Economic Impacts of Integrated Pest Management in Developing Countries: Evidence from the IPM CRSP

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(Abstract)

Farmers around the world rely on IPM practices in order to increase their yields and reduce their losses due to pests. Assessing the impacts of previous IPM CRSP studies is crucial for successful continuance of the program and to provide meaningful recommendations to farmers. This thesis summarizes previous IPM CRSP impact studies, and provides additional impact assessments of IPM practices developed on the program. Scientist-questionnaires were sent to scientists in each IPM CRSP site around the world. Using the data from the questionnaire responses in combination with additional secondary information on elasticities, prices and quantities, economic surplus analyses were conducted. The tomato IPM program in Albania, the plantain IPM program in Ecuador, and the tomato IPM program in Uganda resulted in net present values of approximately \$8 million, \$7 million and \$1 million, respectively. Sensitivity analyses for each case were also conducted, and net benefits ranged from \$5 to 23 million in Albania, from \$4 to 7 million in Ecuador, and from \$0.03 to 3 million in Uganda. Additionally, an ordered probit analysis was conducted to determine the factors affecting adoption of IPM technologies in Bangladesh. The level of education, being a female, IPM training and awareness of pesticide alternatives were found to have positive and statistically significant impact on the adoption of IPM technologies in Bangladesh.

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Dedicated to Mom, Dad and Stefan

~Thank you for being the best family ever~

And to Vuko

~Thank you for being by my side~

Посветено на Мама, Тато, и Стефан

~затоа што сте најдобрата Фамилија~

Chapter I. Introduction

Agriculture is an important part of every economy, especially in developing countries where most of the people depend on agriculture as their primary source of income. According to the United States Agency for International Development (USAID 2007), more than a billion people live on less than a dollar per day; approximately 70 percent of which live in rural areas and spend all or part of their time farming or raising livestock. Although agriculture is very important part of each country, it is not as reliable as it needs to be in less developed countries to be a dependable source of income. A lot of the farmers in developing countries often do not produce enough to feed their own families. USAID has stated that increasing the productivity of the agricultural sector is a crucial goal (USAID 2007). Some factors that affect agricultural productivity and the variability of production from year to year are weather, insects and diseases.

I.I. Integrated Pest Management

Numerous programs around the world work toward increasing agricultural productivity and improving the lives of farmers, one of which is Integrated Pest Management (IPM). IPM is a systems approach that works toward reducing the negative productivity effects caused by pests, but without harming the environment in that process (IPM CRSP, 2008a).

The Environmental Protection Agency (EPA) has defined IPM as an effective and environmentally sensitive approach to manage pests that relies on a combination of common-sense practices (EPA, 2007). Using current information about pests and the environment, IPM combines available pest control methods to manage pest damage by the most economical means, and with the least possible harm to people, property, and the environment. According to the EPA (2007), IPM practices can be implemented in agricultural and non-agricultural settings (like the home, garden, and workplace). According to Norton and Mullen (1994), IPM is an approach which uses increased information to make pest control decisions, and also uses multiple tactics to manage pest populations in a way that is both economically efficient and ecologically sound.

IPM practices natural, environmentally friendly approaches that increase agricultural productivity. Examples of IPM practices are adoption of pest-resistant varieties of crops; biological and physical control methods; environmental modification; biopesticides; and when absolutely necessary, non-residual, environmentally-friendly and low mammalian-toxic chemical pesticides (IPM CRSP 2008a).

The Integrated Pest Management, Collaborative Research Support Program (IPM CRSP), started in September 1993 and is funded by USAID. The objective of the IPM CRSP is to develop and implement IPM practices that can help increase the standard of living as well as improve the environment in various countries around the world. The objectives are achieved through research, education for behavioral changes, policy and institutional reforms and the development of sustainable, resource-based local enterprises (IPM CRSP 2008b). Over the years, the IPM CRSP has helped numerous countries in Eastern Europe, Africa, Latin America, Asia and the Caribbean. There have been several regional projects specifically tailored to a particular problem in a particular country, but there are also global programs.

