Potential Economic Benefits from Plantain Integrated Pest Management Adoption: The Case of Coastal Rural Households in Ecuador.

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(Abstract)

This thesis evaluates the potential of Integrated Pest Management (IPM) technologies for plantain to benefit the poor in Ecuador. First, a socioeconomic analysis of plantain producers in the Ecuadorian coast is presented. Second, adoption rates for different size farms are estimated for use of various improved management practices. Projected adoption rates are then used in an economic surplus analysis to estimate potential benefits of IPM technologies. Results indicate that most producer benefits will accrue to medium-scale plantain farmers. However, we find plantain farmers to be in general poor. Adopting farmers increase their demand for labor, benefiting mostly poor rural landless households. Urban consumers and rural poor households also benefit from the induced plantain price reduction resulting from increased production.

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Chapter 1: Background

1.1 Agricultural Development and Poverty

The use of improved agricultural technologies has increased the production and consumption of food around the world. Increases in foodgrain supply resulted from the adoption of modern varieties during the Green Revolution and demonstrated the potential of agricultural technologies to lower poverty (de Janvry and Sadoulet, 2000). However, the multifarious nature of poverty has made it difficult for scientists and policy makers to create pro-poor technologies that will direct most benefits to the poor.

Different views have emerged from studies of the distribution of technological benefits. Some studies find that agricultural technologies have improved conditions in well-endowed environments, while there has been smaller impact under marginal environments where households have poorer socioeconomic conditions (Scobie and Posada, 1978). Some studies have found that poorer households can obtain more benefits from improvements on indigenous crops and non-traditional export commodities (Byerlee, 2000). Others have found that the underlying social and political institutions are the decisive factor of the distribution of technological benefits (Kerr and Kolavalli, 1999). However, technical change is only attained through continuous research and extension investments (Alwang and Siegel, 2003). Ex-ante studies on the potential of agricultural technologies to reduce poverty are imperative to complement such investments (Alwang and Siegel, 2003; de Janvry and Sadoulet, 2000).

Welfare benefits of increased productivity are multidimensional. De Janvry and Sadoulet (2002) do an extensive analysis of the dynamism of technology effects. In general, agricultural incomes improvement has the potential to reduce poverty, increase household food security and reduce inequality in rural areas (de Janvry and Sadoulet, 2002). Nevertheless, when household income is not enhanced by technological progress, poverty can be ameliorated through their effects in household's health, education, community building, and other indirect dimensions (de Janvry and Sadoulet, 2002).

The effects of agricultural technologies are either direct or indirect. Direct effects of technologies "result from increases in incomes of farmers and other indirect uses of innovations produced by the research" (Byerlee, 2000, 435). Increases in crop yields and changes in productivity are direct effects. Production increases for own consumption, higher gross revenues from agricultural sales, and lower production costs are directly affected by agricultural technology.

Studies have found that the direct effects of technological advances in agriculture are important and that results of research can be more successful concentrating on technologies that increase food availability and lower output prices. Nevertheless, the difficulty in measuring direct technological effects originates from the fact that agricultural research benefits hinge on adoption rates, changes in prices, and quantities of agricultural output, which are known with certainty only after the technology is available.

Multiple indirect effects of technology on poverty are possible. Indirect effects refer to impacts on economic agents and the socioeconomic environment not directly caused by adoption. Indirect effects take place through spillins of direct effects in different markets, households and the environment. Examples of indirect effects are:

1. Employment and wage changes caused by increased labor use associated with the use of new technologies.

2. Household income changes caused by labor market changes.

3. Increases in household consumption due to reduced commodity prices.

4. Improvements in household health and environmental quality due to reduced use of agricultural chemicals.

5. Increased access to agricultural inputs due to the effects of technology on input prices.

The extent of indirect effects depends on characteristics of the technology and also on site-specific socioeconomic and environmental characteristics of affected areas. Generally, the broader scope of indirect effects on households complicate their assessment, often due to the absence of necessary data. (Alston, Norton and Pardey, 1995).

1.2 Agricultural Development and Poverty in Ecuador

Agriculture has an important role in Ecuador's economy. The share of the agricultural sector in the nation's GNP was 7.3% in 1995, while in 1999 and 2002 it reached to 9.1% of the total GNP (BCE, 2003a). The agricultural sector employs a large percentage of the economically active population. In 1995, the agricultural sector employed 31% of the total economically active population in the country and 64% in rural areas. Currently the agricultural sector employs 31% of the economically active population (Project SICA/MAG, 2004).

There are three geographical regions in Ecuador: (1) the Sierra (highlands), (2) the Costa (coastal), and (3) the Oriente (easter). Agricultural activities are particularly important for the highlands and coastal regions due to their favorable climate and soil characteristics. Agricultural activities in the highlands include corn, grains, potatoes, flower production and cattle-raising. In the coastal region, warm climate is suited for fruit crops and grains. Banana and cereals are among the most important export crops of the agricultural sector. Rice, coffee and cacao are also important export commodities in the region, and are important for the economy of small and poor households (BCE, 2003a; World Bank, 2003a).

Although rural households in the different regions diversify part of their income, agriculture is one of the most important sources of income, especially for the rural poor. Participation of household members in the agricultural sector was 19% for non-poor coastal households in 1999, compared to 25% for poor households. In the highlands, participation was 25% and 40% for non-poor and poor households respectively (World Bank, 2003a). Furthermore, the last census information indicates that coastal farmers and farmers in the highlands depend on agricultural production for 80% and 60% of their income respectively (Project SICA/MAG, 2002). As a result, 58% of households in the rural coastal are poor, while in the rural highlands poverty incidence is 66% (World Bank, 2003a). The low contribution of the sector to the GNP and the high dependency of households' income on wage labor and self-employment in agriculture suggest that agricultural households have low average incomes and are more vulnerable to fall into poverty.

The importance of the agricultural sector for rural households' livelihoods, and higher incidence of poverty among rural households underscore the need to understand agricultural systems and reduce rural household's vulnerability. Studies have found that high poverty rates in rural areas of Ecuador in the late 1990's are explained partly by the impact of the financial crisis that affected the overall economy during those years, and partly by major damages caused by "El Niño" current on agricultural lands (Vos, 1999;

World Bank, 2003a). Also, the unequal distribution of agricultural land and major differences in agricultural productivity of different farm sizes contribute to poverty increases rural in areas. Some of other factors found to increase poverty rates are low levels of formal education, skewed land distribution, lack of access to agricultural technologies and poor market access (World Bank, 2003a; 2003b). Policies that improve the conditions of agricultural and rural households are necessary to reduce poverty in Ecuador.

1.3 Plantain in Ecuador

Plantain production requires a temperate climate and fertile soils. In Ecuador, plantain is mostly grown in the humid tropics of the coastal region, especially in the "Plantain-belt" area located in the fringe that goes from the cities "La Maná" to "Santo Domingo de los Colorados" and "El Carmen"(See figure 1). There are approximately 82,400 Ha of monoculture plantain in Ecuador (Project SICA/MAG, 2002). Approximately 41,650 Ha are under production in the "Plantain-belt", especially in "El Carmen" located in Manabí (Orellana, Unda and Analuisa, 2002).

Plantain is an important food staple in Ecuador (FAO, 2004; Project SICA/MAG, 2004; Orellana et al., 2002). Food production of plantain in Ecuador is about 700,000 MT, which represent 8.2% of the total production of Latin American and Caribbean countries (FAO, 2004). In 2001, approximately 86% of Ecuador's plantain production was consumed locally; the remaining 14% was devoted to exports, mainly to Colombia, the United States, and some European countries (BCE, 2003; FAO, 2003).

Figure 1: Plantain producing areas of Ecuador.

Plantains vulnerability to insects and diseases and farmer's inability to successfully treat their crops have been the major constraints to the development of Ecuadorian plantain exports. Black Sigatoka (caused by *Micosphaerella figensis*) and nematodes (*Radopholus similis*) are the most important threats to the Ecuadorian plantain crop (Suarez-Capello et al, 2001/2002). Studies performed in the export producing areas indicate that in some farms as many as 60% of the plants are lost due to the presence of parasitic nematodes (Suarez-Capello, 2001/2002). Poor control of insects and diseases also decreases the weight of the fruit, complicating farmers' attempts to meet exports standards (Orellana et al., 2002; Tazan, 2003). Natural disasters such as "El Niño", which caused floods in the coastal region affecting 27% of agricultural production in

1999, have also constrained plantain yields and limited exports (Vallejo, 2002; Vos, 1999).

Limited farmers' information about technologies to treat insects and diseases of plantain have also resulted in misuse of pesticides and in poor management practices. Some techniques to treat insects and diseases, transferred from banana crops, have not been successful and instead have increased producers costs (Suarez-Capello et al, 2001/2002). Dissemination of information of specific technologies for plantain pest and disease management is imperative for the improvement of plantain production in Ecuador.

Due to intensive management requirements (drainage, soil treatment, careful elimination of weeds, etc), the plantain production process is labor intensive. In the "El Carmen" area, for example, there are 3,100 plantain producers, and plantain production generates employment for 25,040 people, 30% of whom are permanent workers and 70% are family and wage temporary workers (GERMEN, 2002). Differences in management practices and farmers' use of technologies determines the amount of labor used. Nevertheless, regardless of the technology use of farmers, labor is one of the most important inputs of plantain production.

1.4 Integrated Pest Management in Plantain Crops

Research has been conducted to develop technologies to improve traditional farm management practices and increase resistance of plantain to nematodes and Black Sigatoka (Suarez-Capello et al, 2001/2002). Over the years Integrated Pest Management (IPM) has emerged as "cultural, biological and information-intensive practices" (Norton, G. Rajotte and Gapud, 431, 1999) to control pest incidence and reduce pesticide use without negatively affecting the livelihood of farmers. The Integrated Pest Management Collaborative Research Program (IPM-CRSP), funded by the United States Agency of International Development (USAID) and in collaboration with institutions in more than 20 participating developing countries, was created to promote research, education, and information exchange focused on sustainable agricultural production systems (IPM-CRSP, 2004).

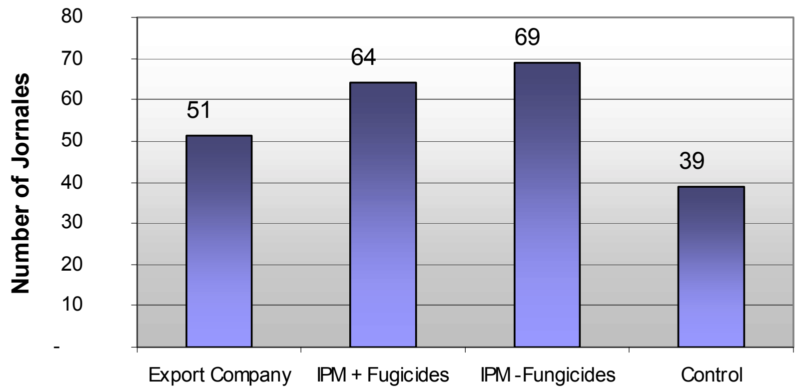
IPM-CRSP in Ecuador began in 1997. For all research activities in the country the IPM-CRSP has worked in association with the National Agricultural Research Institute (INIAP). Plantain research is conducted by INIAP Tropical Experimental Station's scientists at Pichilingue, located in the city of Quevedo, and inside the major plantain producing area of Ecuador, the Plantain Belt area. Experimental trials to evaluate current management practices and identify the differences with new IPM technologies started in 1999 (IPM-CRSP, 1998/1999).

Four combinations of management practices for plantain have been evaluated by the IPM-CRSP in Ecuador: (1) control plots using traditional management practices such as weeding twice yearly and annual removal of dead leaves, (2) plots using recommendations of Banana and Plantain Export Companies with weekly sanitary leaf pruning, herbicide application and twice a month use of traps with pesticides for Black Weevils. Rehabilitation plots have replaced old management practices with IPM techniques. Within the rehabilitation practices, there are two recommendations: (3) IPM with fungicides and (4) IPM without fungicides. The IPM package includes removal of the diseased area of the leaf every 15 days, and management of pruned leaves on the ground to avoid dispersal of inoculums; trapping weevils using baits with 1g of pesticide furadan; manual weed control with natural cover (Geophila macrophoda) and fertilizer following soil analysis. IPM with fungicide adds to the previous package fungicides recommended by Export Companies with 45 day intervals (Suarez-Capello et al, 2002/2003).

Results of experimental trials have shown that the use of IPM technologies has positive results. For Black Sigatoka, the use of IPM with fungicides has reduced pest incidence by 30% compared with the control plot, the traditional farmer practices (Suarez-Capello et al, 2002/2003). Results for IPM without fungicides and Export Companies recommendations are similar in terms of pest incidence. Nevertheless, higher fungicide use and lower plantain production than IPM treatments make Export Companies recommendations less profitable for farmers.

Labor is the most important input for management of plantain. According to the experimental results, the labor share of total variable costs is greatest for traditional farm practices (88%). The share of labor costs is the lowest for management practices recommended by banana and plantain export companies (53%). Labor share of variable input costs is 55% and 77% for IPM with fungicides and without fungicides respectively. Therefore labor requirements differ with the use of different technologies, but it remains one of the most important components of plantain farmer's costs.

Figure 2: Total annual labor-day requirements in experimental plots.



Source: Pichilingue Experimental Station Budgets. Values projected to hectares.
A fixed wage rate of $5 was assumed. Results are averages of the three different trial plots applying the different technologies in a one year period. The amount of labor is the number of jornales used per year.

Figure 2 shows the amount of *jornales*[1] used by the different technologies evaluated in the experimental trials in one-year period. The results are averages of labor used in 4 different trial plots each one measuring 335 m2, for three consecutive production cycles, and projected to reflect per hectare values. Comparing the results we can see that labor use is more intensive with IPM technologies. IPM without fungicides uses the most labor since the absence of herbicides requires more careful weeding and pruning to prevent pest incidence. The export companies' recommendation package has higher dependency on herbicides to control pests and therefore labor use for manual practices is less frequent.

The use of IPM technologies on plantain production can have direct and indirect effects. Direct effects of IPM technologies come from the benefits farmers receive by adopting the technologies. Adopting farmers will increase yields and therefore have

[1] In Ecuador most agricultural production labor is paid by *jornales*. A *jornal* is the equivalent of a daily basis wage (labor-day). Accounts for labor use the number of *jonales* paid in a time period. The results from the experimental budgets are based in fixed wage rate (jornal) of $5.

more product available to sell in the market. By adopting the technologies, farmers will increase the use of labor in plantain production. Indirect effects of the adoption of IPM technologies will come from increased labor employment. Increased labor employment can benefit resource poor farmers by creating alternative income generating activities, and also landless rural households through increased employment opportunities.

1.5 Problem Statement

Concerns about poverty in Ecuador have encouraged agricultural research to improve conditions among poorer people. A large percentage of plantain producers are poor. Furthermore, agricultural employment is an important income-generating activity of the rural poor, and in the coastal region plantain production provides a major source of income for landless laborers. Production of plantain has been constrained by vulnerability to insects and diseases. IPM techniques can reduce the incidence of insects and diseases on plantain and also limit use of chemicals. Technologies have been generated to reduce plantain production constraints. IPM technologies are labor intensive; increased adoption of IPM could create important impacts in labor markets. Nevertheless, such labor requirements possibly will slow adoption rates and reduce the potential impact of IPM.

1.6 Objectives

The present study has as its primary objectives to:

(1) Describe characteristics of plantain producers and other actors in plantain production that will affect the distribution of potential benefits of IPM. Specifically, identify differences in land holdings, market integration, input use and socioeconomic variables to differentiate among poor, non poor rural farmers and landless laborers, and link these characteristics to plantain pest management practices and labor markets.

(2) Estimate the distribution of benefits of the adoption of IPM technologies among different size farms. Farm size distribution of benefits will allow us, along with objective (1), to approximate the distribution of benefits among farmers with different socioeconomic conditions.

(3) Simulate the indirect potential benefits of IPM adoption by rural households as a result of income generated from increased demand for labor.

1.7 Organization

In the next chapter we present the conceptual framework for the analysis of the welfare distribution of benefits of agricultural technologies. Data description and requirements are also presented. Chapter 3 includes an overview of the plantain production system in Ecuador including a socioeconomic description of plantain farmers. It also includes a description of the type of economic activities that landless households undertake in the study area. Chapter 4 includes the application and results of the economic surplus model for plantain IPM technologies. Finally, conclusions and policy recommendations are discussed along with implications for future studies.

Chapter 2: Methods and Data description

In this chapter we describe in detail the methodology and information required to achieve the objectives of the study. The chapter begins with a brief description of methods and data sources. Next, we describe in detail the approach used in the economic evaluation of the direct and indirect effects of adoption of IPM in plantain. Finally, we present information of the plantain market in Ecuador and how we adapt the approach used to reflect current conditions.

To achieve objective 1, description of socioeconomic characteristics of plantain related households and how they influence the effects of IPM technologies, we use the 1998 Living Standard Measurement Survey (LSMS) for Ecuador.[2] The survey contains information for 5693 households; 3,193 urban households and 2,500 peripheral and rural. A total of 453 households in the survey reported producing plantain in 1998; 232 of these are located in the coastal region. The rest of the plantain plots are scattered around the humid areas of the country.

The LSMS provides information on demographics of the household, such as age, education, and agricultural education. Public infrastructure can be approximated by looking at access to services such as water and electricity. Available information on income sources is used to distinguish between agricultural and non agricultural activities. For farm households, we consider input use such as fertilizer and pesticides, and amount of labor hired and household labor. To assess distributional effects of IPM technologies (objective 2 and 3), we use landholdings information to create farm size classes (FSC)

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[2] Appendix 1 contains a description of the LSMS data, area of study and definitions of the terminology, also used in the analysis of chapter 3.

that allow us to analyze socioeconomic differences among farmers and also landless laborers.

We use a secondary data source to fill in gaps in agricultural information in the LSMS data. The National Institute of Agricultural Research (INIAP) of Ecuador conducted in 2001 a survey on 120 plantain farmers. All responders are located in the plantain belt area (mainly in Santo Domingo and El Carmen). The survey gives insights into differences in management practices by farm size, the number of years growing plantain, and age of the plantations. Budgets information from this source is also used when needed to complement the LSMS data.[3]

To achieve the second objective, the measurement of the direct effects of IPM technologies on farmers, we use a economic surplus approach for the measurement of technology benefits that will potentially accrue to producers and consumers of plantain. The rest of this section describes in detail the economic surplus approach applied to plantain production in Ecuador. We present a subsection with the methodology used to simulate the effects of the IPM technologies on labor use, which is the last objective.

2.1 Economic Surplus Approach

The economic surplus method is one of the most common frameworks to evaluate the distribution of benefits among consumers and producers. Economic surplus approaches in agricultural research impact assessment and priority setting have been widely covered in the literature.[4] The advantages of this approach include its flexibility to

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[3] In later sections we estimate labor use per hectare from the Plantain Belt survey. Nevertheless, the data is limited by its small sample size by FSC, particularly for farms with more than 100 ha.

[4] For a complete discussion of the literature on the economic surplus approach, its benefits and disadvantages see Alston, Norton and Pardey (1995).

adjust to international trade and market price distortions. Also, the economic surplus is generally conducted in a partial equilibrium setting to look at single commodity market effects. Partial equilibrium frameworks are appropriate for ex-ante studies with limited market data. Nevertheless, the economic surplus approach has implicit assumptions about market pricing. It assumes a perfect competition commodity market (price equal to marginal cost) which allows the aggregation of benefits and cost, regardless of whom is receiving/paying them (Alston et al, 1995).

One of the fundamental concepts of the Economic Surplus approach is the Producer surplus (PS). The PS is the return producers receive minus the cost of production, and is measured by the area above the supply curve and below the market price. Research-induced changes in the supply of a commodity cause changes in consumer and producer surplus. Depending on the ability of farmers to make use of the technologies and integrate to markets, these areas can be measured to estimate the distribution of benefits among consumers and producers.

Another important concept for the economic surplus approach is the Consumer surplus (CS). The CS is measured as the area below the Marshallian demand curve above the market price. Marshallian demand curves refer to the demand of a good as a function of it own price, for a given level of income and holding other prices fixed. CS is therefore the excess willingness to pay above the price that is actually paid. Benefits from the use of Marshallian demand curves (thus CS concept) are its easier estimation and that its money metric measure is a good approximation of utility changes[5] (Sadoulet and de Janvry, 1995).

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[5] Changes in the CS can approximate changes in utility only under a constant marginal utility of money.

