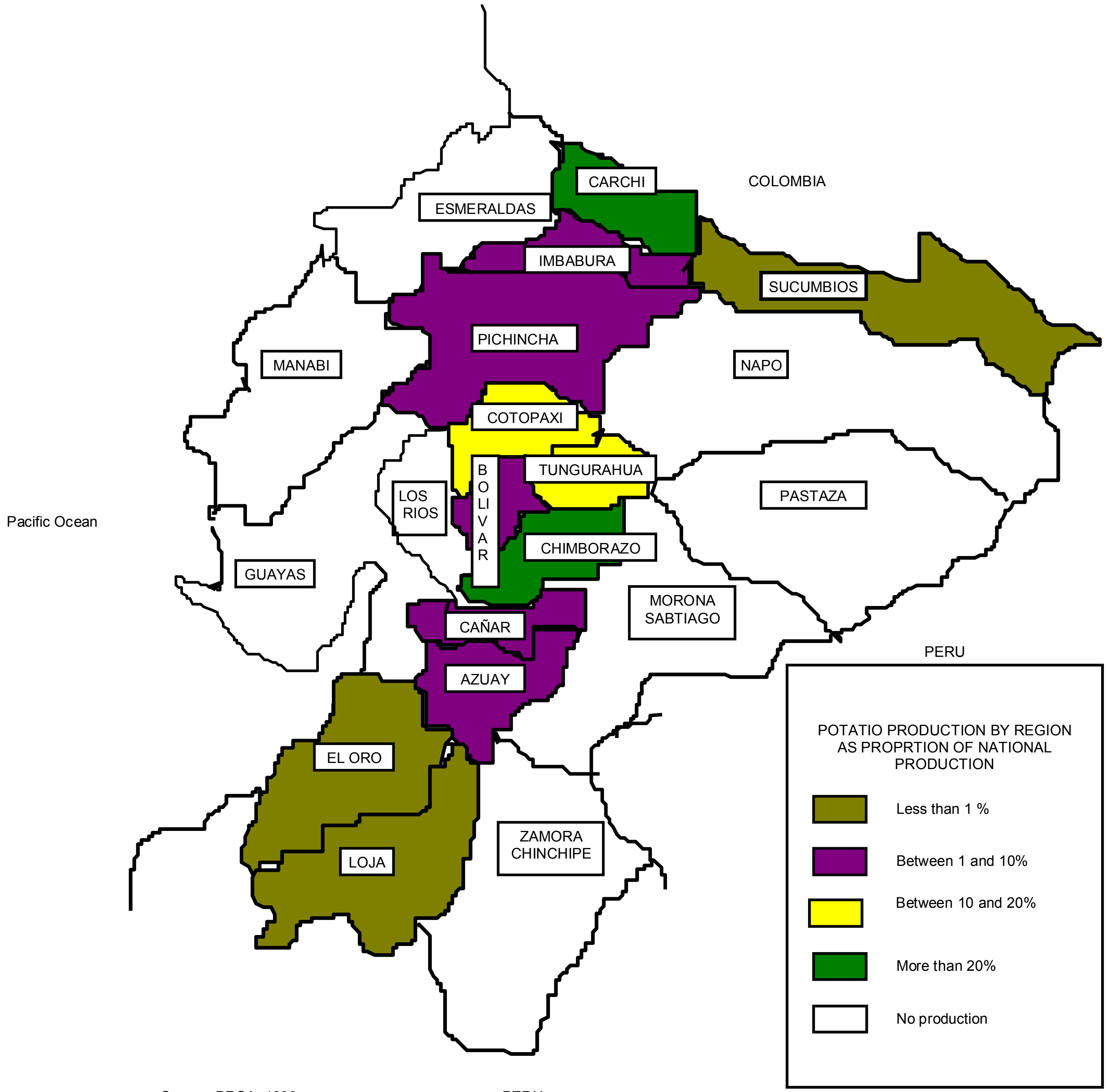
Results from Ordered Probit Model: Marginal Effects

Marginal Effects on Adoption										
	0% Adoption (n=22)		1-25% Adoption (n=19)		26-50% Adoption (n=22)		51-75% Adoption (n=35)		76-100% Adoption (n=11)	
	dy/dx	sig.	dy/dx	sig.	dy/dx	sig.	dy/dx	sig.	dy/dx	sig.
FAGE (farmer age)	0.0000	0.981	0.0000	0.981	0.0000	0.981	-0.0001	0.981	0.0000	0.981
EDUC (education)*	0.0908	0.276	0.0495	0.139	-0.0074	0.682	-0.1306	0.203	-0.0293	0.158
FHHS (household size)	0.0486	0.020	0.0347	0.035	0.0036	0.616	-0.0641	0.023	-0.0228	0.024
HHOLDb (# in household >14)	-0.0096	0.620	-0.0069	0.621	-0.0007	0.721	0.0127	0.619	0.0045	0.623
FHEAL (sick from pesticides)*	-0.0763	0.102	-0.0634	0.176	-0.0170	0.461	0.1084	0.114	0.0482	0.271
LSIZ2 (land holdings)	-0.0050	0.835	-0.0036	0.839	-0.0004	0.855	0.0066	0.837	0.0023	0.839
FEXP1 (attend FFS)*	-0.2849	0.000	-0.2458	0.000	-0.1549	0.000	0.2709	0.000	0.4147	0.000
FEXP2 (learn from FFS farmers)*	-0.1439	0.003	-0.1518	0.015	-0.0883	0.120	0.2105	0.000	0.1734	0.114
FEXP3 (learn IPM from non-FFS)*	-0.0860	0.156	-0.0810	0.252	-0.0323	0.484	0.1292	0.164	0.0701	0.391
FEXP4 (attend field day)*	-0.1815	0.000	-0.2046	0.000	-0.1546	0.003	0.2167	0.001	0.3239	0.009
FEXP5 (used pamphlets)*	-0.1370	0.003	-0.1490	0.013	-0.0906	0.126	0.2025	0.000	0.1741	0.104

* dy/dx is for discrete change of dummy variable from 0 to 1

Appendix C

Potato Production in Ecuador by Region and Province



Source: PRSA, 1996