I.II. Problem Statement

There is a need for a standardized assessment of impacts across all projects on the IPM CRSP. According to Norton et al. (2005, pp.241) "impact assessment is crucial for making meaningful recommendations to farmers, for demonstrating the value of IPM programs, and for assessing who will adopt so that programs can be tailored to audiences to obtain consistency with program goals." There has been an uneven distribution of IPM CRSP impact assessment studies and projects, therefore it is necessary to provide more up to date impact assessments for the countries that have not been studied extensively, for example Uganda, Albania and Ecuador.

Some of the effects resulting from implementing IPM practices can be: reduced pesticide use, reduced crop losses, reduced loss of biodiversity, reduced damage to natural ecosystems, increased farmer income, improving research and education capabilities, and increased involvement of women in decision-making. Each of these effects has a specific type of economic impact, a summary report for all the economic impacts has not been prepared. A summary report is needed to inform stakeholders of the overall joint progress of the IPM CRSP over the years. This type of report will help participants, project planners, and funding agencies in their future decisions. It can serve as a general data base for information on each project, while more detailed information for each project will still be available.

Dissemination of IPM technologies is an important part of the IPM CRSP efforts. Despite the positive effects from IPM technologies, and the efforts of numerous scientists, students, non-government officials, volunteers etc., farmers are not always aware or fully informed about the existence of and all the effects resulting from the adoption of IPM technologies. There are different factors that affect adoption, and analyzing those factors provides useful information that can help improve the adoption of IPM technologies. Due to the newly available up-to-date data and the changing conditions in each country, conducting adoption analyses is necessary. Analyzing the factors affecting adoption of IPM technologies is especially important in the case of less developed countries (LDCs) because as Feder, Just, and Zilberman (1985) point out, the majority of the population depends on agriculture and the adoption of new technologies has proven to increase agricultural production and income. One of the poorest nations in the world, Bangladesh, is one of the primary sites on the IPM CRSP. Analyzing the factors that affect adoption of IPM technologies is an important step toward designing strategies for scaling up the spread of IPM technologies to Bangladeshi farmers.

I.III. Objectives

The two primary objectives of this study are to measure and summarize the impacts of the IPM CRSP from its beginning to the present, and also to analyze the factors affecting the adoption of IPM technologies in the case of Bangladesh. This study will include a large number of IPM CRSP projects and will provide a consistent analysis of the projects. It will:

I. Review and summarize results from previous impact studies on the IPM CRSP

II. Assess the impact of specific IPM CRSP programs in Albania, Uganda and Ecuador

III. Identify factors that affect adoption of IPM technologies in Bangladesh.

I.IV. Hypotheses

1. IPM practices result in a positive Net Present Value (NPV) of benefits in every country where the IPM CRSP is working.
2. The adoption of IPM increases as the level of education increases, if the farmer is female, as the number of working family members increases, as the percentage of farm income from total annual income increases, if the farmer had an IPM training, and if farmer is aware of pesticide alternatives.

   The adoption of IPM practices decreases as the farmers' age increases, as the farm size increases, and as the distance (km) to the nearest extension agent increases.

I.V. Organization of Thesis

Chapter II is a literature review of IPM CRSP impact studies by region (Africa, Asia, Eastern Europe). Chapter III discusses the methods used in the impact studies. Chapter IV includes additional impact analysis (for tomatoes in Albania and Uganda, and plantains in Ecuador). Chapter V is devoted to analyzing the factors affecting the adoption of IPM technologies in Bangladesh. Chapter VI provides a summary, conclusions and limitations.

Chapter II. Literature Review

The IPM CRSP has published numerous work plans, trip reports, annual reports, articles, books and other documents. This chapter briefly describes the results from previous IPM CRSP impact studies beginning with those summarized in the book "Globalizing Integrated Pest Management: A participatory research process" published in 2005. Section II.I presents the basis for better understanding section II.II, which provides specific information about IPM CRSP impacts by country. Since the publication of the book in 2005, the number of countries where the IPM CRSP has presence has increased. Some of the new participant countries are: Indonesia, Moldova, Ukraine, Uzbekistan, Tanzania and Kenya. Currently the IPM CRSP is in 32 countries (IPM CRSP 2008).