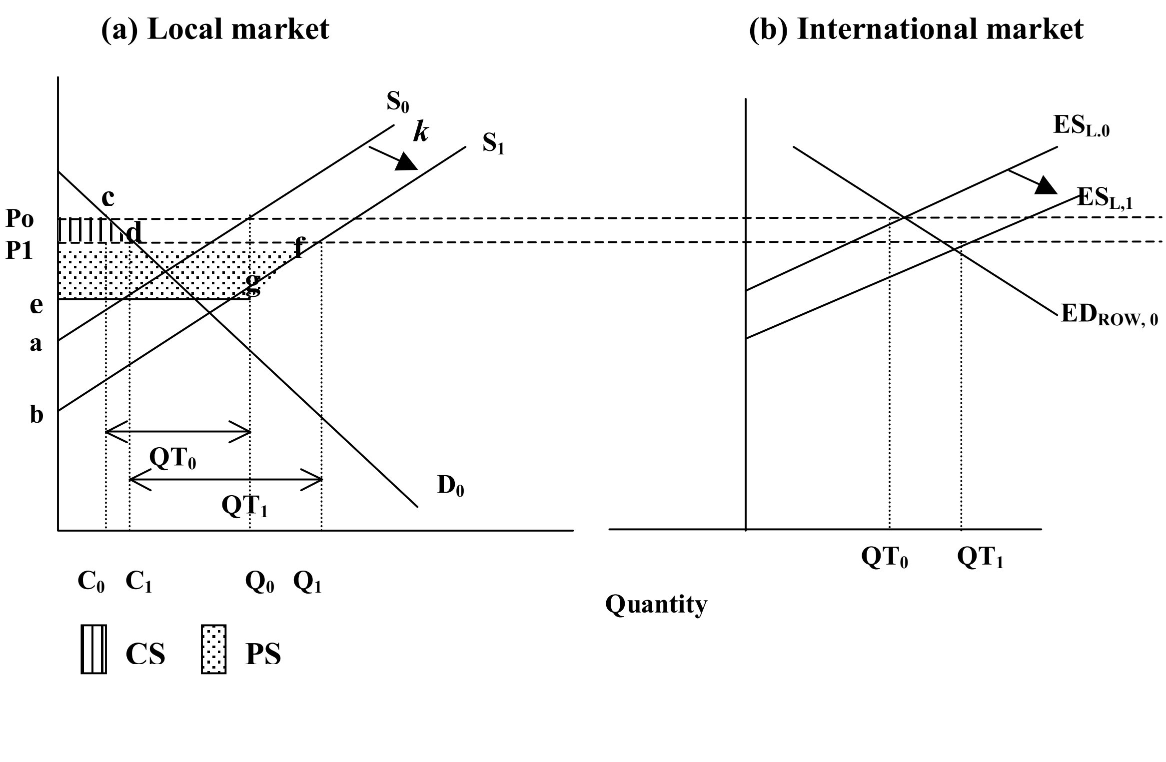
The use of Marshallian demand curves to estimate CS has been criticized by many economists. Some of its most important limitations are the impossibility to adjust to multiple price changes or simultaneous income-price changes (Sadoulet and de Janvry, 1995). The reason for these limitation is that there is a path dependency when using Marshallian demand curves when evaluating CS in either price changes or income-price changes; in other words the CS is different depending on which of the changes we evaluate first (Sadoulet and de Janvry, 1995). Measures that do not suffer from this path dependency deficiency are the Equivalent Variation (EV) and Compensating Variation (CV).

EV as defined by Hicks, measures the amount of additional money that would leave the consumer in the new welfare position as if prices remained at the initial level. CV instead, measures the amount of money that the consumer would need to remain as well off as before, given the new price levels. To obtain these measures we would require Hicks compensated demand functions, which give the demand for a commodity as a function of its own price for a constant level of utility and not income (as in the Marshallian demand). Many have argued that Hicks' EV is a more accurate measure than CS (Alston et al, 1995). Nevertheless, Hicksian demand curves can not be directly observed or estimated as is the case of Marshallian demand curves (Sadoulet and de Janvry, 1995), and use of a Marshallian demand represents a good approximation.

If research benefits are analyzed for a commodity that is not traded, the local supply and demand price elasticities are major determinants of the size and distribution of total benefits in the economic surplus approach. However, when we introduce trade in the analysis, the position of the country in the Rest of the World (ROW) can also influence the local distribution of research benefits. In the case of a small open economy the market is small enough such that any change in the local supply of the commodity does not affect local and world prices. Nevertheless, in the case of a large open economy, a technology-induced increase in local supply will also affect international market prices and therefore local prices will also change.

Figure 3 shows the distribution of the local benefits in the large country exporter case. The local market is that of a large country exporter, while for the ROW we would be analyzing for a large country importer. In panel (a) we find the local market for plantain, and in panel (b) we find the excess supply and excess demand framework for the international plantain market. A basic assumption for the functionality of this framework is that all the supply and demands are linear.

Figure 3: Economic Surplus changes with increased supply – Large Exporting Country Case



Assuming that the introduction of the IPM technologies causes an outward parallel shift of the local supply of plantain (*k* shift in figure 3), quantity supplied increases from Q_0 to Q_1. Increased local export production induces an increase (shift down) in the excess supply curve of the international market from $ES_{L,0}$ to $ES_{L,1}$, causing the plantain prices to decline in the world from P_0 to P_1. Panel (a) shows the increase of local consumption from C_0 to C_1 as a result of lower prices, and also the change in quantity exported (imports of the ROW) from QT_0 to QT_1. Equilibrium is reached in this framework by equating excess local supply at the new equilibrium price (P_1) to the excess ROW demand.

Direct effects on adopting farmers are represented by unit cost- lowering effects of the technology. Producers benefit from the IPM technology as increased output sold in the local and international market and lower costs. The area $\mathrm{P_1fge}$ in figure 3 is the change in PS. Consumer benefits are the result of the decrease in local prices and therefore increased ability to consume. The change in CS is represented by area $\mathrm{P_0cdP_1}$ in figure 3.

Alston, Norton and Pardey (1995) contain detailed information for the measurement of the supply shift in different scenarios of the economic surplus model. In any case, to measure the distribution of benefits it is necessary to calculate the relative reduction in price $Z = -(\mathrm{P_1} - \mathrm{P_0}) / \mathrm{P_0}$, and also the supply shift of the local supply curve K. Assuming that the local market is that of a large export country, we can obtain the relative price reduction by solving price in the linear demand and supply equations of the local and ROW markets:

Domestic Supply: $Q_L = \alpha_L + \beta_L(\mathrm{P} + \mathrm{k})$
Domestic demand: $C_L = \gamma_L + \delta_L \mathrm{P}$
ROW supply: $Q_{ROW} = \alpha_{ROW} + \beta_{\mathrm{ROW}} \mathrm{P}$
ROW demand: $C_{ROW} = \gamma_{ROW} + \delta_{\mathrm{ROW}} \mathrm{P}$

Where α and γ are the intercepts, β and δ are the slopes of the respective demand and supply curves. Using the equilibrium condition $Q_L + Q_{ROW} = C_L + C_{\mathrm{ROW}}$ to solve for P and transforming into elasticity form we find:

$$Z = \frac{\varepsilon_L K}{[\varepsilon_L + S_L \eta_L + (1 + S_L)\eta^E_{ROW}]}$$

Where ε_L is the local supply elasticity, S_L is the fraction of production consumed locally, η^E_{ROW} is the absolute value of the elasticity for export demand. We can estimate the elasticity for export demand in the following form:

$$\eta^E_{ROW} = \frac{Q_{S,ROW}}{Q^E_L}\varepsilon_{ROW} + \frac{Q_{D,ROW}}{Q^E_L}\eta_{ROW}$$

Where $Q_{S,ROW}$ and $Q_{D,ROW}$ are the production and consumption of the commodity in the ROW, ε_{ROW} and η_{ROW} are the supply and demand elasticities in the ROW, and Q^E_L is the export quantity in the local country.

The supply shift (K) can be obtained in the following form:

$$K = \left[\frac{E(Y)}{\varepsilon_L} - \frac{E(C)}{1 + E(Y)}\right] pA$$

Where $E(Y)$ is the expected proportional percentage increase in yields per hectare with technology adoption, $E(C)$ is the proportional percentage increase in costs per hectare, p is the probability of success in achieving the expected yield with adoption of technologies, and A is the expected maximum adoption rate of the new technologies.

Changes in the CS and PS in the local country are therefore obtained measuring the shaded areas in figure 3:

$$\Delta CS = P_0 \mathrm{C}_{\mathrm{L},0} \mathrm{Z}(1 + 0.5Z\eta_L)$$
$$\Delta PS = P_0 \mathrm{Q}_{\mathrm{L},0} (\mathrm{K} - \mathrm{Z})(1 + 0.5Z\varepsilon_L)$$
$$\Delta TS = CS + PS$$

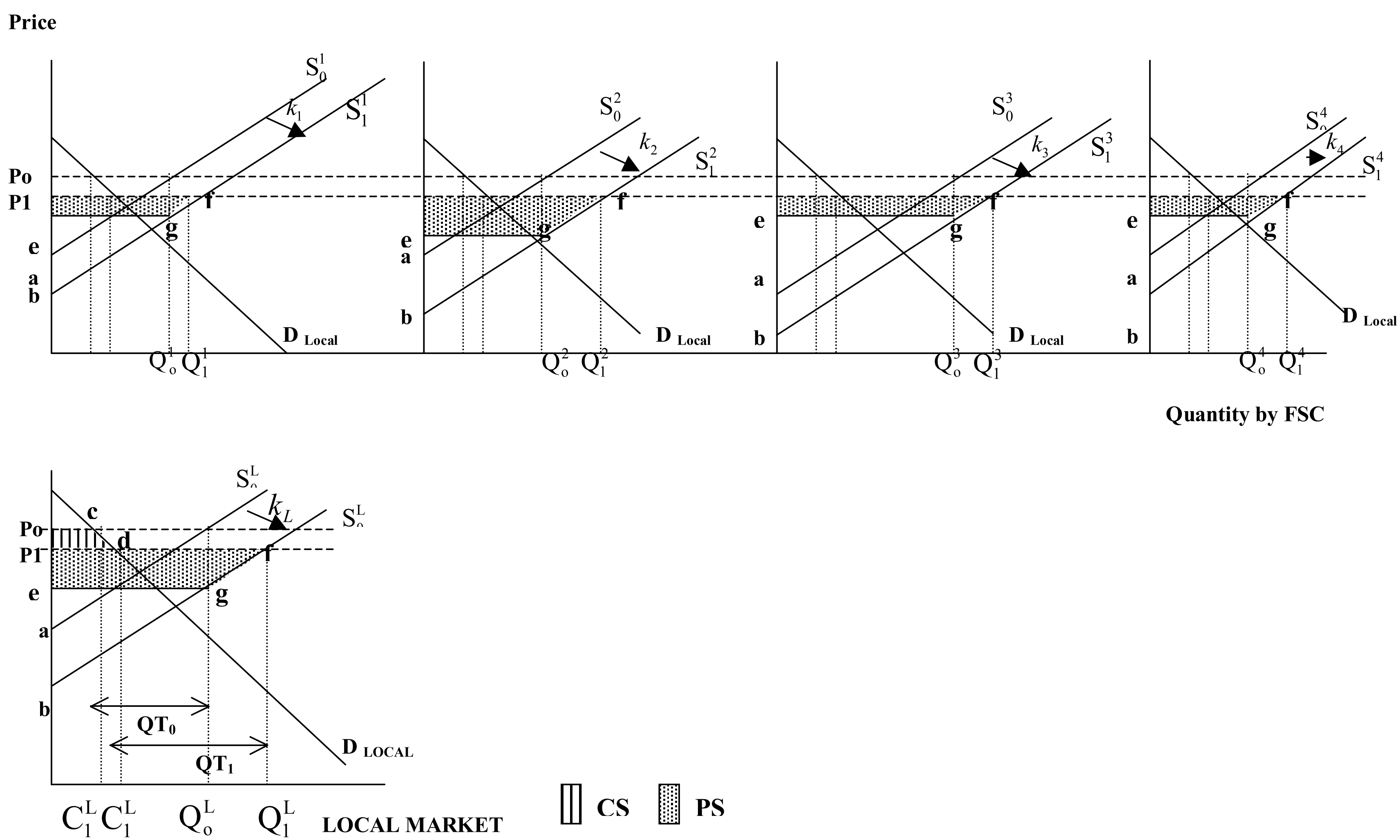
2.2 Finding the producer surplus for each Farm Size Class (FSC)

The above model is the general form for the estimation of the producer surplus with large open economy. We are interested in differentiating the benefits accruing to different farm size classes. Distribution of benefits among farm size classes is influenced by various factors such as adoption rates, initial quantity supplied, ability of farmers to respond to market price changes, access to commercialization channels, among others. Socioeconomic factors, as we will see in following sections, affect the level of adoption of new technologies, influencing the distribution of producer benefits among farm size classes. Graphically (figure 4) we can see that every farm size class FSC_i has its initial supply function S_0^i and therefore an initial level of output Q_0^i. As we developed in the general case, the introduction of the IPM technologies causes the supply curve to shift by a k factor. To disaggregate the supply shift we assume that each FSC_i has different technology adoption rates A_i , which depend on socioeconomic characteristics of the individual group. Different adoption rates cause different supply shifts and therefore every FSC_i will face a k_i factor. New technologies will therefore increase the supply to Q_1^i for the ith farm size class.

Changes in producer surplus for individual farm size classes will therefore be given by the sum of the disaggregated changes in producer surplus of every FSC_i .

Individual changes in producer surplus will be given by $PS = P_0 Q_0^i (\mathrm{k_i} - \mathrm{Z})(1 + 0.5 Z \varepsilon_L)$. Where k_i is the FSC_i supply shift, and Z is the proportionate market price decrease induced by the aggregated supply shift. We can observe the individual changes in producer surplus in figure 4. Change in producer net benefits are given by the area $P_1 fge_i$ of the different FSC_i . Total regional net producer benefits are therefore equal to the aggregation of individual net producer benefits equivalent in figure 4 to $\sum P_1 fge_i$ (market shaded area).

Figure 4: Disaggregated market supply by FSC.



2.3 Labor Demand and Supply

To assess the indirect effects of the adoption of the IPM technologies we evaluate the potential effects of adoption in the market for labor. In the present study we assume that the supply of labor for plantain is completely elastic. Although a completely elastic supply assumption implies that any labor will be supplied at the same wage rate, the importance of temporary labor in agriculture for rural households and the rates of unemployment make it reasonable to have this assumption.

In general, temporary labor is the most important component of the agricultural labor market in Ecuador. The latest census information states that of total agricultural labor, 53% is seasonal labor and 39% are permanent workers (Project SICA/MAG, 2003). Although there are no statistics for labor supply and demand in plantain, in the areas of highest production of plantain, occasional labor provides an important source of income for households (Germen, 2001).

Participation of family labor in the production of plantain and high unemployment rates contribute to the structural characteristics of the supply of labor. As is shown in latter sections, family labor for plantain producing households of the coastal region of Ecuador is around 35% to 40 % for households with less than 20 hectares of agricultural land.[6] Also, for many small and poorer farm households wage labor can be an important alternative source of income.

Unemployment is another factor that can affect the characteristics of the labor supply. According to official statistics for urban areas, the unemployment rate in Ecuador was 9% of the economically active population in 2001 (INEC, 2004).

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[6] Own calculations using LSMS 1998 data for Ecuadorian households.

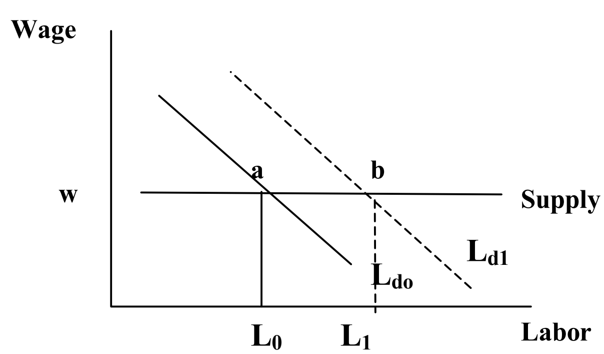
Furthermore, in the coastal region unemployment is higher than the national rate with 9.7% of the economically active population in 2001 (INEC, 2004). Although unemployment rates for rural areas are not available, high migration to urban areas reflect the lack of employment opportunities in rural areas; high unemployment rates in urban areas reflect the importance of temporary income generating activities such as agricultural labor for rural farm households.

If we had a different assumption about the elasticity of supply of agricultural labor, a multimarket analysis would be necessary to simultaneously solve for production of plantain and supply of labor in the coastal region. Labor supply would have to be estimated for the different types of households, and the distribution of net benefits from the adoption of IPM technologies would also depend on the elasticities of labor supply and demand.

It is also important to notice that assuming a completely elastic supply curve has implicit strong assumptions about the cost of labor. Not having an upward sloping labor supply curve implies that there is no opportunity cost for people that are been drawn into the plantain labor market from other sectors. However, as we will se in later chapters, agricultural wages is as an important alternative source of income for poor farm households in the rural coast. Participating in wage labor activities could represent little cost for these households. Nevertheless, for simplicity we assume that there is no opportunity cost to increase plantain labor and simulate the income effects for rural coastal households.

The adoption of IPM technologies increases the demand for labor. Although increments of labor increase costs for plantain farmers, increased yields related to the use of IPM compensate by contributing to an overall decline in unit cost. Input mix changes from high cost inputs, such as agrochemicals, to lower cost inputs such as labor, are likely to contribute to the unit cost reduction. Although labor requirements could slow IPM adoption, adopting plantain producers will increase the demand of labor, shifting the labor demand curve outwards. Figure 5 shows the labor market as it is assumed in this study. The introduction of the new technology increases demand of labor from L_0 to L_1. We are interested in measuring the income effect created by the increased demand for labor. The labor income effect from the introduction of IPM technologies will be measured as the area L_0abL_1 in figure 5.

Figure 5: Labor Market effects of the introduction of IPM technologies.



Since the increase in demand for labor is created as the different farm size classes adopt the technologies, labor demand increases will be proportional to farm size class increments in output. Figure 5 could be disaggregated by farm size class as we did for output. Labor demand by individual farm size class before technology adoption will be given by L_0^i. Adoption of the technologies will increase labor demand by farm size class to L_1^i. Income benefits for labor will therefore be given by $L_0^i ab L_1^i$.

The adoption of the technologies will require a proportional change in labor per hectare given by δ. The increment in labor δ will be measured as the proportional increase in labor use per hectare when switching traditional farm practices to IPM. Nevertheless, increments in labor will be determined by the level of adoption A_i of the individual FSC_i. Change in labor demand ΔL_D^i will be given by $\delta \ A_i \ L_1^i$. Benefits for labor will therefore be given by the change in labor demand multiplied by the wage rate $w * \Delta L_D^i$.

Distribution of income generated from the increments in labor will be determined by the distribution of labor income in the rural coast. Income will be distributed among the different household types HH_i composed by the four FSC plus one class of rural landless households according to its share of total wage income in the region. The share of agricultural wage income of the ith household type (S_i) will be measured as the proportion of total rural wage income obtained by HH_i. We further decompose the distribution of wage income by poor and non poor households in the rural coast.

Disaggregating Consumer Benefits

In previous sections we indicated how the adoption of new technologies would generate benefits for consumers (CS). However, one of the purposes of this study is to estimate the distribution of benefits generated by IPM adoption. To disaggregate the CS we use household expenditures on plantain in the region. We use six different types of households. We differentiate among urban poor, extreme-poor, and non-poor households. Also, we distinguish among rural poor, extreme-poor, and non-poor households. We estimate shares of regional consumption by the different household types and use them as a proxy for the distribution of consumer benefits.

2.4 Adoption of IPM technologies

The extent to which IPM technologies will be adopted by plantain farmers depends on various factors. From a socioeconomic point of view, as farmers increase their perceived profits from the use of agricultural innovations, the likelihood of adoption increases. There is ample literature on the theory adoption of agricultural technologies and the factors that influence adoption rates (Feder, Just and Zilberman, 1985; Strauss et al, 1991; Ferdandez-Cornejo, Daberkow and McBride, 2001; Nowak, 1996). In general, technology adoption depends on the nature of the technology, farmer characteristics, physical characteristics and the institutional environment of farms (Feder et al, 1985).

Human capital has been found to be an important determinant of technology adoption (Strauss et al, 1991; Feder et al, 1985; Feder and Umali, 1993). Farmers education for example, increases the ability to make use of improved inputs and allocation of production resources (Feder et al, 1985). Also, better education permits farmers into integrate to markets more easily and increase sales after yield improvements due to technology adoption (Feder et al, 1985).

Household structure also affects the ability of households to perceive profits from adopting new technologies. Household headship for example can influence management decisions. For plantain producing households in Ecuador, a preliminary study of management practices has found that female heads are in general less aware of plantain diseases and management practices (Harris et al, 2002/2003). Age of household head can be related to experience in agricultural practices. According to the theory, younger farmers are more likely to adopt new agricultural practices (Shaw, 1985). However, empirical evidence shows that in many cases younger farmers are less experienced and have less access to information, limiting adoption of new technologies (Shaw, 1985) Household size also influences farm decisions about management practices. If innovations are capital intensive, farms with larger number of dependents may be less able to overcome cash constraints. If new technologies require increments in labor costs, family labor can reduce labor expenses and increase the ability of households to profit from adoption of new technologies (Feder et al, 1985).

The physical environment of the farm affects the welfare of farmers. Agricultural equipment for example is an indicator of wealth and could influence adoption of new technologies. Agricultural equipment can serve as collateral to gain access to credit. Also, having agricultural equipment can help to reduce the cost of implementing new technologies. Landholding size and tenure have also been factors considered in adoption studies. Some studies have found that relative allocation of land for agricultural innovations increase with farm size. Nevertheless, assuming that all farmers are risk averse it is also possible that, relative to farm size, smaller farms could devote a larger proportion of land producing using new technologies (Feder et al, 1985; Feder and Umali, 1993). Furthermore, factors such as human capital, credit constraints and input requirements influence the relationship between farm size and adoption (Feder et al, 1985, 271).

Prices of inputs can also be determining factors of adoption of new technologies Feder and Umali, 1993). Expectations of prices of inputs and output could slow down technology adoption in their early stages (Feder and Umali, 1993). Imperfect information about the effects of technologies and slow diffusion of knowledge influences farmer expectations about prices. Looking at labor costs among different types of households could provide information on input constraints and input price differences that could influence adoption of new technologies.

The institutional environment such as agricultural credit provision, technical assistance, and extension services affect the probability of farmers' adopting new technologies. Resource-poor farmers may have less access to technology know-how and high cost inputs, and technology adoption may be perceived as less profitable. Credit access helps resource poor farmers to gain access to agricultural innovations. Technical assistance can also provide support for farmers' perception of the adoption of new technologies. Availability of technical assistance can increase farmer's ability to receive important information about the benefits of adopting improved farm practices and therefore influence farmer decisions about technology use. Extension services can help farmers obtain information necessary for their production decisions with imperfect information (Feder and Umali, 1993).

2.5 Approach to assess the likelihood of adoption of IMP technologies

Although IPM technologies have not thus far been adopted by plantain farmers, we can assess the probability of adoption by FSC from the observed use of agricultural management practices. We use the LSMS survey to observe the socioeconomic differences among different FSC and farm management practices. The survey contains information about fertilizer and pesticide use in agricultural practices. Fertilizers and pesticide use are influenced by socioeconomic factors that could encourage/discourage the use of new improved management practices for plantain production.

Fertilization is less frequent among plantain farms and could proxy access to production resources and knowledge of management practices. High costs of fertilization constrain resource-poor farmers from its use. Many plantain farms are small and during the dry season there is little or no fertilization, sanitary controls or irrigation, and most of the surplus production for sales is harvested during the rainy season from January to June (Tazan, 2003). Proper use of fertilization requires some access to technical assistance. Some farmers that have been found to have higher production technology use fertilization combined with other improved management practices (Orellana et al., 2002). Nevertheless, it is important to notice that fertilization practices for plantain production, when recommended by extensionists, are used with previous soil analysis, most of all for old plantations (Tazan, 2003); thus proper use fertilization techniques may also be influenced by socioeconomic factors.

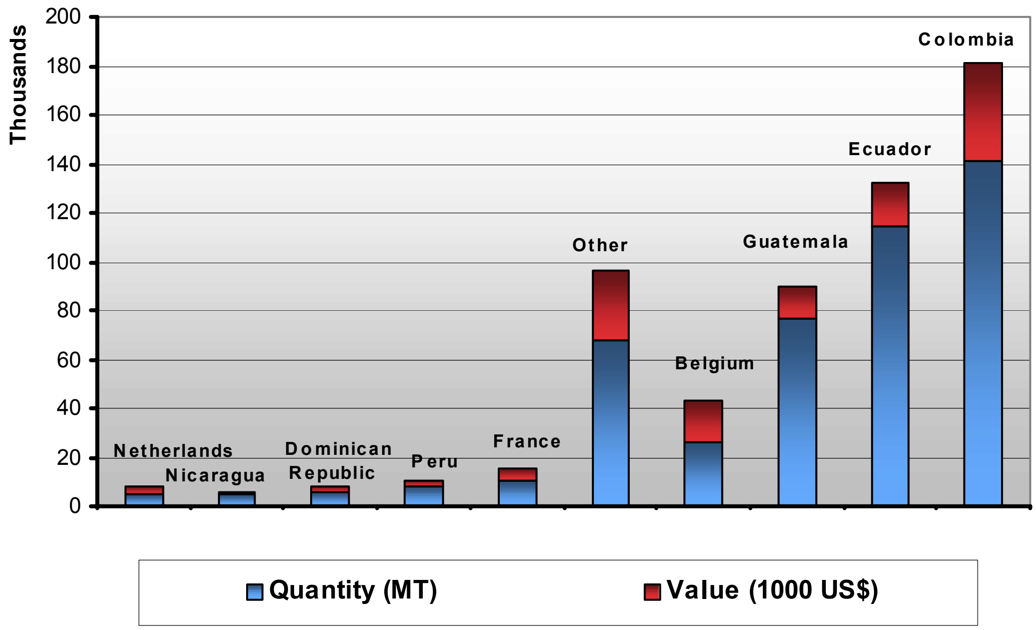
Pesticide use is common in plantain farms. Traditional management of insects and nematodes has been through pesticide application. However, in the case of a common insect, locally named “El Picudo”, pesticide is used with traps in granulated form and does not impose high health risks for farmers (Tazan, 2003; Orellana et al., 2002). Nevertheless, farmers with low knowledge of management practices also use pesticides to spray the leaves and use it frequently in the high producing rainy season. Farmers with medium and high knowledge of management practices use pesticides in traps and spray once yearly or do not spray (Orellana et al., 2002).

From the information in the LSMS survey, we can estimate the unconditional probability of adoption of pesticide and fertilizer use. Average use of fertilizer and pesticides can be obtained by FSC to approximate disaggregated adoption rates that will be used in the empirical simulation. To analyze users and non-users of fertilizers and pesticides we present statistics of their socioeconomic characteristics. Appendix 3 contains a background analysis of the probability of use of the two practices conditional on socioeconomic factors pertaining to farm households of Ecuador.

2.6 The case of plantain in the Ecuadorian economy

In the last decades, exports have become more important for the livelihood of Ecuadorian plantain producers. Although in 2001 domestic consumption was about 86% of the total plantain production, exports increased at a constant rate of 12% in 2000 and 2001, providing 27% of the worlds exports (FAOSTAT, 2004). Ecuador is the second most important exporter in the world market. As shown in figure 6, Ecuador's quantity of exports in 2001 was 114 thousand metric tons with an export value of 18 million US dollars (FAO, 2004). However, instability of local prices, poor commercialization channels, and quality constraints due to pest incidence have hindered the increase in value of plantain exports (Orellana et al., 2002; Tazan, 2003).

Figure 6: World's 2001 plantain exports



Source: FAOSTAT, 2004.

The United States is the biggest importer of plantain in the world and is the most important buyer of Ecuadorian exports (FAOSTAT, 2004; Project SICA/MAG, 2004). In 2003, the United States imported approximately 253 thousand tons, of which 28% was imported from Ecuador (Project SICA/MAG, 2004). The price of plantain for export producers is generally influenced by commercialization companies and usually set by the government. Currently, for export boxes that contain 50 pounds of plantain, farmers receive 3.5 US$ (Orellana et al., 2002, pg. 98). Average price per metric ton at December 2001 and 2002 was 160 US$ (Project SICA/MAG, 2004; BCE, 2003c).

In 2001 there were 54,500 hectares of monoculture plantain in coastal Ecuador.[7] Average yields in monoculture harvested area were approximately 4,5Mt/ha (Project

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[7] The study area includes parts of Pichincha province where plantain is produced (Santo Domingo peripheral areas) which is within what we have called before the plantain belt. Although the region in

SICA/MAG, 2002). Not taking into account the year 1997 to 1998 when major floods destroyed cropping areas[8] in the coastal region, plantain harvested area has increased by an average of 8% since 1990 (FAOSTAT, 2004). Plantain yields per hectare are quite variable. From 1999 to 2000, plantain yields decreased by 32%, while from the year 2000 to 2001 yields increased 28% (FAOSTAT, 2004). One of the important reasons for the fluctuations in yields is that most plantain is cultivated with traditional management practices; therefore little technology is applied, and thus yields are highly vulnerable to pest incidence (Suarez-Capello et al, 2001/2002; Orellana et al., 2002).

2.7 Farm Size Class distribution of Plantain Farmers and Labor Use

We model the benefits for producers in four farm size classes. We differentiate among farmers with fewer than 5 hectares, farmers with 5 to 20 hectares, farmers with 20 to 100 hectares, and farmers with 100 or more hectares of plantain. The reason for this disaggregation, is that there are differences in the socioeconomic characteristics of the four farm size classes and our interest, besides the measurement of the size of benefits for producers, is to understand to whom these benefits are going.

There are approximately 121,000 hectares of plantain in the coastal area of Ecuador, and 54% are hectares of plantain associated with other crops (Project SICA/MAG, 2002). Figure 7 presents the principal association of plantain crops for the country. Cacao and Plantain occupy 38% of the total associated plantain hectares in Ecuador. Coffee is also grown associated with plantain and along with cacao represents

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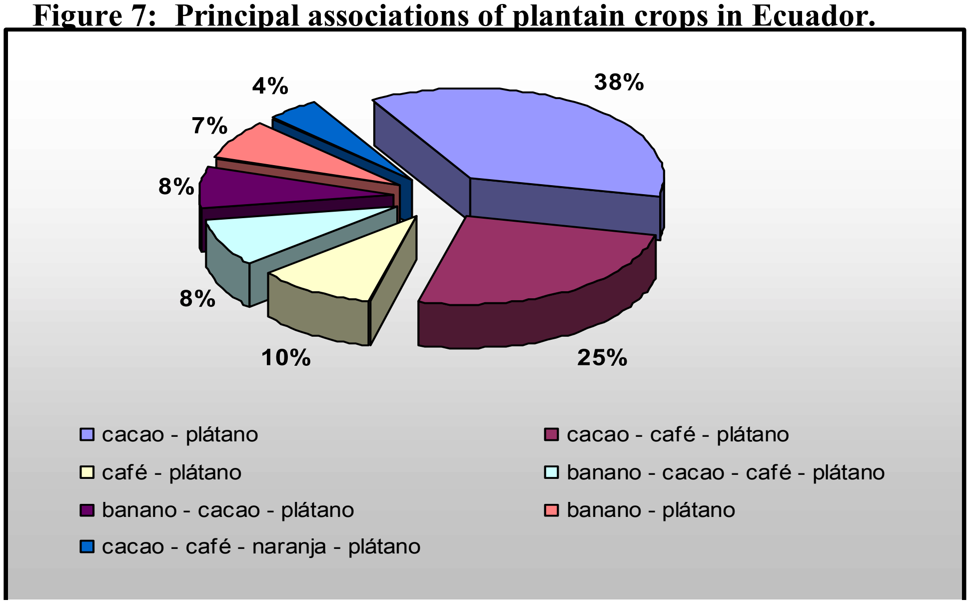
which this area is located is the Sierra, most socioeconomic conditions, including climatic and landscape correspond to that of the Coastal region.

[8] According to FAO statistics, from 1997 to 1999 59% of the harvested area of plantain was reduced.

25% of total associated hectares of plantain. Banana and orange are also among the important associations of plantain crops.

Figure 7: Principal associations of plantain crops in Ecuador.



Source: Agricultural Census, 2001.

According to the results of the most recent agricultural census, 13%, of total production of plantain (including associated land) is obtained from farms with fewer then five hectares, 34% in farms with 5 to 20 hectares of land, 43% in farms with 20 to 100 hectares of land and 10% in farms with 100 or more hectares of land (Project SICA/MAG, 2002). Table 2.1 presents information about the number of farmers and the corresponding production estimates for total hectares of plantain in the area of study region.

Table 2.1: Total plantain hectares and production by farm size class[a].

Farm Size Class	Number of Producers	Plantain Hectares	Harvested area (Ha)	Production (Mt)	Ave.Yield Kg/ha
< 5 hectares (Ha)	16,819	14,373	12,921	41,395	3,204
≥5 Ha < 20	15,005	41,946	37,619	110,145	2,928
≥ 20 Ha < 100	11,621	51,391	46,254	136,820	2,958
≥100	1,630	13,334	11,854	32,647	2,754
TOTAL	45,075	121,044	108,647	**321,007**	

Source: Agricultural Census, 2001
a The estimates include the production of the province of Pichincha, that is included in the study area due to its importance in export production.

Most plantain production for exports is grown in monoculture production[9] (Orellana et al., 2002; Tazan, 2003). In the area of study there are approximately 24,500 producers of monoculture plantain (Project SICA/MAG, 2002). Production from monoculture plantain in 2001 was about 214 metric tons (Project SICA/MAG, 2002). Estimates for the distribution of monoculture plantain hectares and production are presented in table 2.2.

Table 2.2 : Monoculture plantain hectares and production by farm size class[a].

Farm Size Class	Number of Producers	Plantain Monoculture (Ha)	Harvested area (Ha)	Production	Ave.Yield Kg/ha
< 5 hectares (Ha)	10,291	7,914	6,580	31,675	4,814
≥5 Ha < 20	8,650	16,717	14,091	63,094	4,478
≥ 20 Ha < 100	7,415	24,942	22,296	97,910	4,391
≥100	1,128	4,941	4,280	21,049	4,918
TOTAL	27,484	54,514	47,247	213,728	

Source: Agricultural Census, 2001
a The estimates include the production of the province of Pichincha, that is included in the study area due to its importance in export production.

Distribution of monoculture production by farm size class differs slightly from the distribution of total plantain land. According to table 2.2, production from farms with 20

[9] Also, doing a background check with the available data of the Plantain Belt survey, we estimated average production. For this we used gross income and a price of $3.5 for a box of 50 pounds. Converting into kilograms, averages for production in the export producing areas where this survey was obtain are slightly higher than the production averages estimated with the agricultural census for monoculture production.

to 100 hectares represent 46%, while 30% is produced in farms with 5 to 20 hectares of land. Farmers with 5 or fewer and 100 or more hectares of land produce 15% and 10% respectively. The results show the importance of medium scale farms in the production of plantain export crops.

Labor demand estimates are based on the previous estimates of the distribution of plantain hectares for total land and monoculture plantain. Due to the lack of census information of labor demand for plantain production, per hectare labor-day use was obtained from the Plantain Belt survey, collected by INIAP technicians in 2001. The number plantain hectares are then multiplied by the labor-day estimates to obtain estimates of labor demand. The results are displayed in table 2.3.

Table 2.3: Labor demand estimates for the coastal region.

Farm Size Class	# Farms[a]	Average Labor-day /ha year[b]	Total Demand	Monoculture Demand
< 5 hectares	28	43.63	563,743	287,103
≥5 to < 20	65	12.25	460,833	172,613
≥ 20 to < 100	26	9.93	459,302	221,397
≥100	2	20.05	237,673	85,813
TOTAL			**1,721,551**	766,926

Source: INIAP Plantain Belt survey, 2001. Agricultural Census, 2001.
a. The number of surveyed farms per FSC in the Plantain Belt area.
b. Labor-day per hectare is the number of jornales per hectare used in one year. The estimates are yearly averages by FSC obtained from the Plantain Belt survey.

Table 2.3 also indicates the number of farms in the Plantain Belt survey, from which the average of labor-day estimates were obtained. However, in particular for farms with more than 100 hectares of land, the estimates are obtained from very few observations. Nevertheless, the majority of plantain is grown in small and medium size plots. The estimates of labor demand are therefore rough approximations using the available data.

Chapter 3: Plantain Farmers of Ecuador

To provide a profile of the people potentially affected by plantain IPM technologies, we use census information and the Living Standard Measurement Survey (LSMS) of 1998. We describe demographic characteristics of farmers in the area and the characteristics of plantain laborers. We examine characteristics such as landholdings, education levels, technical assistance, income sources, community organizations and welfare status of households.

3.1 Landholdings

Plantain farmers have a disparate distribution of land. According to the last agricultural census, 3.6% of the producers in the study area own 11% of the land, while 37% own 11% of the land used for plantain production. For the distribution of agricultural land in the area (not just plantain) the results are more striking: 3.6% of producers use 39% of the total agricultural land, while 51% of the producers use 4.5% of the land (table 3.1).

Table 3.1: Coastal region agricultural land distribution

	All Agricultural Land	All Farmers	Total Plantain Land	All Plantain Farmers
Less than 5	245,934	143,778	14,373	16,819
5 to less than 20	1,078,557	80,392	41,946	15,005
20 to less than 100	2,034,676	50,036	51,391	11,621
100 or more	2,109,455	9,629	13,334	1,630
TOTAL	5,468,622	283,835	121,044	45,075

Source: Agricultural Census, 2001. Coastal region refers to the area of study, Coast and Pichincha province.

Gini coefficients estimated with the LSMS data on the distribution of land among Ecuadorian farms confirm the previous results on inequality of land distribution. According to table 3.2, the gini coefficient of the distribution of land for all farms in Ecuador is 0.77[10], while the result for plantain farms is 0.65. Furthermore, in all regions of Ecuador we find that plantain farmers have more equitable distributions of land than farms in general. The most inequitable region is the Sierra with a gini coefficient of 0.82 among all farms and 0.62 among plantain farms. Thus although plantain land is unequally distributed, it is far more equitably distributed than land in general.

Table 3.2: Gini[a] coefficients of the distribution of land in Ecuador

Region	# Households	Farms	# Household	Plantain
Costa	568	0.76	232	0.65
Sierra[b]	1089	0.82	66	0.63
Oriente	290	0.58	153	0.52
All	1946	0.77	451	0.62

Source: Own calculations using LSMS data.
a The gini coefficient is calculated using the statistical package stata. The command used to obtain various inequality measures is the *inequal* command. The estimates are weighted by the household size.
b. Six observations were not use for this estimation. These households had extremely large landholdings and reported very low consumption.

3.2 Poverty and Extreme Poverty

Table 3.3 shows household characteristics of all rural households in the country; for farm[11] households, and for households that produce plantain in Ecuador. Socioeconomic conditions of plantain households in the country do not differ from those

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[10] The World Bank estimate for Ecuador's gini coefficient of land in the year 2000 is 0.81. According to these results Ecuador is has one of the most inequitable distribution of land in Latin America and the Caribbean.
[11] See appendix 1 for an explanation of the terminology used for household types.

of farm households in general. Welfare estimates[12] using the LSMS data show poverty incidence among plantain households is higher than rural households in general. Nevertheless, the incidence of extreme poverty is lower for plantain households than that of rural or farm households.

Results by plantain farm size classes show some differences (table 3.3). Poverty for farmers with landholdings 100 hectares of more are significantly lower than poverty rates for other farm size classes[13]. Results are quite different for extreme poverty. Extreme poverty for the smaller farm size class is 38%, while the estimate for farmers with 20 to 100 hectares of land is 43%. It is important to note that high poverty rates in the 1997-1998 LSMS survey might be overstated by particular factors that occurred on the survey year. Farmers in the Costal region were all affected by the devastating forces of the "El Niño" current that flooded crops and destroyed infrastructure. Studies have found that the most affected people in terms of income losses were small and medium scale producers and to lesser extent, laborers in banana and sugar cane (Vos, 1999). Also, rural as well as urban households were affected by the financial crisis that worsened in 1999, and ended with the bankruptcy of many financial institutions and the dolarization of the economy. Higher rates of extreme poverty in the survey year for medium-scale producers may reflect crop losses that all farmers faced that year, high

[12] Consumption expenditures were used to estimate rates of poverty and extreme poverty. Consumption poverty lines were obtained from a study for Ecuador conducted by the Ecuador Integrated System of Social Indicators (SIISE, 2003). According to this study a household would be considered poor if its monthly per capita expenditure falls under $53. For extreme poor households expenditures of $26 per capita were used. The exchange rate used for 1998 was 1US$=4,780 Sucres (BCE, 2003b).

[13] Adjusted Wald Test for significance in the differences among different farm size classes do not show sufficient evidence to reject the null in the equality of incidence of poverty rates among classes. Nevertheless, Adjusted Wald Test for the significance in the differences on farm size class respect to the larger farm size class can reject the null at a 15% level of significance.

dependence on production sales of lost crops, and lack of access to credit for household consumption.

Table 3.3: Welfare conditions among different types of households[a]

	Rural Ecuador			Coastal Plantain Households (Ha)			
	Rural	Farm	Plantain	<5	5 to 20	20 to 100	>100
# of Households	2500	1671	410	97	79	48[†]	7
PC Consumption	460	400	452	477	435	461	2110
	(11)	(9)	(21)	(46)	(43)	(47)	(865)
PC Income[b]	380	331	326	255	256	353	1575
	(27)	(33)	(30)	(27)	(34)	(77)	(841)
General Poverty[c]	81%	87%	85%	82%	86%	79%	52%
	(0.155)	(0.009)	(0.020)	(0.042)	(0.043)	(0.060)	(0.192)
Extreme Poverty[d]	43%	49%	40%	38%	40%	43%	-
	(0.011)	(0.135)	(0.027)	(0.052)	(0.058)	(0.075)	-

Source: Own calculations using the 1998 LSMS.
a Standard errors presented in parenthesis bellow the corresponding estimate.
b Income estimates are rough estimates using primary, secondary and tertiary economic activities as a proxy for income. No estimations of remittances, charities or taxes were included.
c Adjusted Wald Test for the differences of general poverty rates among farm size classes do not show strong evidence to reject the null on the equality of incidence.
d Adjusted Wald Tests for the differences of extreme poverty among farm size classes show strong evidence to reject the hypothesis on equality of incidence.
† One outlier was ignored for the estimates.

3.3 Household Composition and Human Capital

Rural households in the Ecuador show similar characteristics of household composition (see Appendix 2). Female household headship is not common in rural Ecuador. Primary education[14] is in general the highest education level for most rural households. Household age composition also shows similarities, with an average of 24% dependency rate for all rural households. Nevertheless, plantain households show slightly lower dependency ratio (21%) than the other household types.

Coastal plantain households show similar household composition than other rural households (see Appendix 2). However, we found some differences in education levels

[14] Primary education is the equivalent of middle school level of education.

among plantain farm size classes. There is evidence suggesting that larger farm size classes have higher rates of medium and high education levels of its most educated members.[15] The results are consistent with lower general poverty rates for the largest farm size class found previously. Nonetheless, no strong evidence shows differences among smaller and the medium farm size classes. Thus, results of differences on levels of education and poverty rates among farm size classes are ambiguous; lack of statistically significant information prevent us for making strong conclusions, especially for medium farm size classes where we found higher extreme poverty rates.