II.I. Descriptive summary of impacts of IPM in specific regions

Asia (Miller et al. 2005)

The Philippines and Bangladesh face numerous pest problems and have large populations to feed. Vegetable IPM programs that include participatory appraisals (PA), stakeholder meetings, monitoring, prioritizing of pest problems etc., have been undertaken in both countries. The IPM CRSP has provided assistance in diagnosing insect, disease, and weed problems that farmers are having difficulty managing. The IPM CRSP has worked on developing environmentally safe and economically sound approaches for managing pests in eggplant (brinjal), tomato, okra, cucurbits, and cabbage in Bangladesh, and in the Philippines in rice and other vegetable-vegetable cropping systems focused on onion and eggplant. IPM CRSP research has addressed some of the most economically harmful insects and diseases. Appropriate technologies and approaches have been developed which provided the farmers with "tools" to reduce their pest losses. Successful IPM programs require interdisciplinary collaboration among scientists, economists, and local farmers. Successful technologies that are being adopted include using disease and insect resistant varieties, grafting for tomato and eggplant for bacterial wilt resistance, pheromones and/or bait traps in cucurbits and onion production. Also, various weed-management practices are being adopted such a hand weeding in combination with reduced pesticide use, stable seedbed technique (a soil conservation tactic that reduces erosion) etc. IPM CRSP research on the most important pest in eggplant, *Leucinodes orbonalis* or eggplant fruit and shoot borer (EFSB), showed that simply by removing the damaged fruits and shoots during harvest rather than throughout the season, labor costs could be reduced and there could be a net incremental benefit of $2,500/ha for weekly removal and $1,000/ha for biweekly removal. Adoption of a reduced insecticide application practice can reduce insecticide applications from 30-50 to six in a cropping season. The IPM CRSP also found that using larval and pupal parasitoid *Trathala flavoorbitalis*, can reduce EFSB infestation of the 1st instar larvae by 91%. Bacterial wilt (BW) is caused by *Ralstonia solanacearum* and causes tremendous losses in eggplant production. The yield losses for farmers in Bangladesh are often in excess of 50%, while in Central Luzon, Philippines yield losses can be from 30 to 80%. The use of bacterial wilt-resistant *Solanum melongena* line showed increased resistance to BW of 20 to 30% (Miller et al. 2005). These were just a few examples of the many results obtained showing the role of IPM in improving the livelihood of farmers and people in the Philippines and Bangladesh.

Africa (Erbaugh et al. 2005)

IPM programs in Africa require a different approach than in Asia. Developing IPM programs that help small-farmers has been challenging. Studies have found that intensive exposure to IPM practices through farmer-field schools increases the chances of adoption. Participatory IPM has had some difficulties with respect to cost, and communication issues between the scientists and farmers in distant areas. The development of new technologies has been proposed to be completed in two stages due to the necessity to expand the number of farmers reached. The first stage is to develop the new technology and the second stage involves adapting the technologies to specific sites and providing the technologies to farmers. In Mali in 1999, an innovative approach was started to control Striga parasitism using herbicide application on sorghum seed, which resulted in reduced number and dry weight of Striga plants attacking sorghum by over 50 percent. In Uganda and Kenya, cowpea emerged as an important export crop and the crop that is most likely to be sprayed with chemical pesticides. The IPM CRSP developed packages that effectively reduced insect pests on cowpea and increased the grain yield by over 90 percent.

Latin America (Alwang et al 2005) **and the Caribbean** (Lawrence et al 2005)

The use of IPM practices in Latin America showed significant reduction of insects and diseases which can have positive effects on the socio-economic status of the people in the countries in question (Alwang et al 2005). Implementation of such IPM practices and institutionalizing the pest-management programs can ensure more sustainable export markets. Farmer-field schools have proven to effectively increase the adoption of IPM technologies and are being redesigned to reach larger numbers of farmers. In Guatemala the IPM CRSP worked on reducing pesticide residues and improving snowpea quality. One IPM tactic included pest scouting for insects, which resulted in a 61 percent reduction in pesticide use and a 6 percent increase in average total yield. Another effective IPM package was developed for tomato. IPM production costs for tomato were $700/ha lower, profits were $1,700/ha greater, and pesticide use decreased from more than 23 sprays to 13 sprays (Weller et al., 2002). In the case of potato production in Carchi, Ecuador it was found that the net benefits from an IPM package (involving: late-blight resistant variety (INIAP-FRIPAP99), traps and limited leaf spraying for Andean weevil, monitoring and limited spraying for the tuber moth, and other low-input controls) resulted in $643 per ha net benefits compared to local practices. Another impact study of late blight resistance in the North Region in Ecuador found that the net present value of research was $34 million (Alwang et al 2005).

Although Jamaica was the primary IPM CRSP site in the Caribbean, there has been an IPM impact on the broader region as well (Lawrence et al 2005). Workshops, on-farm demonstrations and variety trails, all have had positive impacts on reducing the farmers' losses and in educating farmers. A prototype web-based pest monitoring system was also set up as a part of the IPM CRSP program. This type of monitoring system can be used for pest surveillance in the future in other IPM CRSP sites. IPM also influenced trade in the Caribbean, by introducing improved varieties and reducing their losses. The three main case studies presented by Lawrence et al (2005) were sweet potato, hot pepper and callaloo. In the sweet potato case study, the factors being assessed included: weevil populations, usage of cultural practices, trap maintenance, and resultant crop losses. A significant yield loss difference due to weevil was found between the IPM users and cultural practices users, averaging 4% and 13%, respectively. In the case of pheromone traps (for male weevils) there was a significant difference in the number of pests caught on 0.1 ha of sweet potato resulting in mean weevil catch of 22 and 779, for IPM users and cultural practices users, respectively. In the case of hot peppers in Jamaica it was found that weekly application of JMS Stylet-Oil® using a backpack mist blower delayed the field spread of *Tobacco etch virus* (TEV) for seven days and reduced TEV incidence by 24% compared to unsprayed plots (McDonald, 2004). It was also found that using Stylet-Oil® together with reflective mulch delayed the TEV incidence in pepper plots for more than two months, even with inoculum pressures of 33-67% infection from surrounding plants (Lawrence et al 2005).

Eastern Europe (Pfeifer et al 2005)

The IPM CRSP project has also functioned in Albania (Pfeifer et al 2005). A project was conducted to measure IPM impacts on the olive fruit fly. Economic cost-benefit analysis of olives under IPM practices was conducted. Although different methods were used (harvest timing, pruning and timing of copper sprays, vegetation management and pheromone based management of the olive fly), all IPM methods were feasible and showed net profits compared to no-spray and a hypothetical full spray program. A harvest timing/olive fruit fly study produced the highest net gains of $21.1 million, the pheromone based olive fruit fly management was second, with gains of $11 million, the weed management practice was on the third place with gains of $4.3 million, and the pruning/copper sprays resulted in gains of $2.5million. Sixty three percent of these gains were attributed to yield gains and the rest from quality gains.

II.II. Additional IPM CRSP Impact Studies

This section reviews additional economic impact assessments of the IPM CRSP. Antle and Capalbo (1995), define the economic impact assessment of integrated programs as "an application of the economic tool of benefit cost analysis, combined with appropriate data and models from production economics, environmental science, and health science." The studies reviewed in this section range from the beginning of the IPM CRSP in 1993 until today. Each study is reviewed individually. There are four sub-categories in this section, the sub-categories refer to the different geographical regions. Depending to the country in which the studies were conducted, each study is placed in one of the three sub-categories. Studies that contain a mix of counties were divided and each part of the study was placed in the appropriate sub-region.

II.II.A. Africa

Moyo et al. (2007) conducted partly ex-post and partly ex-ante analysis in Uganda that focused on poverty reduction as a result of research to develop a peanut-disease resistant seed. An economic surplus analysis was combined with analysis of household level data, in order to estimate the poverty reduction. The following three steps were undertaken during the economic surplus analysis:

a. The unit cost reduction associated with adopting the new seed technology was calculated

b. Information for the expected rate of adoption was gathered based of other new technologies being adopted in the past and the fact that 15 percent of the farmers have already adopted the improved seed in the first two years since its release.
c. The poverty change resulting from technology adoption was estimated by computing the household level value of welfare (income and consumption per capita) and comparing the income to the poverty line, determining potential adopting households and the welfare change by level of adoption and adding up the change in the number of poor households/people due to adoption.