3.4 Economic Activities and Income Sources

Agricultural self-employment is the most important economic activity for rural households in Ecuador (see Appendix 2). On average 26% rural households have members for which agricultural self-employment is their primary activity. However diversification into non-agricultural activities is common for all rural households, where non-agricultural wage employment also has an important part of household member's activities. Although self employment in agriculture is the most important economic activity for farm households, agricultural wage and non-agricultural employment are important alternative economic activities.

Primary and secondary economic activities among plantain farm size classes of the coastal region show some differences (see Appendix 2). Self-employment in agriculture becomes more important as landholdings increase, and is higher for farmers

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[15] Adjusted Wald Tests for the equality of levels of education were performed. There is strong evidence of differences in the rates of medium and high education levels among farm size classes of coastal plantain households. Jointly for both levels we can reject the null of equality at the 2% level. Nevertheless, individual differences among classes are more significant for the larger farm size class. Among medium scale farms there is very little evidence of differences in levels of education.

with 20 to 100 hectares of land.[16] Participation in non-agricultural activities is also important for larger sizes of farms. Wage activities in agriculture and in non-agriculture are also important components of primary economic activities. Agricultural wage participation is equally important for small and medium farm size classes.[17]

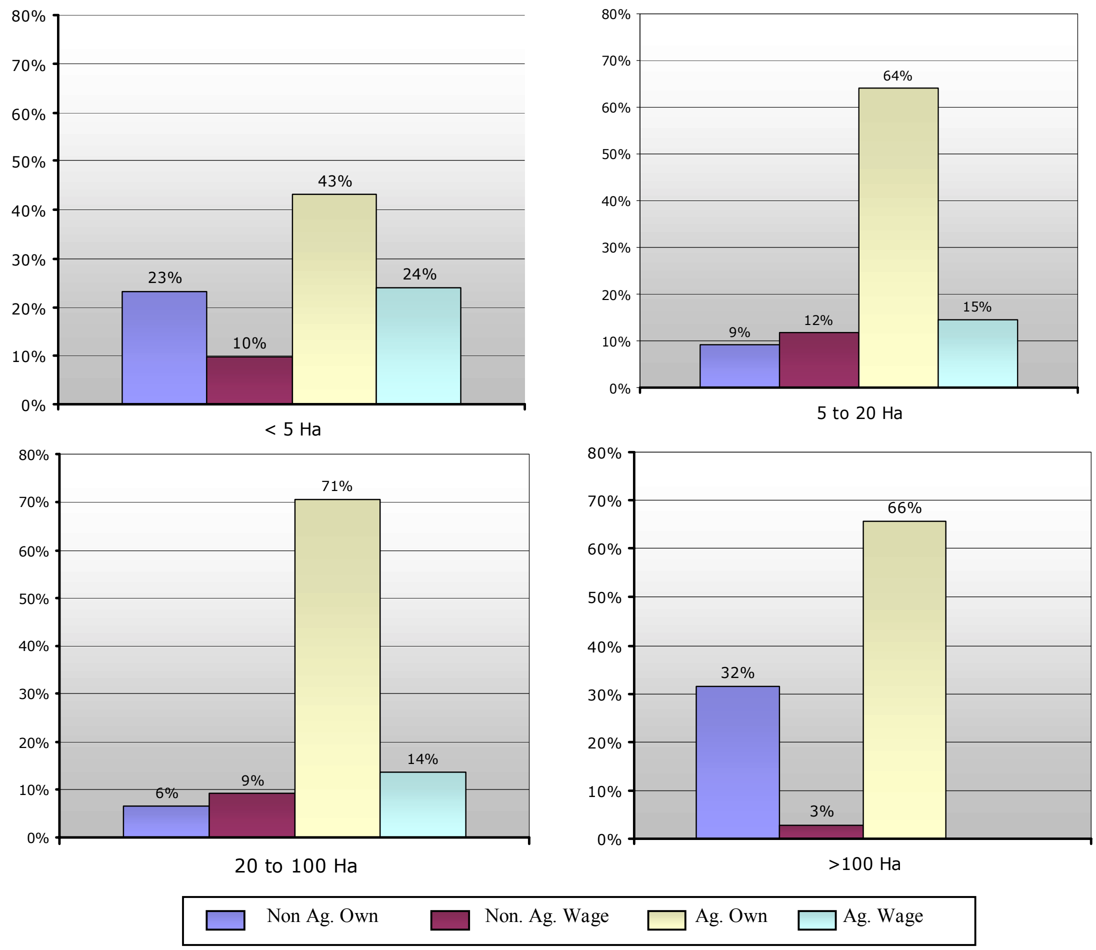
Plantain households' percentage of income sources are presented in figure 8. The graphs show high dependency of income on agricultural self-employment in general for all farm sizes. Nevertheless, there is some income diversification, particularly in the smaller farm size classes. Agricultural wage income is particularly important for small and medium scale farms. For plantain farm households with less than 5 hectares agricultural wage provides 24% of household income; while for households with 5 to 20 hectares of land agricultural wage represents 15% of household income. The importance of agricultural wage on household income indicates that, although own agricultural production provides most farm income; an increase in agricultural wage employment opportunities can offer plantain households alternative methods to secure household welfare.

As expected, non-agricultural self-employment is an important source of income for larger farm size class (32% of household income). However, non-agricultural self-employment also represents 23% of household income for farms with less than 5 hectares of land. Non-agricultural wage is not as important for plantain households as other income sources.

[16] There is strong evidence suggesting that there are differences among farm size classes participation in agricultural self-employment. We can reject the hypothesis of equality of activity participation for farmers with 20 to 100 hectares of land with respect to other classes at a 2% level of significance.
[17] Adjusted Wald Test for the equality of participation of medium and smaller farm size classes do not have sufficient evidence to reject the null.

Diversification of plantain household income depends on the ability of households to access sources of income such as wage employment and non –agricultural activities. Although rates of participation of household member in agricultural wage are low, agricultural wage represents a large percentage of income, indicating easier access to off-farm labor in the agricultural sector.

Figure 8: Plantain household's percentage of income source by FSC



Source: Own calculations using the 1998 LSMS data.
Income estimates are only approximations using net income earned from primary, secondary and tertiary income generating activities. Social security benefits, charities, remittances or other indirect sources of income are not considered in the calculations.

Extreme poverty rates are higher for plantain households in the medium farm size classes and we have found that diversification from agricultural self-employment is low among these farms. Dependency on agricultural income makes medium scale farms more vulnerable to any unexpected shocks to agricultural production. Nevertheless, medium scale plantain farms dependence on agricultural activities suggests that potential benefits from the adoption of IPM technologies mostly benefit these farms. Furthermore, the importance of agricultural wage income for small and medium farm size classes suggest that an increase in labor demand caused by the introduction of IPM technologies will benefit the poorer and most vulnerable plantain farmers.

3.5 Landless Households

To examine economic activities for landless households in the coastal area and how they are related to their welfare status we have divided landless households by education levels. As previous sections indicated, plantain households with smaller landholdings had lower levels of education, and economic activities for small farms differed from those in the larger farm size classes. For landless households, we expect to see differences in the nature of economic activities influenced in part by their level of education. We want to observe how important wage activities are for this type of households and if an increase in agricultural labor would be important for the welfare of rural landless households.

Rural landless households in the coast suffer from low levels of well-being. According to the results of table 3.4, 78% of low-educated landless households from the rural coast are poor and 34% are extremely poor. There are differences in the nature of economic activities by education level. On average 8% of low education level household members participate in agricultural wage activities (see Appendix 2, table A2.3). Although participation of landless households in agricultural activities is not as important as non agricultural activities, per capita income derived from agricultural wage activities still represents 24% of household per capita income for the lowest educated households (table 3.4). Participation in non-agricultural self-employment (own) and wage activities are more common for higher educated households. On average 36 % and 24% of household members participate in non agricultural self-employment and wage activities respectively (see Appendix 2, table A2.3). Most household income for highly educated households comes from the non-agricultural sector (97% of household income). In the case of secondary economic activities, non-agricultural self-employment is more important for all landless households.

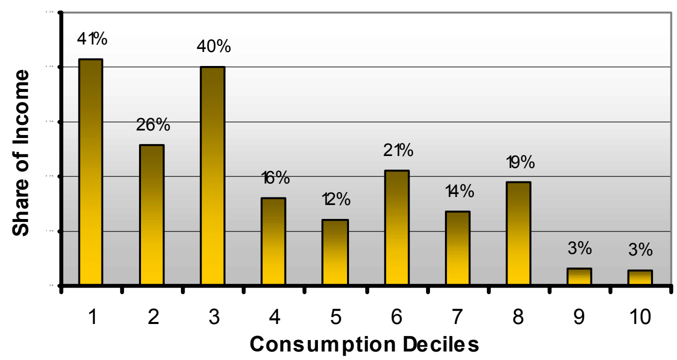
Table 3.4: Characteristics of the rural landless in the coastal region

	Low Education	Std. Err.	Medium Education	Std. Err.	High Education	Std. Err.
Poor	78.0%	0.0337	48.5%	0.0591	17.2%	0.1117
Extreme poor	33.9%	0.0386	9.3%	0.0377	-	-
Female head	16.5%	0.0305	13.4%	0.0407	12.7%	0.0865
Percentage of Income by Source						
Non Ag. own	37.0%	0.0373	49.4%	0.0530	40.1%	0.1203
Non Ag. wage	39.2%	0.0371	47.5%	0.0521	56.6%	0.1140
Agricultural wage	23.7%	0.0322	2.9%	0.0132	-	-
Agricultural own*	0.07%	0.0005	0.20%	0.0020	3.28%	0.0309

Source: Own calculations using the 1998 LSMS data.
* Although households are not registered as having agricultural land, households reported participating in agricultural self employment as a secondary activity. Some landless households in rural Ecuador posses patio agricultural production, that although small and mostly for self consumption, may be reported as an economic activity.

Previous sections showed the importance of agricultural wages for poorer and smaller farm households, figure 9 indicates that in the case of landless households, agricultural wages are important, especially for poorer households. The figure shows that the share of agricultural wage for the poorest 10% (measured by consumption) is approximately 40% of household income. Results of figure 9 and table 3.4 indicate that agricultural labor provides for poor and low educated households a major source of income in the coastal region. Increased demand for plantain labor will benefit mostly households in the lowest consumption deciles.

Figure 9: Household share of agricultural wage income by consumption deciles.



Source: Own calculations using the LSMS 1998 survey.

3.6 Public Services Infrastructure

Access to public services such as water and electricity are limited for rural households, and access to these services by plantain households is lower than other rural households. Coastal region estimates show similar results for access to water for farm households and plantain households (table 3.5).

Table 3.5: Coastal region Households Public Services Infrastructure[a].

	Plantain Farm Size Class (Ha)				Rural	Farm	Region
	<5	5 to 20	20 to 100	>100			
Water pipe	5% (0.026)	3% (0.024)	3% (0.029)	16% (0.145)	11% (0.012)	5% (0.011)	48% (0.013)
Electricity Hook up	74% (0.046)	57% (0.058)	43% (0.074)	87% (0.121)	79% (0.014)	71% (0.021)	93% (0.005)

Source: Own calculations using the 1998 LSMS.
a Standard errors presented in parenthesis below the corresponding estimate.

Infrastructure across farm sizes of plantain show some differences (table 3.5). Only 5% of households in the smaller farm size class have access to water. Even for the largest farm size class, access to water is only 16%. Electricity is more common; 74% of the smaller farm size class and 87% of the largest farm size class having electricity. These results reflect major differences in the infrastructure of farm households of the coastal region[18]. Small and medium farms are located away from rural towns; road infrastructure is poor, and public services are seldom provided. Also, high vulnerability to floods during the rainy seasons has made it harder for extension of infrastructure to those areas. Also, low access to water and electricity for medium-scale farms is consistent with higher extreme poverty rates found previously. Infrastructure could therefore be a proxy of welfare status of remote plantain households.

3.7 Farm Practices and Institutional Support

The LSMS household survey gives us general information about differences in farm practices. We are interested in looking at the differences of plantain households' management practices among farm size classes. From field observation, especially of plantain households in the Plantain Belt area, use of fertilization not common among resource poor farmers. Generally if a farmer used fertilization, even if it was organic fertilization, he or she would be more likely to have some knowledge and use advanced management practices. Fertilization can give us an idea of the use of improved management practices.

[18] Wald Tests for the significance in the differences of access to infrastructure are significant for water access. There is strong evidence to suggest that access to water and electricity is not equal by farm size class, especially when comparing farms of 20 to 100 hectares of land to the rest of the classes.

To improve agricultural production, rural households can receive institutional support in the form of job training, credit for agricultural and non agricultural activities, and technical assistance. Dissemination of technical innovations or improved management practices depends on access to costly inputs and information. Ability to adopt technologies therefore depends on socioeconomic factors and on the ability to access institutional support.

There are no major differences in coastal farm and plantain households' use of inputs (table 3.6). Nevertheless, fertilizer use among plantain households is less common then the average use by farm households in the region. Pesticide use is widespread in the rural coast. We observe limited access of coastal farm and plantain households to agricultural credit and technical assistance.

Table 3.7 also shows differences in management practices and institutional support by farm size of plantain households. The results show some significant differences. Plantain farmers with less than five hectares of land have reported lower frequency of use of fertilizers and pesticides.[19] Larger farms have more access to agricultural and non agricultural credit. Nevertheless, differences in access to credit are not as significant as differences in input use.[20] Technical assistance access is almost non-existent among plantain households.

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[19] Adjusted Wald Test for the differences in farmers reporting the use of pesticides and fertilizers are significant at the 10% level of significance for fertilizer and less than 1% for pesticides among the smaller farm size class and farmers with 5 to 20 hectares of land.

[20] Adjusted Wald test do not show strong evidence of the differences in access to agricultural credit and technical assistance among medium and small farm sizes, as in the case of fertilizer use.

Table 3.6: Coastal region differences in farm practices and institutional support of the different types of rural households.

Household activity	Rural Coast		Farm Size Class (Ha)			
	Farms	Plantain	<5	5 to 20	20 to 100	>100
# Households	513	225	97	79	48	7
Uses seeds for agricultural production	20%	17%	16%	15%	22%	-
	(0.020)	(0.027)	(0.040)	(0.044)	(0.061)	0.000
Uses fertilizer for agricultural production	44%	34%	28%	42%	30%	48%
	(0.024)	(0.034)	(0.049)	(0.059)	(0.069)	(0.192)
Uses pesticides for agricultural production	52%	50%	36%	57%	67%	54%
	0.024	(0.036)	(0.052)	(0.059)	(0.068)	(0.192)
A member received some work training during the last year	7%	10%	8%	11%	12%	0%
	(0.012)	(0.022)	(0.029)	(0.041)	0.050	0.000
Received agricultural technical assistance	1%	1%	0%	2%	0%	0%
	(0.006)	(0.005)	0.000	(0.014)	0.000	0.000
Received agricultural credit	10%	8%	7%	7%	10%	27%
	(0.014)	(0.019)	(0.028)	(0.030)	(0.040)	(0.171)
Received non agricultural credit	3%	2%	3%	0%	1%	49%
	(0.008)	(0.010)	(0.020)	0.000	(0.012)	(0.296)

Source: Own calculations using the 1998 LSMS survey.

Only recently have improved management practices been transferred from national research organizations to plantain farmers. The IPM-CRSP and PROMSA[21] projects are the two main efforts to transfer technologies in plantain-producing areas. Both efforts are funded by international organizations and operated mainly by INIAP technicians. The IPM-CRSP is currently evaluating the most efficient diffusion techniques for IPM technologies in plantain farms. Alternatives to farmer field schools used previously with IPM technologies in potatoes are under study. Some preliminary results have indicated that there is good response of farmers to visual aids, such as photographs of technology use, instead of on-farm experiments (Harris et al, 2002/2003). Studies of farmer's agricultural assistance have shown that most of technical assistance in

[21] Project for Modernization of Agricultural Services (PROMSA).

the plantain belt area has been provided by PROMSA; nevertheless the same studies indicate that at least 40% of the farmers have not received any technical support (Harris et al, 2003/2003; Orellana et al., 2002).

Technology adoption can be promoted through agricultural assistance, such as technical assistance and field training. Dissemination of knowledge among farmers could be improved by increased knowledge of farmers about benefits of technologies and increased provision of credit for farmers to overcome cash constraints in agricultural production. Therefore, successful extension services can play an important role in increasing the adoption of IPM technologies.

3.8 Market integration

Institutional support and infrastructure affect the degree of market integration of farm households. In the case of plantain households, factors such as access to irrigation could increase yields during the dry season allowing surplus production for markets; technical assistance can provide crop management knowledge so farmers could improve the quality of the product and increase their market integration.[22] To be able to assess the degree of market integration of plantain households, we could only approximate quantities of production used for consumption and sales. Estimated percentage of a household's consumption[23] of plantain as a share of its production is our only proxy of market integration by farm size class.

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[22] According to Tazan (2003), in the last years, newer plantain lots have been created by farmers that have better access to irrigation for the drier seasons, technical assistance, and knowledge of sanitary practices to control pests. These plantations are mainly located in the export producing area, more commonly know as the Plantain Belt.

[23] Consumption estimates in this section are estimated using the reported portion of production used for own consumption. These estimates are rough approximations since the survey was not designed to measure agricultural variables.

Table 3.7: Plantain households own consumption and production.

Household Class	Ave Household Consumption (kg/year)	Std Err.	Number of Households[a]	Consumption (Mt)	Production (Mt)	Proportion Consumed
< 5 hectares (Ha)	480	(37)	16,819	8,067	41,395	19%
≥5 Ha < 20	520	(37)	15,005	7,799	110,145	7%
≥ 20 Ha < 100	524	(39)	11,621	6,092	136,820	4%
≥100	406	(92)	1,630	661	32,647	2%

Source: Average consumption estimates and the corresponding standard errors are obtained using the 1998 LSMS reported household consumption. Number of households and production estimates are obtained using the information of the Agricultural Census, 2001.

Larger farms have a lower proportion consumed and therefore surplus production to sell (table 3.7). Even for smaller farms, consumption of plantain is only around 20% of total yearly production. Nevertheless, greater production per year is obtained by medium scale-farms. Since we do not know the proportion of land with plantain or other crops, we use the number of farmers including those that have associated plantain with other crops. Therefore estimates of quantities of production include production that grows associated with other crops; the estimates correspond to 66% of total plantain production in Ecuador (Project SICA/MAG, 2002).

Using an INIAP survey with information on 120 plantain farmers in the “Plantain Belt” we can assess how plantain area is related to total cropped area. It is expected that the area used for plantain will have a greater proportion of monoculture plantain. According to the results of table 3.8, the smaller the farm size class the larger the proportion of plantain cropped area. As a result, smaller plantain households are more dependent for their subsistence on plantain crops. A large proportion of excess production for exports will come from medium and large farms. Furthermore, excess production for exports from small farms might be limited by the lack of commercialization channels (Orellana et al., 2002).

Table 3.8: Average hectares of plantain per farm size class.

Farm Size Class (Ha)	Num. Households	Ave. Percentage Plantain Ha.
< 5 hectares (Ha)	28	71%
≥5 Ha < 20	64	64%
≥ 20 Ha < 100	26	32%
≥100	2	51%

Source: Own calculations using the 2001 INIAP "plantain belt" farmer's survey.

3.9 Labor Use

Using the LSMS data we estimate the labor composition of farm households. Farm households may hire labor but family labor is usually an important component of labor input especially for poor rural households. Hired labor-land arrangements such as sharecropping are also available. The LSMS data results (table 3.9) show percentages of labor demand by source and farm size class. The results were obtained by only taking into account rural plantain households in the coastal region. Nevertheless, the percentages show labor distribution in the production of all agricultural crops and it are not exclusively plantain labor.

Table 3.9: Percentage of labor use by source[a]

		Farm Size Class (Ha)			
	ALL	< 5	≥5 to < 20	≥ 20 to < 100	≥100
Total Labor (jornales)	1,721,551	563,743	460,833	459,302	237,673
Temporary	29%	25.47%	31.67%	24.58%	59.82%
Family	61%	71.70%	58.51%	62.13%	16.46%
Sharecropped	7%	2.83%	8.84%	8.05%	4.09%
Permanent	3%	0.00%	0.98%	5.25%	19.63%
TOTAL	100%	100%	100%	100%	100%

Source: Own calculations from the 1998 LSMS survey. Plantain Belt survey, 2001. Agricultural Census, 2001. a. Labor demand estimates are calculated using Plantain Belt results for per hectare labor use by farm class; the total demand was estimated using total hectares of plantain land (including associated land).

The results show that plantain households depend heavily on family and temporary labor for agricultural production (table 3.9). Even in the medium farm size classes, family labor represents 59% and 62% of total labor use for farms with 5 to 20 hectares and 20 to 100 hectares of land respectively. For the largest farm size class, the most important labor source is temporary labor, comprising 60% of their annual demand for labor. Smaller farm size classes hire labor mostly in the rainy season when plantain production is higher (Tazan, 2003), and for this reason, temporary labor constitutes 26% of yearly demand. Permanent labor is not frequent among plantain households and it only represents 3% of total labor demand. Even for the medium and larger farm size classes, permanent labor constitutes only 5% and 20% of their annual demand.

3.10 Summary of findings

Analysis of socioeconomic characteristics of plantain and rural households indicates that the adoption of IPM technologies by plantain farmers could potentially benefit poor rural households. High poverty rates of plantain farms and high dependency on agricultural income indicates that yield improvements could lessen poverty conditions of plantain households. The importance of medium-scale farms in the production of plantain and their superior market integration indicate that producer benefits will be greater for these farms. The latter leads us to expect labor demand generation mostly from medium farm size classes. The importance of wage labor income for rural landless households indicates that benefits from income generation resulting from a labor demand increase will mostly benefit poor and low educated landless households. However, labor income is an important alternative income source for poor small farm households and therefore we expect some benefits also accruing to these households.