The poverty reduction data were collected through the Uganda National Household Survey, conducted with the help of the International Food Policy Research Institute (IFPRI) and the Uganda Bureau of Statistics. The data set consisted of 2,949 peanut producing households. The effects of adoption of the new technology were spread over a fifteen year period starting in May 2001. Changes in poverty were calculated using measures of the Foster-Greer-Thorbecke (FGT) type. The FGT indices are commonly used because they are additively decomposable with population share weights, which allows evaluation of impacts of agricultural and other policies on subgroups such as peanut producers. The results indicated a modest 5-6 percent increase in income in an open economy and 2.3 to 2.5 percent in a closed economy case. The beneficiaries of this study are the people from Uganda. Both consumers and producers gain from the implementation of the technology. Producers have higher yields and income and consumers have lower prices. Since poor people spend most of their income on food, they benefit a lot from the technology. Getting poor people closer to the poverty line is a step forward compared to the current situation they live in. Finally, in an open economy model with 100 percent adoption, the poverty severity index decreases by 2 percent, which represents a 10.5 percent decline in poverty severity. These numbers are lower for a closed economy model. The net present value (aggregate net returns to the research) for an open economy is estimated to be $43.0 and $35.6 million at 3% and 5% discount rates, respectively. The beneficiaries are the producing households, while the costs are borne by the research sponsors. In a closed economy, the net benefits are estimated to be $41.1 and $34.0 million at 3% and 5% discount rates, respectively. The beneficiaries in this case are both producing and consuming households. Sensitivity analysis was also conducted. At the 25 percent adoption rate, the NPV increased both in the case of an open economy model to $62.0 and $51.3 million at 3 and 5 percent discount rates, respectively and for a closed economy to $58.3 and $48.2. (Moyo,et al. 2007).

Nouhoheflin et al.(2009) conducted a research study on tomatoes in Mali. According to the author tomatoes are one of the most important crops in Mali and are grown throughout all the seasons. Despite of the wide usability and trade in West Africa, tomatoes are susceptible to pest and diseases which cause losses of about 30-50%, while tomato viruses such *Bemissia tabaci,* vectored by the whitefly can cause losses of up to 90-100%. Nouhoheflin et al. (2009) summarized the baseline survey results and assessed the economic impacts of the efforts to reduce the tomato virus problem. The baseline survey provides socio-demographic data and information about the tomato production and pest problems in Mali. In order to address the tomato virus problems in Mali, IPM technologies and biotechnology (GMO) were developed. The economic surplus approach was used to assess the impacts of those technologies on consumers and producers. Few different scenarios were examined. Under the first scenario when both IPM strategies and GMO technologies are used in a closed economy, the total economic surplus was estimated to be approximately $1.35 million, out of which approximately $0.9 million was consumer surplus and $0.45 million were gains to producers. The NPV of the benefits from adopting IPM technologies and GMO strategies over 15 years was estimated to be about $11.64 million, while the IRR was estimated to be 102%. The second scenario considered only the adoption of IPM strategies in a closed economy. The total economic surplus in this case was about $1.16 million, out of which about $0.77 million were gains to consumers and $0.38 were gains to producers. The NPV of the benefits from adoption of IPM strategies over 15 years was approximately $10.3 million and the IRR was 134%. The third closed economy scenario only considered adoption of GMO's, which generated a total economic surplus of approximately $0.2 million, out of which about $0.13 million were gains to consumers and about $0.07 were gains to producers. The NPV of the benefits induced by GMO technologies over 15 years was estimated to be approximately $1.5 million, while the IRR was estimated to 50%.

The three cases were also estimated in an open economy, which changes the results. Under the first scenario (IPM practices + GMO technologies), the total economic surplus was $1.44 million, while under the second scenario (only IPM practices) the total economic surplus is $1.23 million, and under the third scenario (only GMO's) the total annual economic surplus is $0.21 million. The NPV of benefits from technology adoption are: $12.4, $10.9 and $1.6 million, respectively (Nouhoheflin et al. 2009).