Chapter 4: Results and Discussion

The objective of this chapter is to present the results obtained in this study. Section 4.1 lays out the parameters needed for the empirical implementation of the economic surplus approach. Section 4.2 describes in detail the results of the technological scenarios of direct and indirect benefits of IPM adoption. Also, it contains the estimation of the distribution of economic benefits for farmers, consumers and laborers. Finally, section 4.3 indicates some equity considerations of the generation of benefits from adopting IPM technologies.

4.1 Parameters in the Economic Surplus approach.

In the present study we have three types of parameters. First, we have parameters obtained from experimental station budgets that differentiate the technologies under study. Second, we have market parameters such as elasticities of supply and demand, plantain price, and labor wage rate that reflect laborers and plantain farmers' current situation. And third, we have parameters that reflect differences in adoption rates by different farm sizes.

Technology Parameters

During 1999 to 2002, experiment plots were evaluated by INIAP technicians under the IPM-CRSP project in the Pichilingue experimental station. The experiment station is located in Quevedo in the Manabí province, within the Plantain Belt area, where plantain is most suited to grow. Data on yields, labor use, and variable costs, were collected by scientists. The data was collected from four experimental plots, each one measuring 375 square meters, for three consecutive production cycles. With this data, estimates of costs and profitability of different technologies were obtained and projected to hectares. Returns per hectare were scaled down by 10%, following CIMMYT recommendations to translate experiment to farm returns (Cabanilla, 2004, pp: 19). Partial budgets for the different technologies are displayed in table 4.1. Changes in yields and labor use are assessed by comparing the results of the different technologies with a control plot.

Table 4.1: Per hectare technology trial averages of experiment budgets.

Trial Averages	Control	IPM+ Fungicides	IPM - Fungicides	Export Companies
Yields (kg)	7,372	16,254	14,796	9,641
Gross Trial Benefits[a]	1,202	2,651	2,413	1,572
Labor Costs	195	322	345	256
Other Variable Costs	26	259	105	230
Total Variable Costs	220	581	450	486
Net Trial Benefits	982	2,070	1,963	1,086

Source: INIAP Pichilingue experiment station budgets. Values projected to hectares.
a. Average gross trial benefits are calculated with a price per plantain box (50 pounds) of 3.7.

The estimated average production for monoculture plantain farms from census data is approximately 4,000kg/ha. Analyzing the Plantain Belt survey[24]production averages of plantain farms are estimated at approximately 6,000kg/ha. Therefore trial production estimates from table 4.1 are comparable to values per hectare for monoculture production.

Although we study three technologies, economic analyses of trial technologies budgets indicate that Export Companies recommendations are dominated by the two IPM treatments (Suarez-Capello et al, 2001/2002).

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[24] The available variable from the Plantain Belt survey was gross income from production. To compare, we transform into production yields using a price value, reported in the same survey, of $3.5 for a box of 50 pounds (Orellana et al, 2002: pp: 98).

IPM – Fungicide Scenario (IPM-F)

Results for IPM technology with no fungicides show that its adoption doubles yields compared to traditional farm practices. However, IPM-F requires an increase in variable costs by 104%. Although there is a significant increase in variable costs, adopting farmers will increase their profits due to decreasing per unit costs of production. Use of IPM-F requires a per hectare labor demand increase of 77%.

IPM + Fungicides Scenario (IPM+F)

Budgets for IPM + fungicides show a variable cost increment of 163% respect to the control plot. Higher costs than IPM – F are due to the input mix change from labor to fertilizer. Thus, labor demand requirements are 12% lower than IPM-F with the use of this technology. However, the use of this technology produces 19% higher increment in yields than IPM – F. A summary of the technological parameters is presented in table 4.2.

Table 4.2: Summary of technological parameters for the empirical simulation[a]

Variable	IPM - F	IPM + F
Variable Costs $E(C)$	104%	163%
Yields $E(Y)$	101%	120%
Labor (*jornales*) δ	77%	65%

Source: Pichilingue experiment station budgets.
a Proportional % change with respect to the control plot

In this study we have assumed that proportionate changes of technology use do not differ by FSC. Nonetheless, assuming that technology parameters do not vary by FSC infers that farmers in different FSC face the same cost function, a rather strong assumption. Absence of detailed farm household production data has limited our ability to address this issue. However, the parameters of table 4.2 can be used in the economic surplus approach to estimate the economic benefits of the potential adoption of IPM technologies. The estimated results can be useful for priority setting purposes.

In ex-ante studies proportionate changes in yields and input costs are often calculated using experiment data. Nevertheless, the use of experiment data, from controlled farm environments, can potentially overestimate the benefits for adopting farmers of new technologies. Conservative practices scale down technology trial yields to approximate yields under an uncontrolled farm environment (Alston, et al., 1995; Maredia, Byerlee and Anderson, 2000). In the present study, experiment yields have been scaled down by scientists at 17%. The 17% reduction was chosen to account for loses at harvest time such as discounting the weight of the rachis, fruit malformation, and damages to the fruit, recommended by extension technicians in the Plantain Belt area (Cabanilla, 2004, pp: 19).

Market parameters

Market parameters reflect current plantain market conditions and do not vary by farm size class. The main market parameters used in this study are the local and ROW elasticities of supply and demand for plantain. Although the local supply elasticity of plantain could vary by farm size class, we look only at the aggregate market elasticity. No known studies have estimated the elasticity of supply and demand of plantain. However, some priority setting studies have approximated their values. Based on Palomino and Norton (1992), the local plantain elasticity of supply is assumed to be 0.4, while the local plantain elasticity of demand is assumed to be -0.3.

In most parts of the country, plantain is produced as a staple, and it is a basic dietary element of households on the Coast. Even in plantain exporting areas, most production comes from farms with less than 20 hectares of land. Farmers with less than 5 hectares produce for own consumption and sell the remaining production. In this case, theory suggests a less responsive supply; however in the long run, farmers have increased ability to adjust to market changes and most commodities supply elasticities are expected to be greater than one. Nonetheless, for priority setting or ex-ante studies the time frame for elasticities is intermediate rather than long-run (Alston et al, 1995). Economic theory suggests that an in the case of perennial crops such as plantain, supply elasticities are smaller than for other crops because specific capital (in this case trees) is fixed for a time (Alston et al, 1995).

Although we expect the elasticity of supply to be lower than one, the use of an inelastic commodity supply together with a large research induced supply change may cause an overestimation of producer benefits. Economic surplus measures used in our study assume linear supply and demand functions that have small changes around an equilibrium point. Therefore, the nature of the supply shift affects the size of producer benefits. In this case, the potential research induced supply change is quite large.[25] Alston et al (1995, pp: 60) show that in the economic surplus approach with an inelastic supply "the proportionate cost reduction implied by a rightwards shift of supply can be unreasonable, giving rise to overestimated results." To avoid this problem Alston et al (1995) suggest the use of a supply elasticity of 1, most of all when information available about the supply curve is limited.

[25] As we discuss in latter sections, an elasticity of supply of 0.4 causes a 71% shift in the supply curve in the case of IPM-F, the estimated shift for IPM+F is 80%. The size of the shift of the supply curve causes the intercept of the supply after adoption of new technologies to fall under the zero price level. In this case the producer surplus will be overestimated by the area that falls below the zero price level.

Few studies report demand estimates for the plantain demand elasticity. Nevertheless, studies of the local demand elasticity of banana indicate a value of -0.86.[26] Banana demand elasticities are more elastic than plantain. Banana is not a staple crop and while plantain might be considered an inferior good in the areas where it is mostly consumed, banana has many characteristics of a normal good. As supply increases, we do not expect local consumption to be highly responsive to price changes. A local own-price elasticity of demand of -0.3 fits with what we would expect for local plantain demand.

Since we are using an excess-demand-supply framework, we also need parameters for the ROW elasticities of supply and demand. Since the ROW is the aggregated excess demand and supply of the rest of the trading countries, we expect the ROW supply and demand elasticities to be more elastic than the local supply and demand elasticities. The average of supply elasticities for world banana trade is 1.08.[27] Plantain world trade is relatively new and efforts to increase world exports are recent. It seems reasonable in the case of plantain to use a ROW supply elasticity of 1. For the ROW own price elasticity of demand, the average for various countries is 0.86 for banana.[28] However, banana is a traditional export crop for Ecuador and other countries, and the international market and demand for imports is larger than for plantain. In the case of the ROW own-price elasticity of demand, a value of -0.6 seems reasonable considering the information available for banana.

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[26] Implications of Changes in the EU Banana Regime for World Banana Trade. Retrieved from <www.fred.ifas.ufl.edu/courses/ AEB6533/Readings/BANANAS.DOC>.
[27] Ibid.
[28] Ibid.

For the initial equilibrium quantity we use the estimated monoculture plantain production of 213,728 MT. The quantity was based on the 2001 agricultural census data (table 2.1). We use monoculture production rather than all plantain production (including associated crops) to be more consistent with the conditions under which the technologies were developed.[29]

According to FAO statistics, in 2001 86% of the production was consumed locally. The economic benefits estimation is made at the international market price. Market price for producers of plantain is assumed to be 160 US$[30] per metric ton, the average price for producers in 2001 (Orellana et al., 2002, pp: 98; BCE, 2003c).

The initial quantity of labor demand used [31]is approximately 767,000 *jornales* (daily-labor) in a year (table 2.3). The estimations of per hectare labor-day use in a year were obtained from the Plantain Belt survey of 120 farmers. The estimates of labor-day yearly use were then combined with the estimated hectares of plantain in the area. Labor wage is assumed to be $5 per jornal.[32] Producer price and labor wage rate do not vary by farm size class. The discount rate used to obtain net benefits over time for the economic surplus is 4%. The rate is an average of the last two years passive interest rate reported by the Central Bank of Ecuador (BCE, 2004).

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[29] Also, looking at the budgets provided by experimental stations and the Plantain Belt survey, we found that values for costs and production are comparable with the monoculture production.
[30] The value of a metric ton was estimated at the current export price. Each export box weights 50 pounds and its official price is $3.9, however real producer price is $3.5. (See Orellana et al., 2002, pp: 98).
[31] See section 2.7 for limitations of the estimations of labor demand.
[32] The value of a jornal (labor-day)varies across the country and depending on the crop produced. The value of US$5 is an average of the observed field rates for plantain labor in the plantain belt area.

Adoption Parameters

IPM technologies are new to plantain farmers and information about IPM adoption is not available. INIAP technicians conducted a survey to extension workers of the Plantain Belt area to estimate the likelihood of adoption of IPM technologies. According to the results, the maximum expected rate of adoption of IPM technologies among farmers is 30% (Cabanilla, 2004). Use of IPM technologies in Ecuador is recent and there is little or no information on adoption rates for these technologies.

Adoption rates vary according to the type of commodity and the region's socioeconomic characteristics. For crops like cassava, grown in the same socioeconomic environments as plantain in Colombia and Ecuador, rates of adoption of improved management practices in Colombia have been estimated to be up to 30% of farmers (CIAT, 1997). For different socioeconomic environments such as the highlands in Colombia, adoption of IPM for beans has been estimated to be 18% - 28% by the CIAT–ICA research studies (CIAT,1997). A 30% adoption rate for plantain IPM practices seems feasible.

Increases in labor costs and socioeconomic factors will be determinants of IPM adoption. Nevertheless, most labor in plantain is occasional labor, and increased yields during the rainy season compensate for the increased labor costs; during dry season, family labor is likely to be used, primarily by resource poor farmers. However, from section 3.7, we learned that FSC farmers differ in their socioeconomic characteristics; these results led us to believe that adoption rates may vary by farm size class.

In chapter three we investigated average use of improved fertilization and pesticide by FSC. We also suggested that the use of fertilizers and pesticides can give an approximation of farmers' likelihood of adoption of IPM technologies. To approximate differences in adoption rates by FSC, we use farmers' unconditional probability of using improved farm practices, such as fertilization. In this case, the average use of fertilizer is the approximation of the probability of using fertilizers, not conditional on any specific factor, for example having low levels of education. However, adoption of improved management practices (such as fertilization) is conditional on factors such as education, agricultural services, etc. Conditional probabilities therefore indicate the FSC probability of adopting improved farm practices conditional on, for instance, having received agricultural assistance.

Estimates of unconditional probabilities of using fertilizer by FSC are a good approximation for differences in adoption rates necessary for the economic surplus approach. However, the use of conditional probabilities of adoption is important for agricultural research targeting. In research targeting the interest is to identify the specific factors that encourage or discourage the adoption of new management practices. However, the present is an ex-ante study of the potential benefits from adoption of IPM. Unconditional probabilities of adoption by FSC serve the purposes of this study.

The purpose of this section is to describe characteristics of fertilizer and pesticides users to understand what factors might affect IPM technology adoption. To understand the socioeconomic differences among users and non users of fertilizers and pesticides, we summarize variables and perform tests on the differences between the two groups. Summary statistics from the LSMS data are presented for the various farm household samples (all Ecuadorian farms, coastal farms, Ecuadorian plantain farms and coastal plantain farms). Differences in means between adopters and non-adopters are presented.

We also discuss findings from appendix 3, a probit model of the determinants of fertilizer and pesticide use. The sample used for the probit estimates in the case of fertilizer is the Ecuadorian plantain sample, and for pesticides the probit estimates are obtained from the Ecuadorian farm sample.[33]

Fertilizer Use

Summary statistics for users and non-users of fertilizers in the country and variable descriptions are presented in table 4.3. Educational levels of farmers in Ecuador are generally low, there is no significant evidence indicating that education influences adoption/use of fertilizers (Appendix 3). However, it is more frequent to find medium education levels among users of fertilizers than non users (see section 4.3).

Agricultural assets can be an indicator of household wealth. For all farm types, the value of agricultural equipment is higher for users than non users of fertilizer. Furthermore, increased value of agricultural equipment increases fertilizer adoption (Appendix 3).

[33] Chow tests on the differences of the probit coefficients with different farm samples were performed. In the case of fertilizers, results indicated that there is no difference between the coefficients obtained from the Ecuadorian plantain sample and the coefficients of the coastal plantain sample. For pesticides we did not find significant differences in the coefficients on the Ecuadorian farm and the coefficients of other samples, therefore coefficients are obtained from the Ecuadorian farm sample.

Table 4.3 Characteristics of Users and Non Users of Fertilizers in Agricultural Productiona

	All Farmers		Coastal Farmers		Plantain Farmers		Coastal Plantain Farmers	
	Non-User	User	Non-User	User	Non-User	User	Non-User	User
# of Households	1259	685	312	256	345	106	155	77
Household Structure								
Household Size	4.9	5.2*	5	5	5.2	4.8	5.2	4.9
	(0.081)	(0.105)	(0.156)	(0.167)	(0.170)	(0.275)	(0.231)	(0.316)
Dependency Ratio[b]	25%	**20%**	24%	**18%**	23%	17%**	22%	17%
	(0.008)	(0.009)	(0.016)	(0.015)	(0.016)	(0.023)	(0.021)	(0.027)
Human Capital [c]								
Low Education	80%	80%	80%	77%*	82%	78%	83%	80%
	(0.007)	(0.009)	(0.011)	(0.015)	(0.011)	(0.023)	(0.014)	(0.023)
Medium Education	17%	16%	17%	20%*	16%	19%*	15%	17%
	(0.005)	(0.007)	(0.009)	(0.012)	(0.008)	(0.016)	(0.011)	(0.017)
High Education	3%	4%	3%	3%	3%	4%	2%	3%
	(0.003)	(0.004)	(0.004)	(0.005)	(0.005)	(0.012)	(0.006)	(0.011)
Capital Assets and Input Access								
Value Ag. Equipment	130	**886.3**	137.5	1336.4**	136.9	1669.7*	144.3	1410.4**
($/year)	(26.1)	(247.4)	(39.1)	(554.2)	(21.7)	(926.7)	(30.4)	(1001.6)
Labor Expenses	66	**270.4**	137	328.7*	73.2	**368.4**	75.7	309.1
($/year)	(22.1)	(38.6)	(65.6)	(72.4)	(13.2)	(102.4)	(18.2)	(109.9)
Heads of Cattle	3.2	3.7	3.9	3.6	5.3	8.7	5.2	6.7
	(0.3)	(0.5)	(0.7)	(1.0)	(0.7)	(2.3)	(1.0)	(2.3)
Infrastructure								
Electricity hook up	76%	**86%**	70%	**80%**	57%	**69%**	57%	68%**
	(0.010)	(0.009)	(0.021)	(0.018)	(0.025)	(0.039)	(0.033)	(0.045)
Water Pipe	31%	29%	10%	16%**	11%	9%	4%	4%
	(0.013)	(0.017)	(0.017)	(0.022)	(0.015)	(0.025)	(0.015)	(0.021)
Institutional Support								
Agricultural Credit	3%	**15%**	5%	**19%**	3%	**15%**	4%	16%**
	(0.006)	(0.015)	(0.013)	(0.026)	(0.011)	(0.039)	(0.015)	(0.045)
Technical Assistance	0%	**3%**	0%	3%**	0%	2%	0%	2%
	(0.002)	(0.007)	0.000	(0.012)	0.000	(0.012)	0.000	(0.014)
Farm Size Classification								
<5 ha	69%	71%	60%	64%	40%	32%	46%	35%
	(0.014)	(0.018)	(0.030)	(0.032)	(0.031)	(0.051)	(0.043)	(0.058)
5 to 20 Ha	15%	20%*	24%	25%	28%	41%**	31%	44%*
	(0.011)	(0.016)	(0.026)	(0.029)	(0.029)	(0.053)	(0.040)	(0.060)
20 to 100 Ha	13%	**7%**	13%	8%*	30%	20%**	22%	18%
	(0.009)	(0.010)	(0.020)	(0.018)	(0.028)	(0.041)	(0.035)	(0.044)
>100 ha	2%	2%	3%	2%	2%	7%**	2%	4%
	(0.005)	(0.005)	(0.009)	(0.008)	(0.007)	(0.024)	(0.010)	(0.021)

Source: Own calculations using the 1998 LSMS survey

a. Standard errors below the corresponding coefficient.

b. Number of members aged below 15 or above 64 divided by the number of individuals aged 15 to 64, expressed as a percentage.

c. Low levels of education are defined as households most educated member having at most a primary school degree which is equivalent to middle school degree, medium education is equivalent to at most a high school degree and high education equivalent to a university degree.

* Means are significantly different from non users at a 10% level, **significantly different at a 5% level. Bold coefficients indicate means are significantly different form non users at less than 1% level.

We use public infrastructure to indicate remoteness of farm households. Some remote farm households do not have access to water and electricity services[34] unless they have good economic conditions. Also, access to water can be an indicator of access to irrigation for agricultural production. In the Ecuadorian plantain farm sample, there is evidence at the 5% level that access to electricity is greater for users than non users of fertilization. However, small evidence suggests that increased electricity access increased the adoption/use of fertilization (Appendix 3).

As we mentioned in section 3.7, various institutions provide farm households support in their agricultural production. From chapter two we learned that access to agricultural credit and technical assistance can have important impacts on adoption. For fertilization techniques, we found that agricultural credit is significantly greater for users than non users of fertilizer at a 5% level. Also, increased access to agricultural credit increases significantly the probability of adoption/use of fertilizer (Appendix 3).

Technical assistance is not common for any sample of farm households. However, in the Ecuadorian and coastal farm samples, users of fertilizers show significantly greater access to technical assistance than non users. Absence of technical assistance and extension services could slow the diffusion of information on the proper use and benefits of new technologies constraining farmers' knowledge and ex-post adoption of IPM technologies.

In section 3.6 we indicated that the rate of use of fertilizer on costal plantain farms by FSC did not show significant differences. However, individual marginal effects of each farm size class show some evidence that a larger FSC have higher probability of

[34] Access to water was defined as having a water pipe. Access to electricity was defined as having an electricity hook up.

fertilizer use (Appendix 3). Tests on the percentages of households in every FSC for users of fertilizers indicate that at the 1% level they are significantly different.

Pesticide Use

Summary statistics for the same variables are shown for users and non users of pesticides (table 4.4). Although pesticide use is on average more common among Ecuadorian farms than fertilizer, resource poor farmers might still be constrained in using pesticides due to cost.

As for fertilizers, dependency ratios are significantly smaller for users of pesticides. Higher dependency ratios significantly decrease the probability of pesticide use (Appendix3). Education levels are not significantly different for users and non users of pesticides.

Test on the means of agricultural assets among users and non users of pesticide indicate that users of pesticide are wealthier. Tests on the average dollar value of agricultural equipment indicate significantly higher value for users than non users of pesticides. However, variables for agricultural assets did not show significant effects on the determinants of pesticides use (see Appendix 3)

Access to agricultural credit is more frequent among users of pesticides. We found that credit access significantly increases the probability of pesticide use (Appendix 3). Technical assistance is almost nonexistent for all types of households whether they use or not use any specific management technique.