Debass (2000) assessed the economic impacts of IPM CRSP activities in Bangladesh and Uganda using geographical information system (GIS) applications and economic surplus analysis. Bangladesh and Uganda depend on agriculture, and numerous pests, insects, diseases etc., affect the yields and increase the costs to farmers. Using pesticides has drawbacks because farmers tend to overuse them which harms the environment and people's health. The results from Debass's analysis were divided in two sections, the results from Uganda are presented in this section and the results from Bangladesh are presented in the following section regarding countries in Asia. In Uganda the IPM CRSP is mainly focused on beans, maize, sorghum, and groundnuts. The main goals are increasing yields, lowering costs, and improving the life of farmers and the overall population. In order to measure the effects of the IPM CRSP in Uganda, partial budget and economic surplus models were used. GIS was used to measure the transferability of IPM technology across regions. The results from this study were divided by region in each country. In Uganda, under the baseline scenario the overall net present value for beans using the seed dressing practice (chemicals mixed with seed grain to prevent incest and rodent infestation and infection by fungi) was approximately $202 million and the internal rate of return was 250%. Under the baseline scenario, the overall net present value for maize (in Uganda) using the Longe-1 variety was $36 million and the internal rate of return was 250%. This study found that IPM practices implemented through the IPM CRSP are more viable and profitable than the conventional practices used by the local farmers (Debass 2000).

II.II.B. Asia

Debass (2000) also assessed the economic impacts of IPM CRSP activities in Bangladesh where the IPM CRSP research is focused on eggplant (birnjal), cabbage, cauliflower, and gourds. The goal of the IPM CRSP program in Bangladesh is increasing yields, lowering costs, and improving the life of farmers and the overall population. In order to measure the effects of the IPM CRSP in Bangladesh partial budget and economic surplus models were used. GIS was used to measure the transferability of IPM technology across regions. The results from this study were divided by region in each country. Under the baseline scenario, the overall net present value for eggplant using the neem leaf powder practice in Bangladesh was approximately $29 million and the internal rate of return was 684%. Under the baseline scenario, the over all net present value for cabbage using the hand weeding practice in Bangladesh was approximately $26 million and the internal rate of return was 696%. The net present value and the internal rate of return change with the adoption rates. (Debass 2000)

Mamaril and Norton (2006) conducted economic surplus analysis for transgenic pest resistant rice in the Philippines and Vietnam. Rice is a staple food in Asia, and poor people obtain more than half of their calories from rice. The *Bt* rice contains soil bacterium *Bacillus thuringiensis (Bt)*, that has been especially developed for stemborer control. The Philippines is a net importer of rice and most of the imports come from Vietnam. A partial equilibrium rice model was constructed for the Philippines, Vietnam and the rest of the world (ROW). The Philippines has the strongest bio-technology research program in Southeast Asia and also has a bio-safety program in place, while Vietnam is best positioned to take advantage of Bt rice sometime after the Philippines. The total projected economic gains (in 2000 prices) from adopting Bt rice under the baseline scenario in 2005 in the Philippines and in 2008 in Vietnam were $619 million (range from $306-717 million), $270 million (range from $136-276 million) in the

Philippines, $329 million (range from $159-415 million) in Vietnam, and $20 million (range from $10-26 million) at the ROW. The results differ if both countries simultaneously adopt the Bt rice, with Vietnam benefits increasing significantly to $415 million. Several different scenarios have been developed and each scenario offers different results although the results lie within the ranges mentioned above (Mamaril and Norton 2006).