Table 4.4 Characteristics of Users and Non Users of Pesticides in Agricultural Production[a]

	All Farmers		Coastal Farmers		Plantain Farmers		Coastal Plantain Farmers	
	Non-User	User	Non-User	User	Non-User	User	Non-User	User
# of Households	1164	780	276	292	274	177	119	113
Household Structure								
Household Size	4.7	**5.4**	4.7	5.2**	4.9	5.4*	4.7	5.4*
	(0.082)	(0.101)	(0.169)	(0.154)	(0.184)	(0.228)	(0.254)	(0.271)
Dependency Ratio[b]	25%	**19%**	25%	**17%**	23%	18%	22%	19%
	(0.009)	(0.008)	(0.019)	(0.012)	(0.018)	(0.018)	(0.025)	(0.022)
Human Capital [c]								
Low Education	79%	**82%**	79%	79%	80%	81%*	81%	83%
	(0.007)	(0.008)	(0.013)	(0.013)	(0.014)	(0.015)	(0.018)	(0.016)
Medium Education	18%	**15%**	18%	19%	17%	16%	16%	15%
	(0.006)	(0.007)	(0.009)	(0.011)	(0.010)	(0.012)	(0.013)	(0.013)
High Education	4%	3%*	3%	3%	3%	3%	3%	2%
	(0.003)	(0.004)	(0.005)	(0.004)	(0.006)	(0.007)	(0.008)	(0.007)
Capital Assets and Input Access								
V. Ag. Equipment	128.7	**826**	110.6	1220.6**	140.1	1119.3	164.1	987
($/ year)	(27.4)	(227.4)	(40.6)	(490.3)	(60.6)	(594.9)	(93.3)	(679.2)
Labor Expenses	72.6	**245.3**	173.1	273.7	99.7	229.7**	130.9	178.4
($/year)	(25.3)	(33.5)	(79.8)	(58.5)	(46.5)	(39.4)	(71.5)	(33.1)
Heads of Cattle	2.5	**4.6**	2.4	5.0**	4.4	8.6**	3.8	7.7*
	(0.3)	(0.5)	(0.7)	(1.0)	(0.9)	(1.5)	(1.2)	(1.5)
Infrastructure								
Electricity hook up	81%	78%**	76%	73%	62%	58%	65%	56%
	(0.008)	(0.012)	(0.018)	(0.021)	(0.025)	(0.035)	(0.033)	(0.042)
Water Pipe	34%	**24%**	12%	14%	12%	8%	5.70%	2.90%
	(0.013)	(0.015)	(0.019)	(0.019)	(0.018)	(0.018)	(0.019)	(0.014)
Institutional Support								
Agricultural Credit	3%	**15%**	5%	**18%**	4%	10%**	4%	12%*
	(0.006)	(0.014)	(0.014)	(0.023)	(0.014)	(0.026)	(0.020)	(0.031)
Technical Assistance	0%	**3%**	0%	2%*	1%	0%	1%	0%
	(0.002)	(0.007)	(0.004)	(0.010)	(0.006)	(0.004)	(0.008)	(0.004)
Farm Size Classification								
<5 ha	75%	**63%**	67%	58%*	45%	**28%**	54%	**31%**
	(0.014)	(0.019)	(0.030)	(0.031)	(0.036)	(0.039)	(0.049)	(0.046)
5 to 20 Ha	13%	**23%**	23%	26%	27%	36%*	30%	40%
	(0.011)	(0.016)	(0.027)	(0.027)	(0.033)	(0.041)	(0.046)	(0.049)
20 to 100 Ha	10%	12%	9%	13%*	25%	31%	14%	27%**
	(0.008)	(0.012)	(0.016)	(0.021)	(0.028)	(0.038)	(0.031)	(0.044)
>100 ha	2%	2%	2%	2%	2%	5%	2%	3%
	(0.004)	(0.005)	(0.009)	(0.008)	(0.010)	(0.015)	(0.014)	(0.014)

Source: Own calculations using the 1998 LSMS survey

a. Standard errors below the corresponding coefficient.

b. Number of members aged below 15 or above 64 divided by the number of individuals aged 15 to 64, expressed as a percentage.

c. Low levels of education are defined as households most educated member having at most a primary school degree which is equivalent to middle school degree, medium education is equivalent to at most a high school degree and high education equivalent to a university degree.

* Means are significantly different from non users at a 10% level, **significantly different at a 5% level. Bold coefficients indicate means are significantly different form non users at less than 1% level.

From table 3.6 we found that the use of pesticides is widespread among all farm samples in Ecuador. When considering coastal plantain farms, there is a significantly lower percentage of farms using pesticides within the smaller farm size class. Also, within farms with 20 to 100 hectares of land, there are significantly higher rates of users of pesticides than non users. However, evidence shows that the rate of fertilizer use is different in every FSC. Adjusted Wald Test on the joint significance of the percentage of users of pesticides by FSC indicates that, at every level of significance, there are significant differences on the rate of pesticide use by FSC. Unlike what we found previously for fertilizer use, a larger FSC decreases the probability of use of pesticides (Appendix 3).

Both fertilizer and pesticide users are characterized by higher levels of education. However, education is not affecting the probability of use of both farm practices. Wealthier households use both fertilizers and pesticides more frequently. Differences in wealth characteristics of fertilizer users are also reflected in higher access to electricity. Weak agricultural institutions can be a constraint to farmers adopting IPM technologies. We have observed that agricultural credit significantly increases farmers' use of fertilizer and pesticides. Technical assistance and credit provision are important determinants of new technology adoption.

Medium and larger FSC have higher percentages of use of fertilizer and pesticides (table 3.6). Nevertheless, we find that larger FSC have higher probability of use of fertilizers, and lower probability of adoption of pesticides. These results indicate that pesticides use is conditional on different socioeconomic factors then fertilizer use.

In theory, socioeconomic characteristics of fertilizer users are closer to what we would expect of new agricultural technology adopters. Fertilizer use is less widespread and requires more technical knowledge; differences in use of fertilizer might reflect farmer access to farm management knowledge. Also, we expect that larger farms have greater access to new IPM technologies. Therefore, we will approximate FSC differences in adoption rates with the average use of fertilizer by plantain farmers in the coastal region by FSC (table 4.5).

Table 4.5: Fertilizer adoption rates by FSC.

FSC	Estimate.	Std. Err.	Production Share[a]	Weighted Adoption Rate
< 5 hectares (Ha)	.281363	.0491995	0.15	4.17
≥5 Ha < 20	.4195435	.0589007	0.30	12.39
≥ 20 Ha < 100	.291693	.067933	0.46	13.36
≥100	.4847761	.1922405	0.10	4.77
ALL			1.00	34.69

Source: Own estimations using the LSMS 1998 sample.
a. Production shares are calculated from our estimations of monoculture production by FSC (table 2.2)

Weighting the adoption rates to account for the production share of each FSC (table 4.6) we find that the maximum adoption rate is 35% with the current adoption rates. Recalling the elicited maximum adoption rate calculated by INIAP technicians of 30%, the estimates do not appear to be far from what would be expected.

To simulate the adoption path we use a linear approximation of a basic adoption profile as indicated by Mills and Kamau (1998). Since the technologies are ready to be adopted no research lag is included. We simulate a 15 year adoption path, with a 5 year lag before maximum adoption is achieved. Estimations of the adoption path are made for each FSC using the previously estimated adoption rates for fertilizer in plantain farms.

Weighted averages of adoption per year are obtained weighting the adoption rate of each FSC by its corresponding production share (see table 4.5).

4.2 Economic benefits from the adoption of IPM technologies

In this section we calculate the potential producer benefits for two IPM technologies: (1) IPM – F, and (2) IPM + F. We will present economic surplus estimates. Then, we perform a sensitivity analysis of the aggregated economic benefits to changes in the local elasticity of supply and demand. Finally, we present the distribution of income benefits for consumers and laborers.

Results of the economic surplus analysis for plantain farmers adopting IPM technologies are summarized in table 4.6.[35] The results are estimates for a period of 15 years, at a 4% discount rate. According to the results for IPM-F, production increases approximately by 17% when maximum adoption is achieved. Net producer benefits are approximately 49 million in the case of IPM-F.

Adoption of IPM+F would induce a supply shift of approximately 16% when maximum adoption is achieved. Total net producer benefits for IPM+F adopting farmers are approximately 46.5 million. Table 4.6 contains the results from the estimation of the distribution of the net producer benefits.

Table 4.6: Estimated net producer benefits

Farm Size Class	IPM-F	IPM+F
< 5 hectares (Ha)	$5,883,374	$5,583,489
≥5 Ha < 20	$17,474,321	$16,583,627
≥ 20 Ha < 100	$18,853,352	$17,892,367
≥100	$6,736,266	$6,392,908
TOTAL	$48,947,313	$46,452,391

Estimations are made at 15 year horizon, 4% discount rate.

[35] For detailed estimation results of the economic surplus approach see Appendix 4.

To disaggregate the net producer benefits we used weighted maximum adoption rates by FSC and estimated the share of net producer benefits for adopting farmers. For instance, for the smallest farm size class, the weighted maximum adoption rate is 4.17 (table 4.5), resulting into a 12% of the supply shift coming from farms with less than 5 hectares of land (4.2/35), and therefore their share of producer benefits. For farmers with more than 100 hectares we estimate a 14% share of net producer benefits. Net producer benefits for the largest and the smallest FSC contrast with the results found for medium FSC. Farms with 5 to less than 20 hectares of land receive 36% of net producer benefits, and farms with 20 to 100 hectares of land receive 39% of net producer benefits. The assumptions of the parameters in the present study do not allow for differences on the distribution of technological benefits with the use of different technologies. However, net producer benefits in the case of IPM-F are in value 5% higher than IPM+F.

Table 4.7: Change in annual net benefits for farmers adopting IPM technologies.

Farm Size Class	Number of adopting farmers[a]	Annual Per Capita Income[b]	Change in Net Benefits per Farm	
			IPM-F	IPM+F
< 5 hectares (Ha)	2,896	255	211	200
≥5 Ha < 20	3,629	256	500	474
≥ 20 Ha < 100	2,163	353	905	859
≥100	547	1575	1,279	1,214

Benefits are estimated at a 4% discount rate.
a. Estimates for a year when maximum adoption rates per FSC are reached.
b. LSMS data income estimates are rough estimates using primary, secondary and tertiary economic activities as a proxy for income. No estimations of remittances, charities or taxes were included.

Using the maximum expected adoption rates from table 4.5, and the estimated share of the supply shift per FSC, we estimated the average change in net benefits for single year by FSC (table 4.7). Results indicate that the average change in annual benefits per farm is larger for larger FSC. Average per capita income estimates for every

FSC can also be observed in table 4.7.[36] Compared to their annual per capita income, average change in benefits for farmers with more than 5 hectares of land are significant. The largest beneficiaries are farms with more than 100 hectares increasing their income by $1,280 with adoption of IPM-F. Nevertheless, for farms with less than 5 hectares of land, results from adoption of IPM are not encouraging. In average, farms with less than 5 hectares of land add $200 to their farm income with the adoption of IPM-F.

Adoption of IPM technologies benefits laborers through increases in labor demand. When adoption of IPM- F reaches its maximum point, labor-day demand would have increased to 206,000 *jornales*, which is roughly equivalent to 686 people working full time in a single year. Nevertheless, labor income benefits are likely to be distributed among temporary workers, and a portion of the increased labor demand will be filled by family labor. However, the estimated net income for laborers, for a period of 15 years at 4% discount rate, if farmers adopt IPM-F, is $9.5 million. In the case of the IPM+F package, lower labor requirements cause 16% lower net benefits for laborers than the IPM-F scenario.

Consumer benefits are greater if farmers decide to adopt IPM+F. With the IPM-F package, incremented yield causes a 1.61% decrease in the market price. Net benefits for consumers, for a 15 year period at a 4% discount rate are estimated at $4.4 million with adoption of IPM-F. In the case of IPM+F prices decline 1.53%. Net consumer benefits are estimated at $4.2 million with the adoption of IPM+F.

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[36] For estimation statistics see welfare estimates for coastal plantain households in table 3.3.

Sensitivity analysis of the elasticity of supply and demand of plantain

We perform a sensitivity analysis of total economic benefits to changes in the elasticity of supply and demand of plantain (table 4.8). In the previous section we argue that using more inelastic supply elasticities might overestimate the size of net producer benefits. In this case we find that the estimated supply shift with a supply elasticity of 0.4 is approximately 71% in the case of IPM-F and 80% for the IPM+F, causing the estimated net producer benefits to be unreasonably high. We run into the same problem when using a supply elasticity of 0.6. We can also note that, supply elasticities lower than 0.9 estimate larger net producer benefits in the case of IPM+F. Higher sensitivity of IPM+F to supply changes are due to its larger proportional yield change compared to IPM-F, inducing a larger per-unit cost reduction (therefore larger supply shift) the lower the elasticity of supply.

As expected, using a supply elasticity of 1 and increasing the demand elasticity, causes consumers to loose 1% of their benefits. However, using an elasticity of supply lower than 1 significantly increases consumer benefits.

Table 4.8: Sensitivity analysis of the economic benefits to changes in the local demand and supply elasticities.

		$\eta_L = -0.3$		$\eta_L = -0.5$	
		IPM-F	**IPM+F**	**IPM-F**	**IPM+F**
$\varepsilon_L = 0.4$	**Consumers**	7,635,083	8,853,300	7,523,628	8,727,438
	Producers	212,010,171	245,887,239	212,142,926	246,037,824
$\varepsilon_L = 0.6$	**Consumers**	6,509,435	7,256,171	6,414,276	7,151,799
	Producers	120,742,827	134,644,075	120,856,324	134,768,971
$\varepsilon_L = 1.0$	**Consumers**	**4,389,763**	**4,167,093**	4,325,406	4,105,707
	Producers	**48,947,313**	**46,452,391**	49,023,920	46,525,369

The sensitivity of total economic benefits to changes in supply and demand elasticities reflects the necessity of specific studies to estimate their values for plantain.

If more accurate information was available on the value of the plantain supply elasticity, it would be possible to measure by how much producer benefits were overestimated.[37] However, we can find insightful information on the disaggregated distribution of economic benefits assuming that the values of the local elasticity of supply and demand are 1 and -0.3 respectively.

Distribution of consumer benefits

To find the distribution of consumer benefits we have estimated plantain consumption shares in the coastal region with the 1998 LSMS survey. We use the estimated plantain consumption shares as an approximation to the distribution of consumer benefits from adoption of IPM technologies. We distinguish among poor, extreme-poor, and non-poor urban, and rural households.

Total expenditures, calculated for different household groups (table 4.9), are estimations for 1998 consumption. The total value of regional consumption is roughly 26% of the value of total production ($43 million). Previously we mention that plantain production was significantly lowered in 1998 due to floods caused by El Niño current, in consequence domestic supply of plantain has increased by 90% from 1998 to 2001 (FAOSTAT, 2004). Furthermore, average plantain prices have increased by approximately 60% from 1998 to 2001 (BCE, 2003c). Estimates of plantain consumption do not apply for 2001; however, we can learn about the differences of consumption among the different household groups. Differences in shares of consumption by different

[37] For a detailed explanation on how different areas are measured in the economic surplus approach, with implications in the case of an inelastic supply, see Alston et al. (1995) pp:59.

household groups can help us approximate the distribution of consumer benefits (table 4.10).

Table 4.9: Coastal household plantain expenditure shares

	# Households	Ave. Expenditure	Esdr. Error	Total Expenditure	Etdr. Error	Share
Rural						
Poor	440	6.27	(0.51)	1,166,718	(117273)	0.10
Extreme Poor	306	4.09	(0.55)	604,074	(90525)	0.05
Non-Poor	251	10.94	(1.24)	1,018,478	(139390)	0.09
Urban						
Poor	475	7.58	(0.54)	2,154,065	(178587)	0.19
Extreme-Poor	115	4.38	(0.37)	346,871	(65484)	0.03
Non-Poor	899	11.42	(0.59)	5,853,251	(399435)	0.53
ALL				11,143,457		1.00

Source: Own calculations using the LSMS 1998 survey.
a. Total consumption is estimated using an exchange rate of 1 $US= 4,780 Sucres,
Total consumption are estimates using svytotal command in stata software.

Average plantain expenditures are higher for rural households, suggesting that most consumer benefits will benefit these households. Looking at the expenditure shares of each household type, urban households receive 75% of consumer benefits, while rural households receive 25% of consumer benefits. However, results indicate that approximately 30% of the consumer benefits form technology adoption will be distributed among poor and extreme-poor households. According to our estimations, rural-poor households receive 10% of consumer benefits, while the urban-poor receive 19% of consumer benefits.

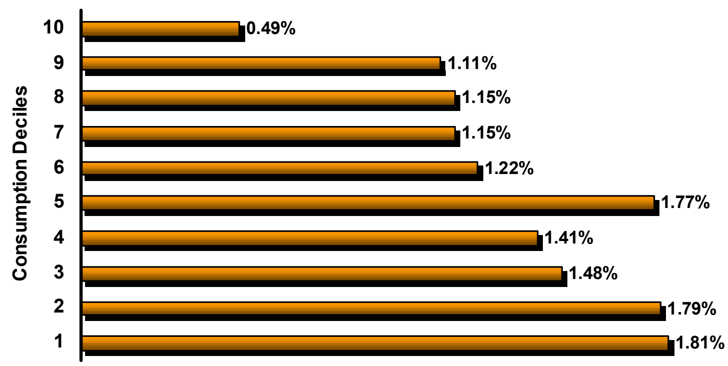
Furthermore, figure 10 indicates that poorer households have larger shares of plantain expenditure on their budgets than households in the higher consumption deciles. Therefore, a large portion of consumer benefits will be distributed among poorer urban and rural landless households.

Table 4.10: Estimated distribution of consumer benefits form adoption of IPM technologies.

Rural	IPM-F	IPM+F
Poor	459,607	436,294
Extreme-poor	237,964	225,893
Non- poor	401,211	380,860
Urban		
Poor	848,555	805,512
Extreme-poor	136,643	129,712
Non-poor	2,305,782	2,188,822
ALL	4,389,763	4,167,093

Estimates are made a 15 year horizon, 4% discount rate.

Figure 10: Average budget shares of plantain expenditure by consumption deciles in the coastal region.



Labor income distribution

In chapters 2 and 3 we indicated that IPM technologies, if adopted, could benefit poor rural households. We indicated that the poorest 10% of landless households depend on agricultural wages for 40% of their income. Furthermore, we mentioned that agricultural wages contribute as much as 24% of total household income for small and medium plantain farms in the coastal region. In this section we estimate the distribution of income benefits created by the potential increase in demand for labor due to the adoption of IPM technologies.

To disaggregate the results obtained through the economic surplus, first we estimate total income shares from the different sources for poor, extreme-poor, and non-poor rural coastal households (table 4.11). Then, poverty rates for different rural household groups are used to estimate the final distribution of net agricultural income for rural households. We differentiate between rural landless and the various farm size classes.

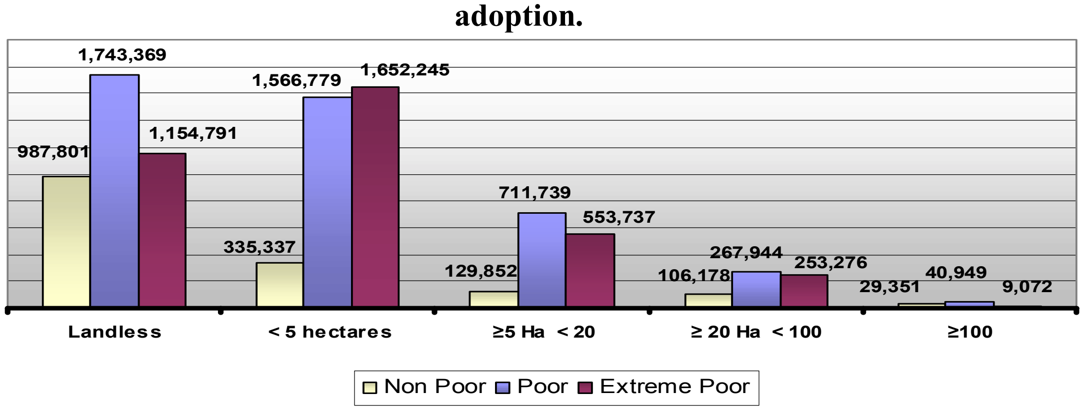
Table 4.11: Total rural agricultural wage income and poverty rates for rural coastal households.

Welfare	# of Households	Total Ag. Wage Income	Stdr. Error	Estimated Share		
Poor	440	11,449,617	(1710070)	0.45		
Extreme-Poor	306	9,578,730	(1250455)	0.38		
Non-poor	251	4,199,691	(945680)	0.17		
ALL	997	25,228,038		1.00		
			Poverty Rates			
Poor	Landless	<5 hectares	≥5Ha< 20	≥20Ha<100	≥100	Total
Extreme-Poor	40.3%	36.2%	16.4%	6.2%	0.9%	100%
Non-poor	31.9%	45.6%	15.3%	7.0%	0.3%	100%
ALL	62.2%	21.1%	8.2%	6.7%	1.8%	100%

Source: Own estimations using the 1998 LSMS survey.

We use the total agricultural wage income shares to distribute labor income among the poor, extreme-poor, and non-poor households. Then we use poverty rates of the different household groups to redistribute labor income benefits. Results for the desegregation of labor income benefits are displayed in figure 11.

Figure 11: Distribution of labor income benefits from IPM technology adoption.



Results indicate that, for a 15 year period at a 4% discount rate, approximately $6.1 million are distributed among poor and extreme-poor landless households and small farms. Extreme-poor households accrue 38% ($3.6 million) of net labor income benefits from adoption of IPM technologies. Labor income benefits for extreme-poor landless laborers amount to 1.2 million; extreme-poor farms with less than five hectares receive $1.7million in labor income benefits. However, it is important to notice that for small and medium-scale farms, family labor represents a large percentage of total labor used in plantain production (see section 3.9); therefore most income benefits for landless households will be generated from temporary labor employment. The dollar value accruing to the different household groups may therefore be overestimated. However, the shares of agricultural income distribution among the different groups of households indicate that most benefits accrue to landless rural poor and extreme poor.

Chapter 5: Conclusions and Recommendations

Summary of Findings

Results indicate there would be significant benefits for farmers and landless laborers from adoption of IPM. The change in net producer benefits for farmers, over a period of 15 years at a 4% discount rate, in the case of IPM-F and IPM+F are estimated at $49 million and $46.5 million respectively. Although benefits with both IPM technologies are significant, costs associated with the implementation of the technologies might slow adoption of new technologies.

Given that IPM technologies have just been released, adoption rates had to be projected in order to disaggregate the total economic benefits. Analysis of pesticide and fertilizer use provided information about socioeconomic characteristics of farmers that might influence the adoption of IPM technologies. Plantain farmers with lower dependency rates, higher value of agricultural equipment, higher access to agricultural credit, and larger landholdings are found to be more likely to adopt IPM technologies.

Projected adoption rates and the current plantain land distribution indicate that 36% and 39% of adoption benefits of technologies will accrue to farmers with 5 to 20 hectares and farmers with 20 to 100 hectares of land respectively. However, annual additional incomes per farmer, at a year when maximum adoption rates are reached, are greater for larger FSC. Results indicated that, in average, adopting farmers with more than 100 hectares of land would gain approximately $1,280 in additional yearly income; while additional yearly income for farmers with less than 5 hectares of land is estimated at approximately $200. These results, compared to average per capita incomes per FSC indicate that adoption of technologies would increase the welfare of medium and large plantain households.

Reduction in the price of plantain induced by adoption of IPM technologies will benefit mostly urban and rural landless households. Results indicate that 75% of consumer benefits are distributed among urban households. However, poor rural households receive 10%of consumer benefits and poor urban receive 19% of consumer benefits. Furthermore, expenditure budget shares of plantain by consumption deciles in the coastal region indicate that in general poorer households spend a higher proportion of their budget on plantain and will greatly benefit from a plantain price reduction.

In a year, when maximum adoption rates are reached, 206,000 and 173,000 *jornales* are generated by increased labor demand from IPM-F and IPM+F adoption respectively. Furthermore, benefits generated by employment generation mostly benefit poor rural landless and small farms. We found that 45%, 38% and 17% of agricultural wage income generation accrues to poor, extreme-poor and non-poor households respectively. Poor rural landless households benefit the most, receiving 18% of total income generation.

Policy Implications

Agricultural development in Ecuador has mostly been directed towards traditional export crops. Increases in plantain demand in the international market have been gaining importance for Ecuadorian plantain exports. Currently, Ecuador is the second most important provider of plantain to the United States, the most important world importer of the crop. Development of plantain as an export crop has been constrained by its vulnerabilities to insects and diseases. A successful transfer of IPM technologies to farmers could potentially increase plantain yield and fruit quality to secure Ecuadorian exports in the international market.

Plantain production also provides an important income source for poor and landless households in the rural Ecuadorian coast. Low education rates and high dependence on agricultural production among plantain farmers indicate that they are especially vulnerable to fall into poverty. Investment in dissemination of IPM technologies could improve welfare conditions of vulnerable rural households.

To achieve high adoption rates, primarily among farms with less than 5 hectares, it is necessary to improve the provision of agricultural services, which can potentially offset small farmers' disincentive to search information about new technologies. Most farmers in the coastal region do not have any access to technical assistance and agricultural credit. Diffusion of information to farmers about the economic benefits of the technologies is essential to achieve high adoption rates. Moreover, it is important that farmers receive technical assistance about the correct application of technology packages in plantain crops. Also, for small farmers to receive technological benefits it is necessary to create accessible commercialization channels.

Larger adoption rates of IPM technologies could potentially create important employment opportunities for the rural poor. Extreme poor and poor landless households largely depend on agricultural wage for their subsistence. Also, agricultural labor provides an important alternative source for small poor farm households. Successful diffusion of information to farmers about technology benefits could improve adoption rates and therefore the conditions of poor households for whom agricultural labor provides improved welfare opportunities.

Implications for Further Research

Research on the benefits of agricultural technologies for plantain is almost inexistent. More comprehensive studies about the impact of plantain technology research on the poor are necessary to target poverty reduction in rural coastal areas of Ecuador. The present study provides important information about the profile of plantain farmers and offers insights into the potential of technology to target poor households. However, limited detailed economic information on plantain farms has prevented us from drawing further conclusions about linkages between technology adoption and the welfare of rural households. Household production budgets along with socioeconomic information of plantain households could provide enough resources to implement a multimarket analysis of the multiple linkages of technology benefits and the welfare of households. The present study is also limited in is assumptions of the supply response of plantain farms. Studies aimed to fill the information gaps of the plantain market would be a major step towards a better understanding of agricultural research benefits for the poor.

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Appendix 1: LSMS sample distribution among the different household types

Table A1.1 shows the regional distribution of the LSMS sample. **Rural households** in the 1998 LSMS were defined as households living in areas with less than 5,000 people or living in urban peripheral areas. The survey contains information of 5693 households from the three regions of the country: (1) Costa (coastal), (2) Sierra (highlands) y (3) Oriente (oriental). Table A1 shows that the majority of households in the sample are urban households (60%). The coastal region contains 54% of the sampled households, however most households are urban (36%).

Table A1.1. Sample Regional Composition by Urban Rural

pweight: fexp Number of obs = 5693
Strata: region Number of strata = 3
PSU: <observations> Number of PSUs = 5693
Population size = 2431638.2

REGION	Urban	Rural	Total
COSTA	36%	18%	54%
SIERRA	24%	20%	43%
ORIENTE	0	2%	3%
Total	60%	40%	100%

Key: cell proportions
Pearson:
Uncorrected chi2(2) = 210.9477
Design-based F(1.38, 7842.06)= 121.5324 P = 0.0000

For the purpose of this study, **farm households** are households that reported to have land (owned, rented or sharecropped) devoted for the production of an agricultural crop (either for sell or own consumption). In the country there are 1952 households that have land devoted to agricultural production. **Plantain households** are households that have reported having plantain crops. In the survey there are 451 households in the entire country that have reported to grow plantain. However, no information is available concerning the relative distribution of land between crops. Productivity estimates can not be made. The LSMS survey was designed to measure living conditions of households, not agricultural production; therefore, any agricultural production or input use estimation are rough approximations using the available data.

Table A1.2 shows the results of the regional distribution by landless and farm households. Farm households have been subdivided in four farm size class (FSC) categories. Although most landless households are urban, rural landless households contain 13% of the households in the sample. Farm households are mostly households with less than 5 hectares of land (22%) and most of them are located in the Sierra region (14%). Farm households located in the coastal region are approximately 11%.

Table A1.2. Household regional distribution by household type.

pweight: fexp — Number of obs = 5693
Strata: region — Number of strata=3
PSU: <observations> — Number of PSU=5693
Population size = 2431638.2

	Landless		Farm Size Class (Ha)			
REGION	Urban	Rural	<5	5 to 20	20 to 10	>100
COSTA	35%	7%	7%	3%	1%	0%
SIERRA	21%	5%	14%	2%	1%	0%
ORIENTE	0%	1%	0%	0%	1%	0%
Total	56%	13%	22%	5%	3%	1%

Key: cell proportions
Pearson:
Uncorrected chi2(10) = 931.0263
Design-based F(8.34, 47445.18)= 107.1484 P = 0.0000

According to the distribution of plantain households, 38% of Ecuadorian plantain households are households with 5 hectares of land or less, while only 3% have larger than 100 hectares of land (table A1.3). In the LSMS sample most plantain households are located in the Coast region (72%) which is consistent with available census statistics. We have selected as the **region under study** the coastal region since it is the region that contains most of the production of plantain crops; therefore, when restricting the results to plantain households we only consider the 231 households located in the coastal region. Although we can't use the information for detailed information of agricultural production, we are able to draw conclusions about the characteristics of the different plantain FSC by looking at the LSMS sample.

Table A1.3. Plantain household regional distribution by Farm Size Class.

pweight: fexp Number of obs = 451
Strata: region Number of strata = 3
PSU: <observations> Number of PSUs = 451
Population size = 154568.42

	Farm Size Class (Ha)				
REGION	<5	5 to 20	20 to 10	>100	Total
COSTA	30%	25%	14%	2%	72%
SIERRA	5%	4%	3%	1%	12%
ORIENTE	3%	2%	10%	1%	16%
Total	38%	31%	27%	3%	100%

Key: cell proportions
Pearson:
Uncorrected chi2(8) = 63.8372
Design-based F(6.34, 2840.23)= 11.6821 P = 0.0000

Appendix 2: Tables on the socioeconomic characteristics of plantain farmers.

Table A2.1: Ecuadorian rural household structurea.

	Rural Ecuador			Coastal Plantain Households (Ha)			
Hectares	Rural	Farm	Plantain	< 5	5 to 20	20 to 100	>100
# of Households	1999	1315	326	71	58	40	6
Head Female	15%	12%	6%	-	8%	4%	-
	(0.008)	(0.009)	(0.013)	-	(0.025)	(0.022)	-
Age of Head	49	50	51	48	51	52	66
	(0.374)	(0.427)	(0.753)	(1.469)	(1.607)	(1.737)	(3.951)
Illiterate Head[‡]	36%	35%	35%	53%	38%	11%	28%
	(0.015)	(0.017)	(0.035)	(0.065)	(0.070)	(0.052)	(0.233)
Education of Most Educated Member[b]							
Low Education	78%	83%	83%	88%	79%	83%	60%
	(0.011)	(0.012)	(0.024)	(0.043)	(0.054)	(0.064)	(0.208)
Medium Education	19%	15%	15%	12%	18%	11%	-
	(0.010)	(0.011)	(0.023)	(0.043)	(0.051)	(0.053)	-
High Education	3%	2%	2%	-	2%	6%	40%
	(0.005)	(0.004)	(0.007)	-	(0.020)	(0.042)	(0.208)
Household age composition							
Younger than 15	32%	31%	31%	35%	28%	23%	11%
	(0.006)	(0.007)	(0.014)	(0.030)	(0.028)	(0.032)	(0.048)
Age 15 to 64	57%	57%	60%	59%	68%	74%	60%
	(0.006)	(0.007)	(0.015)	(0.031)	(0.029)	(0.033)	(0.067)
Older than 64	11%	12%	9%	6%	4%	3%	29%
	(0.006)	(0.007)	(0.012)	(0.019)	(0.015)	(0.012)	(0.089)

Source: Own calculations with the 1998 LSMS.
a Standard errors in parenthesis below the corresponding estimates.
b Low levels of education are defined as households with its most educated member having at most a primary school degree which is equivalent to middle school degree, medium education equivalent to at most a high school degree and high education equivalent to a university degree.
‡ Information was not available for all household heads. As a result, sizes are smaller for this variable.

Table A2.2: Percentages of rural household members' participation in primary and secondary economic activitiesa.

	Rural Ecuador			Coastal Plantain Households (Ha)			
	Rural	Farms	Plantain	<5	5 to 20	20 to 100	>100
# of Households	2500	1671	410	97	79	48	7
Primary Activity							
Agricultural Wage	8%	7%	6%	8%	6%	6%	-
	(0.004)	(0.004)	(0.007)	(0.014)	(0.014)	(0.017)	-
Agricultural Own	26%	37%	41%	31%	38%	53%	50%
	(0.007)	(0.009)	(0.018)	(0.034)	(0.031)	(0.051)	(0.126)
Non Ag. Wage	10%	7%	5%	5%	5%	4%	9%
	(0.004)	(0.004)	(0.007)	(0.015)	(0.015)	(0.017)	(0.059)
Non Ag Own	13%	9%	8%	11%	6%	7%	12%
	(0.005)	(0.005)	(0.010)	(0.020)	(0.019)	(0.025)	(0.068)
Secondary Activity							
Agricultural Wage	1%	1%	1%	1%	1%	0%	-
	(0.001)	(0.002)	(0.006)	(0.007)	(0.006)	(0.002)	-
Agricultural Own	4%	5%	4%	4%	3%	3%	-
	(0.003)	(0.004)	(0.034)	(0.011)	(0.011)	(0.019)	-
Non. Ag. Own	1%	1%	3%	3%	2%	3%	11%
	(0.001)	0.001	(0.005)	(0.011)	(0.008)	(0.012)	(0.072)

Source: Own calculations from the 1998 LSMS.
a Primary economic activities defined as the activity that household members reported as the primary activity of the last week. Secondary activity defined as the second job of the last week. Standard errors in parenthesis below each estimate.

Table A2.3: Characteristics of the rural landless in the coastal region

	Low Education	Std. Err.	Medium Education	Std. Err.	High Education	Std. Err.
Average percentage of household members participating in primary activities						
Agricultural wage	8.1%	0.0123	1.3%	0.0055	-	-
Agricultural own	1.6%	0.0054	1.7%	0.0118	-	-
Non Ag. wage	16.6%	0.0196	20.7%	0.0242	24.2%	0.0591
Non Ag. own	16.2%	0.0166	26.7%	0.0341	35.5%	0.0931
Average percentage of household members participating in secondary activities						
Agricultural wage	-	-	-	-	-	-
Agricultural own	-	-	1.7%*	0.0234	2.5%*	
Non Ag. wage	1.1%	0.0046	1.1%	0.0054	10.1%	0.0937
Non Ag. own	3.0%	0.0085	5.3%	0.0138	7.6%	0.0422

Source: Own calculations using the 1998 LSMS data.
* Although households are not registered as having agricultural land, households reported participating in agricultural self employment as a secondary activity. Some landless households in rural Ecuador posses patio agricultural production, that although small and mostly for self consumption, may be reported as a secondary activity.

Appendix 3: Adoption of farm management practices

From the review literature in adoption we know that a farmer's decision to use different management practices are affected by factors such as human capital, household structure, physical assets, input costs, and institutional support. The objective of this appendix is to determine how farm households' socioeconomic characteristics affect the probability of adoption of fertilizer and pesticides.

Methods

Fertilizer and pesticide use are observed in the Ecuadorian LSMS survey. To analyze the decision making process of farmers, we assume that decisions are made based on their perceptions of the relative expected profits (or utility) from the use of the new management practices π_{N} compared to the profits of traditional management practices π_{T}. We define y_{i} as a dummy variable for adoption of the new farm practice that can only take values of 0 and 1. A farmer would choose to adopt the new farm practice ($y_{\mathrm{i}} = 1$) if the perception is that $\pi_{\mathrm{N}} > \pi_{\mathrm{T}}$, otherwise there would be no adoption ($y_{\mathrm{i}} = 0$). However, farmer's perceptions of the profitability of the new practices are conditional on a vector of socioeconomic factors (X).

Finally, to express the binary response model, we use a probit transformation function $F(x)$, with cumulative standard normal distribution $\phi(x)$. Therefore the probability of adoption can be formally expressed in the probit model as: $P_t \equiv E(y_t \setminus \Omega_t) = \phi(X_t\beta)$; so that $\Pr(y_t = 1) = \Pr(y_t \;\; > 0) = \Pr(X_t\beta + u_t > 0)$, where u_t is the vector of errors and is normally distributed $u_t \approx NID(0,1)$ (Greene, 1997).

We begin by performing an analysis of the significance of being a plantain farm in the probability of adoption of new farm practices. Then, we perform chow tests to evaluate the appropriate sample to estimate rates of adoption/use of the new farm practices.

Results

For each of the farm types discussed in the previous section we run probit regressions using the previous methodology for farmer's adoption of improved farm practices. Using a dummy variable for plantain farms we find that being a plantain farmer has a significant slope effect on the probability of fertilizer use in Ecuadorian and coastal farms (see regression A3.1-2). Also, double-sided t tailed test indicate that we can sustain the hypothesis that there are differences in adoption of agricultural management practices by FSC of plantain farms. For pesticide use, being a plantain farmer has a significant slope effect for the Ecuadorian and Plantain farm samples (see regression A3.1-2). However, for the costal farms sample, being a plantain farm is significant only at a 5% level. Nonetheless, in both cases the evidence is enough to maintain the assumption of different adoption rates by FSC of plantain farms.

A Chow test for the differences in parameters of the farm and plantain farm models indicates that plantain farms differ from the general Ecuadorian farm model (see table A3.2). The Ecuadorian farm and Ecuadorian plantain models indicate that there is evidence at the 5% level of significance that their estimated parameters for the probability of fertilizer use differ. However, there is not enough evidence suggesting the no equality of the parameters estimated using the Ecuadorian plantain farm model and the restricted coastal plantain farm model (see table A3.3). Results indicate that we can use the sample of Ecuadorian plantain farms instead of the coastal plantain farms to analyze the marginal effects of the different socioeconomic variables on the adoption/use of fertilizer.

For pesticides, in the case of Ecuadorian farms and Ecuadorian plantain farms, chow tests indicate that there is not enough evidence to reject the hypothesis of the equality of their marginal effects (table A3.4). The effect of the socioeconomic variables on the probability of use of pesticides does not differ across farm samples. Inferences about adoption of pesticide techniques could be drawn from the Ecuadorian farms sample that contains a larger number of observations than other restricted farm samples (coastal, plantain, and coastal plantain samples).

Table A3.1: Socioeconomic variables marginal effects on the adoption of agricultural management practices.

Fertilizer Use			Sample Size:	367	Pesticide Use		Sample Size:	1573
Variable	Definition	dy/dx	P>z	X[a]	Variable	dy/dx	P>z	X[a]
Npers	# members	-0.011	0.386	5.392	npers	0.016	0.008	5.392
depr	Dependency ratio	-0.226	0.170	0.179	depr	-0.151	0.078	0.179
Lowedu*	Low education hh.	-0.254	0.246	0.769	lowedu*	0.006	0.946	0.769
Mededu*	Medium edu. hh.	-0.138	0.367	0.191	Mededu*	-0.010	0.912	0.191
Dvequip	Value ag. equipment	0.000	0.075	494	dvequip	0.000	0.030	494
agcred*	Received ag. credit	0.279	0.018	0.089	agcred*	0.372	0.000	0.089
agua1	Has water access	-0.276	0.012	0.313	agua1	-0.162	0.000	0.313
Electr~1	Has electricity access	0.099	0.237	0.816	electr~1	-0.020	0.708	0.816
FSC3*	Farm with < 5 ha.	-0.147	0.324	0.670	FSC3*	0.092	0.338	0.670
FSC4*	Farms with 5 to 20 ha.	-0.021	0.874	0.170	FSC4*	0.207	0.034	0.170
FSC5*	Farms with 20 to 100 ha.	-0.142	0.157	0.111	FSC5*	0.112	0.272	0.111

Source: Own calculations using the 1998 LSMS.
a. Marginal effects are calculated at variable means (X). * Indicates that the marginal effect is calculated at as a discrete change of the variable from zero to one.

Determinants of farmers use of fertilizer and pesticide

The variables that we have chosen for the model of fertilization and pesticide use are socioeconomic variables that could encourage/discourage farmers decision making about IPM adoption conditioned on their socioeconomic position. As we mention in the theoretical framework (section 2.4) household size, education, wealth, access to public services and agricultural institutional support are socioeconomic factors that affect a farmer's decisions to adopt new agricultural technologies. The next analysis evaluates the effect of socioeconomic variables in the Ecuadorian plantain sample and the Ecuadorian farm sample for fertilizer and pesticide respectively.

For both farm management practices, fertilization and pesticide use, household dependency ratio's marginal effect on the use of these practices is negative; however it is strongly significant in the case of pesticides (table A3.1). A larger number of members under 15 and over 65 years of age (dependents) decreases the likelihood of adopting pesticide practices. Also, household size increases significantly the probability of pesticide use.

Although we expect education to be a major factor determining the adoption of new farm practices, we find little significant marginal effects for both farm practices. However, in both cases compared to highest education level, having a medium and low level of education decreases the probability of adoption of fertilizer and pesticide.

The value of agricultural equipment increases the probability of use of fertilizers and pesticides at a10% level of significance. However, the magnitude of the marginal effects in insignificant contrary to theory.

In the case of household infrastructure, in both cases access to water significantly reduces the probability of fertilizer and pesticide use. These results are contrary to what we would expect when considering infrastructure as a proxy of wealth. Nonetheless, in the survey year (1998), the available infrastructure in rural areas was reduced by floods caused by El Ñiño current. Therefore infrastructure, in this particular survey, is inadequate in general for farm households.

Agricultural credit and technical assistance can help low resource farm households to gain access to new or improved agricultural practices. In sections 3.7 and

4.3 we indicated that agricultural credit and technical assistance is almost nonexistent among farm households in Ecuador. Section 4.3 points out that farm households using fertilization and pesticide have on average received more agricultural credit and technical assistance than farm households that do not use them. Probit results indicate that credit access has an unambiguous positive effect on the probability of adoption of fertilizer and pesticide. In the case of fertilizer, the marginal effect of access to credit is significant at a 2% level and in the case of pesticides it is significant at the 1% level. The positive marginal effect of agricultural credit, consistent with theory, indicates that increasing its access would increase the likelihood of adopting new agricultural management practices.

To observe the effects by FSC, we have created dummy variables for four categories of FSC. We drop the largest class and do a discrete marginal effect analysis comparing to this class. In the case of fertilizer, we find being in a larger FSC increases the probability of use of fertilizers. Compared to the largest FSC, being a farm with less than 5 hectares, or with 20 to 100 hectares of land, decreases the probability of using fertilizer by approximately 15%. The results indicate that farms with 5 to 20 and more than 100 hectares of land have the higher probabilities of fertilizer use.

In the case of pesticides, we find that the medium FSC has the highest probability of use of pesticides. Compared to the largest FSC, being a farmer with 5 to 20 hectares of land increases the probability of adoption of pesticides by 21%. Farms with 20 to 100 hectares of land compared to the largest FSC have a 11% higher probability of pesticide use. Differences among the largest and the smallest FSC are very small compared to differences with the medium FSC.

Conclusions

Results indicate that adoption of improved farm practices are strongly encouraged by agricultural credit provision. The lack of technical assistance prevents us from measuring its effect on the adoption/use of fertilizer and pesticides. However, technical assistance can be a determining factor to of adoption rates for new and improved farm practices. As expected, household assets influence farmer’s decisions on adopting/using different management practices. From the analysis of FSC, we found that larger land-holdings increase the adoption of new farm practices. Also, lower dependency rates encourage adoption/use of fertilizer. Although we found no significant coefficients in the case of education, timely information to farmers, that increase their knowledge of new technologies, could speed the adoption/rate of use process.

Table A 3.2 Probit results for the fertilizer use for the farm and plantain farm models

	Coef.	Robust Std. Error	z	P>|z|	[95% Conf.	Interval]
Model all farms: 1573 observations						
Npers	0.011	0.015	0.74	0.461	-0.019	0.042
Depr	-0.443	0.223	-1.99	0.047	-0.881	-0.006
Lowedu	-0.120	0.213	-0.56	0.572	-0.538	0.297
Mededu	-0.127	0.223	-0.57	0.567	-0.563	0.309
Dvequip	0.000	0.000	2.09	0.037	0.000	0.000
Agcred	0.928	0.142	6.52	0.000	0.649	1.206
agua1	-0.255	0.103	-2.48	0.013	-0.456	-0.053
electricid~1	0.675	0.145	4.65	0.000	0.390	0.959
FSC3	0.493	0.257	1.92	0.054	-0.009	0.996
FSC4	0.692	0.264	2.62	0.009	0.175	1.208
FSC5	0.224	0.271	0.83	0.409	-0.308	0.756
_cons	-1.151	0.361	-3.19	0.001	-1.858	-0.444
Pseudo R2	0.077					
Model all plantain farms: 367 observations						
Npers	-0.034	0.040	-0.87	0.385	-0.112	0.043
Depr	-0.697	0.513	-1.36	0.174	-1.702	0.308
Lowedu	-0.717	0.594	-1.21	0.228	-1.882	0.448
Mededu	-0.476	0.605	-0.79	0.432	-1.662	0.711
Dvequip	0.000	0.000	1.90	0.058	0.000	0.001
Agcred	0.754	0.301	2.50	0.012	0.163	1.344
agua1	-0.850	0.361	-2.35	0.019	-1.557	-0.142
electricid~1	0.304	0.253	1.20	0.229	-0.191	0.799
FSC3	-0.436	0.433	-1.01	0.314	-1.285	0.413
FSC4	-0.066	0.424	-0.16	0.876	-0.898	0.766
FSC5	-0.508	0.425	-1.19	0.232	-1.342	0.325
_cons	0.498	0.745	0.67	0.503	-0.961	1.958
Pseudo R2	0.1187					
Chow test statistics for the differences of models parameters						
chi2(11)	22.28					
Prob > chi2	0.0223					

Own calculations using LSMS 1998 data.

Table A3.3 Probit results for the fertilizer use for the plantain and coastal plantain farm models

	Coef.	Robust Std. Err	z	P>|z|	[95% Conf.	Interval]
Model coastal plantain farms: 176 observations						
Npers	-0.026	0.046	-0.57	0.569	-0.117	0.064
Depr	-0.434	0.617	-0.70	0.482	-1.643	0.775
Lowedu	-0.123	0.863	-0.14	0.887	-1.815	1.569
Mededu	0.024	0.872	0.03	0.978	-1.686	1.733
lDvequip	0.000	0.000	1.54	0.123	0.000	0.001
Agcred	0.770	0.342	2.26	0.024	0.101	1.440
agua1	-0.311	0.787	-0.39	0.693	-1.854	1.232
electricid~1	0.162	0.311	0.52	0.603	-0.447	0.771
FSC3	0.211	0.829	0.25	0.799	-1.414	1.835
FSC4	0.663	0.823	0.80	0.421	-0.951	2.276
FSC5	0.290	0.822	0.35	0.724	-1.320	1.901
_cons	-0.661	1.195	-0.55	0.580	-3.002	1.681
Pseudo R2	0.082					
Chow test statistics for the differences of model parameters						
chi2(11)	14.82					
Prob > chi2	0.1909					

Own calculations using the LSMS 1998.

Table A3.4 Probit results for the pesticides use for the farm and plantain farm models

	Coef.	Robust Std. Error	Z	P>|z|	[95% Conf.	Interval]
Model all farms: 1573 observations						
Npers	0.040	0.015	2.64	0.008	0.010	0.070
Depr	-0.379	0.215	-1.76	0.078	-0.801	0.043
Lowedu	0.015	0.221	0.07	0.946	-0.418	0.448
Mededu	-0.025	0.229	-0.11	0.912	-0.475	0.424
Dvequip	0.000	0.000	2.18	0.029	0.000	0.000
Agcred	1.029	0.152	6.79	0.000	0.732	1.326
agua1	-0.406	0.106	-3.85	0.000	-0.613	-0.199
electricid~1	-0.051	0.137	-0.37	0.708	-0.319	0.217
FSC3	0.233	0.246	0.95	0.343	-0.248	0.714
FSC4	0.526	0.257	2.05	0.040	0.023	1.029
FSC5	0.283	0.260	1.09	0.276	-0.226	0.792
_cons	-0.503	0.365	-1.38	0.167	-1.218	0.211
Pseudo R2	0.0767					
Model all plantain farms: 367 observations						
Npers	0.024	0.032	0.75	0.451	-0.039	0.088
Depr	-0.892	0.509	-1.75	0.080	-1.891	0.106
Lowedu	-0.225	0.525	-0.43	0.668	-1.254	0.804
Mededu	-0.049	0.539	-0.09	0.928	-1.106	1.009
Dvequip	0.000	0.000	0.76	0.445	0.000	0.000
Agcred	0.616	0.308	2.00	0.045	0.013	1.219
agua1	-0.490	0.309	-1.58	0.113	-1.095	0.116
electricid~1	0.116	0.227	0.51	0.609	-0.329	0.561
FSC3	-0.430	0.382	-1.13	0.260	-1.178	0.318
FSC4	-0.035	0.380	-0.09	0.927	-0.779	0.710
FSC5	-0.006	0.373	-0.02	0.987	-0.738	0.726
_cons	0.148	0.640	0.23	0.818	-1.108	1.403
Pseudo R2	0.070					
Chow test statistics for the differences of models parameters						
Chi2(11)	13.93					
Prob > chi2	0.2368					

Own calculations using the LSMS 1998.

Probit A3.1: Fertilizer probit regression

Ecuadorian Farms Sample
Survey probit regression

pweight: fexp		Number of obs =	1578
Strata: region		Number of strata =	3
PSU: <observations>		Number of PSUs =	1578
		Population size =	621222.1
Subpopulation no. of obs =	1573	F(12, 1564) =	9.14
Subpopulation size =	604726.58	Prob > F =	0.0000

fert	Coef.	Std. Err.	t	P>|t|
npers	.0085295	.0155406	0.55	0.583
depr	-.4723679	.224869	-2.10	0.036
lowedu	-.1148531	.2144504	-0.54	0.592
mededu	-.1217539	.2240753	-0.54	0.587
dvequip	.0001468	.0000713	2.06	0.040
agcred	.9406155	.1431288	6.57	0.000
agua1	-.30207	.1037854	-2.91	0.004
electricid~1	.5888242	.1478198	3.98	0.000
FSC3	.4164861	.2592848	1.61	0.108
FSC4	.695297	.266439	2.61	0.009
FSC5	.2717199	.2737179	0.99	0.321
dumplat	**-.3821264**	**.1021063**	**-3.74**	**0.000**
_cons	-.9288437	.368716	-2.52	0.012

Note: 0 failures and 2 successes completely determined.

Probit A3.2: Fertilizer probit regression

Coastal Farms Sample
Survey probit regression

pweight:	fexp	Number of obs	= 455
Strata:	region	Number of strata	= 1
PSU:	<observations>	Number of PSUs	= 455
		Population size	= 237972.25
Subpopulation no. of obs	= 451	F(12, 443)	= 3.05
Subpopulation size	= 222466.35	Prob > F	= 0.0004

fert	Coef.	Std. Err.	t	P>|t|
npers	-.0053542	.0285186	-0.19	0.851
depr	-.6843041	.4267013	-1.60	0.109
lowedu	-.0689235	.4279284	-0.16	0.872
mededu	.0536484	.4335547	0.12	0.902
dvequip	.0001684	.0000877	1.92	0.056
agcred	.6959611	.2000709	3.48	0.001
agua1	-.1920892	.2481027	-0.77	0.439
electricid~1	.1318779	.2265595	0.58	0.561
FSC3	1.044544	.5900257	1.77	0.077
FSC4	1.213417	.594202	2.04	0.042
FSC5	.8474416	.5987721	1.42	0.158
dumplat	**-.4813276**	**.1493605**	**-3.22**	**0.001**
_cons	-.920476	.6566233	-1.40	0.162

Note: 0 failures and 2 successes completely determined

Probit A3.3: Pesticide probit regression

Ecuadorian Farms Sample

Survey probit regression

pweight:	fexp	Number of obs =	1578
Strata:	region	Number of strata =	3
PSU:	<observations>	Number of PSUs =	1578
		Population size =	621222.1
Subpopulation no. of obs =	1573	F(12, 1564) =	8.74
Subpopulation size =	604726.58	Prob > F =	0.0000

pesticides	Coef.	Std. Err.	t	P>|t|
npers	.0380727	.0151617	2.51	0.012
depr	-.3954911	.2160708	-1.83	0.067
lowedu	.0124132	.2232569	0.06	0.956
mededu	-.026375	.2317072	-0.11	0.909
dvequip	.0001423	.0000658	2.16	0.031
agcred	1.038638	.1509492	6.88	0.000
agua1	-.4412322	.1059685	-4.16	0.000
electricid~1	-.1156354	.1388689	-0.83	0.405
FSC3	.1795859	.2444611	0.73	0.463
FSC4	.5275703	.2554013	2.07	0.039
FSC5	.3138342	.2594043	1.21	0.227
dumplat	**-.2648872**	**.10163**	**-2.61**	**0.009**
_cons	-.3388216	.3638878	-0.93	0.352

Note: 0 failures and 2 successes completely determined.

Probit A3.4: Pesticide probit regression

Coastal Farms Sample

Survey probit regression

pweight:	fexp	Number of obs =	455
Strata:	region	Number of strata =	1
PSU:	<observations>	Number of PSUs =	455
		Population size =	237972.25
Subpopulation no. of obs =	451	F(12, 443) =	1.98
Subpopulation size =	222466.35	Prob > F =	0.0242

pesticides	Coef.	Std. Err.	t	P>|t|
npers	.0147227	.028182	0.52	0.602
depr	-.4552212	.4194763	-1.09	0.278
lowedu	-.1992268	.4430664	-0.45	0.653
mededu	-.1878206	.4470137	-0.42	0.675
dvequip	.0001474	.0001054	1.40	0.163
agcred	.6953189	.2047672	3.40	0.001
agua1	-.2438145	.2503809	-0.97	0.331
electricid~1	-.2305391	.219898	-1.05	0.295
FSC3	.3495832	.4453052	0.79	0.433
FSC4	.4826631	.4580891	1.05	0.293
FSC5	.5960985	.4757496	1.25	0.211
dumplat	-.3604841	.1499597	-2.40	0.017
_cons	.147093	.6167903	0.24	0.812

Note: 0 failures and 2 successes completely determined.

Appendix 4: Economic surplus estimation results

IPM – Fungicides scenario

Net Present Value of Economic Surplus with a 4% discount rate			
Total	**Consumer**	**Producer**	**Labor Income**
$49,281,536	$4,389,763	$48,947,313	$9,542,418

LOCAL MARKET	
Absolute Demand Elasicity	Supply Elasicity
0.3	1
Price	Quantity
160	213,728

ADOPTION PARAMETERS					
Adjusted Yield Gain *\(%)	Adoption Profile (in cummulative years) Research Lag	Maximum Adoption	Start of Dis Adoption	Complete Dis-adoptior	Weighted Adoption MAX Rate (%)
0.48823793	0	5	na	na	35

OPEN LARGE ECONOMY	
Absolute Export Demd Elasticity	Local Prod Consumed Localy (%)
4.98990495	0.859877805

LABOR MARKET
Simulated Proportional Labor Dincrease
77%

0 Year	(1) Demand Elasicity	(2) Supply Elasicity	(3) Adjusted Yield Gain	(4) Adoption Phase	(5) Weghted Adoption Rate (%)	(6) Net K Shift[a]	(7) Plantain Price	(8) Net Price Decrease	(9) Quantity Metric Tonnes	(10) Change in Total Surplus[c]	(11) Change in Consumer Surplus[d]	(12) Change in Producer Surplus[e]	(13) Labor Demand Quantity	(14) Change in Labor Dmeand[f]	(15) Change in Generated L.Income[g]
1	0.3	1	0.48823793	INITIAL ADOP	6.94	0.034	160	0.0032	213728	1144766	94,566	1,050,199	766926	41,185	205,925
2	0.3	1	0.48823793	INITIAL ADOP	13.88	0.068	160	0.0064	213728	2292993	189,224	2,103,769	766926	82,370	411,850
3	0.3	1	0.48823793	INITIAL ADOP	20.82	0.102	160	0.0096	213728	3444682	283,973	3,160,710	766926	123,555	617,775
4	0.3	1	0.48823793	INITIAL ADOP	27.75	0.136	160	0.0129	213728	4599833	378,813	4,221,020	766926	164,740	823,700
5	0.3	1	0.48823793	INITIAL ADOP	34.69	0.169	160	0.0161	213728	5758445	473,744	5,284,702	766926	205,925	1,029,624
6	0.3	1	0.48823793	MAX. ADOPTI	34.69	0.169	160	0.0161	213728	5758445	473,744	5,284,702	766926	205,925	1,029,624
7	0.3	1	0.48823793	MAX. ADOPTI	34.69	0.169	160	0.0161	213728	5758445	473,744	5,284,702	766926	205,925	1,029,624
8	0.3	1	0.48823793	MAX. ADOPTI	34.69	0.169	160	0.0161	213728	5758445	473,744	5,284,702	766926	205,925	1,029,624
9	0.3	1	0.48823793	MAX. ADOPTI	34.69	0.169	160	0.0161	213728	5758445	473,744	5,284,702	766926	205,925	1,029,624
10	0.3	1	0.48823793	MAX. ADOPTI	34.69	0.169	160	0.0161	213728	5758445	473,744	5,284,702	766926	205,925	1,029,624
11	0.3	1	0.48823793	MAX. ADOPTI	34.69	0.169	160	0.0161	213728	5758445	473,744	5,284,702	766926	205,925	1,029,624
12	0.3	1	0.48823793	MAX. ADOPTI	34.69	0.169	160	0.0161	213728	5758445	473,744	5,284,702	766926	205,925	1,029,624
13	0.3	1	0.48823793	MAX. ADOPTI	34.69	0.169	160	0.0161	213728	5758445	473,744	5,284,702	766926	205,925	1,029,624
14	0.3	1	0.48823793	MAX. ADOPTI	34.69	0.169	160	0.0161	213728	5758445	473,744	5,284,702	766926	205,925	1,029,624
15	0.3	1	0.48823793	MAX. ADOPTI	34.69	0.169	160	0.0161	213728	5758445	473,744	5,284,702	766926	205,925	1,029,624

Note: a- Net K shift is the proportional downward shift in the supply curve for each year. The shift is calculated as (Column 6) = (Column 3)*(Column5/100). The adjusted net yield is calculated adjusting the change in yield to account for shifts in input mix at a 0.4 supply elasticity.

b- Net proportionate price decrease is calculated as (Column 8) = (Column6)*(Column 2)/((Column 2)+(0.86+Column 1)+(1+0.86)4.89).

c- The change in total surplus is calculated for each year as (Column 10) =(Column 11+ Column 12)

d- The change in consumer suplus is calculated as (Column 11) = (Column 7 * Column 8)*(266,436)*[1+(0.5*(Column 8)*(Column 1))]

e- The change in producer surplus is calculated as (Column 12) = (Column 7*Column 9)*(Column 6*Column 8)*(1+0.5*(Column 2))

f- The in labor demand is calculated as (Column 14)= (Column 5) (Column 13)*0.77

g- The Change in generated income is calculated as (Column 15)= (Column 14)*$5 assummed labor wage

IPM + Fungicides scenario

Net Present Value of Economic Surplus with a 4% discount rate			
Total	**Consumer**	**Producer**	**Labor Income**
$46,770,658	$4,167,093	$46,452,391	$8,032,943

LOCAL MARKET	
Absolute Demand Elasicity	Supply Elasicity
0.3	1
Price	Quantity
160	213,728

ADOPTION PARAMETERS					
Adjusted Yield Gain *\(%)	Adoption Profile (in cummulative years) Research Lag	Maximum Adoption	Start of Dis-Adoption	Complete Dis-adopt	Weighted Adoption Rate MAX (%)
0.463524179	0	5	na	na	35

PEN LARGE ECONOM	
Absolute Export Dem Elasticity	Local Prod Consumed Localy (%)
4.9899049	0.859878

LABOR MARKET
Simulated Proportional Labor Decrease
65%

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Year	Demand Elasicity	Supply Elasicity	Adjusted Yield Gain (%)	Adoption Phase	Adoption Rate (%)	Net K Shift[a]	Plantain Price	Net Price Decrease[b]	Quantity Metric Tonnes	Change in Total Surplus[c]	Change in Consumer Surplus[d]	Change in Producer Surplus[e]	Labor Demand Quantity	Change in Labor Dmeand[f]	Change in Generated L.Income[g]
1	0.3	1	0.463524179	INITIAL ADOPTION	6.94	0.032	160	0.0031	213728	1086737	89777	996959	766926	34670	173350
2	0.3	1	0.463524179	INITIAL ADOPTION	13.88	0.064	160	0.0061	213728	2176593	179637	1996956	766,926	69340	346701
3	0.3	1	0.463524179	INITIAL ADOPTION	20.82	0.096	160	0.0092	213728	3269570	269579	2999991	766,926	104010	520051
4	0.3	1	0.463524179	INITIAL ADOPTION	27.75	0.129	160	0.0122	213728	4365667	359603	4006064	766,926	138680	693402
5	0.3	1	0.463524179	INITIAL ADOPTION	34.69	0.161	160	0.0153	213728	5464883	449709	5015175	766,926	173350	866752
6	0.3	1	0.463524179	MAX. ADOPTION	34.69	0.161	160	0.0153	213728	5464883	449709	5015175	766,926	173350	866752
7	0.3	1	0.463524179	MAX. ADOPTION	34.69	0.161	160	0.0153	213728	5464883	449709	5015175	766,926	173350	866752
8	0.3	1	0.463524179	MAX. ADOPTION	34.69	0.161	160	0.0153	213728	5464883	449709	5015175	766,926	173350	866752
9	0.3	1	0.463524179	MAX. ADOPTION	34.69	0.161	160	0.0153	213728	5464883	449709	5015175	766,926	173350	866752
10	0.3	1	0.463524179	MAX. ADOPTION	34.69	0.161	160	0.0153	213728	5464883	449709	5015175	766,926	173350	866752
11	0.3	1	0.463524179	MAX. ADOPTION	34.69	0.161	160	0.0153	213728	5464883	449709	5015175	766,926	173350	866752
12	0.3	1	0.463524179	MAX. ADOPTION	34.69	0.161	160	0.0153	213728	5464883	449709	5015175	766,926	173350	866752
13	0.3	1	0.463524179	MAX. ADOPTION	34.69	0.161	160	0.0153	213728	5464883	449709	5015175	766,926	173350	866752
14	0.3	1	0.463524179	MAX. ADOPTION	34.69	0.161	160	0.0153	213728	5464883	449709	5015175	766,926	173350	866752
15	0.3	1	0.463524179	MAX. ADOPTION	34.69	0.161	160	0.0153	213728	5464883	449709	5015175	766,926	173350	866752

Note: a- Net K shift is the proportional downward shift in the supply curve for each year. The shift is calculated as (Column 6) = (Column 3)*(Column5/100). The adjusted net yield is calculated adjusting the change in yield to account for shifts in input mix at a 0.4 supply elasticity.

b- Net proportionate price decrease is calculated as (Column 8) = (Column6)*(Column 2)/((Column 2)+(0.86+Column 1)+(1+0.86)4.89).

c- The change in total surplus is calculated for each year as (Column 10) =(Column 11+ Column 12)

d- The change in consumer suplus is calculated as (Column 11) = (Column 7 * Column 8)*(266,436)*[1+(0.5*(Column 8)*(Column 1))]

e- The change in producer surplus is calculated as (Column 12) = (Column 7*Column 9)*(Column 6*Column 8)*(1+0.5*(Column 2))

f- The in labor demand is calculated as (Column 14)= (Column 5) (Column 13)*0.77

g- The Change in generated income is calculated as (Column 15)= (Column 14)*$5 assummed labor wage