Mishra (2003) assessed the impacts of Bt Eggplant in Bangladesh, the Philippines and India. Eggplant is one of the most important vegetables in Bangladesh, the Philippines and India, but it is highly susceptible to diseases. An economic surplus model for a closed economy was simulated. Under the baseline adoption scenario, it was estimated that yield would increase by 15 percent, and the input costs after the adoption of the BT eggplant would decrease by 30 percent. Under the conservative set of assumptions, the minimum benefits would be a 15 percent increase in yield and a 15 percent decrease in input costs, and India would gain about $279 million (net present value), Bangladesh would gain $25 million (net present value), and the Philippines would gain $19 million (net present value). Under the simulation with a base level of 15 percent increase in yield and 30 percent decrease in input costs, India would gain $411 million (net present value), Bangladesh would gain $37 million (net present value), and the Philippines would gain $28 million (net present value). The maximum benefits, 45 percent increase in yield and 45 percent decrease in input costs, would result in gains of $773 (net present value) million in India, $69 (net present value) million in Bangladesh, and $53 (net present value) million in the Philippines. In all cases, producers would gain 43 percent of the surplus and consumers gain would 57 percent. The baseline scenario simulation assumes a maximum adoption rate of 35 percent. If the adoption rate changes, it consequently changes the benefits to the countries in question. The benefits to each country are also affected by the demand and supply elasticities (Mishra 2003).

Cuyno (1999) conducted an economic evaluation of the health and environmental benefits of an IPM program (IPM CRSP) in the Philippines. Agricultural pests cause significant damage to farm yields and incomes, but the pesticides do not solve the problem. First of all, they increase the costs to the farmers and harm the environment and the health of the farmers and the people around the farm area. Measuring the benefits from the IPM CRSP program is crucial because it affects both the people and the environment, and helping people and the environment is one of the basic objectives of the IPM CRSP. The methods used to measure the benefits are contingent valuation (CV) and benefit cost analysis (B-C). The analysis is complex, at first the impacts are categorized as: impacts on human health, impact on beneficial insects, impact on aquatic species, impact on farm animals, and impact on birds. Then, environmental impact assessment of pesticide use is conducted, the IPM CRSP technology adoption levels are predicted/estimated, and the IPM CRSP impacts on pesticide reduction are estimated. Then, society's willingness to pay is estimated using the CV analysis, and finally the economic value of the environmental benefits resulting from IPM CRSP activities is established. The CV analysis provided the willingness to pay for reduction in pesticide risks of the people in Nueva Ecija (the region in question). People were willing to pay to lower the annual risk: 476 pesos per year for human health, 406 pesos per year for beneficial insects, 385 pesos per year from birds, 404 pesos per year from fish and 434 pesos per year from farm animals. This study found that adoption of the IPM practices reduced the risk to human health and farm animals by 64 percent, the risk to beneficial insects by 61 percent, the risk to fish and other aquatic species by 62 percent and the risk to birds by 60 percent. It was also found that each farmer was willing to pay bids in total of 1,312 pesos to avoid risk, for the percentage reduction of risk, and for the health and environmental benefits form the IPM CRSP for one onion season. The total aggregate net benefits to the five onion farming villages in Nueva Ecija were estimated to be 230,912 pesos (Cuyno 1999).

Alponi (2003) analyzed the adoption of IPM technologies in vegetables and its relative advantage over farmers' practices in selected areas of Bangladesh. Vegetables in Bangladesh are an important part of the diet, but there are many diseases, pests, insects, etc., which increase the losses and lower yield. In order to decrease the losses and increase the yield, farmers use pesticides, but often tend to overuse them which is harmful to human health and the environment. In addition to demographic data, data were also collected about the mortality of vegetable seedlings, inputs, yields and prices. The data were analyzed using tabular methods. The data on yield were analyzed using a completely randomized design (CRD) and the comparison test used was the Duncan's Multiple Range Test (DMRT). Besides the information about the economic situation and agriculture in each region, information about the climate, topography, soil, roads, communication, transport and marketing facilities were collected. The study found that in the study areas the cabbage seedling mortality rate was higher when farmers' practices

(8-23%) were used than on the experimental plots where IPM practices were used (1-4%). The mortality rate of eggplant seedlings was also higher when farmers' practices (16-20%) were used than on the experimental plots where IPM practices were used (5-10%). Regarding the yields under the mustard oil cake and the poultry refuse, this study found that cabbage and eggplant yields on the experimental plots using IPM practices were higher (10-50%) and (13-61%) respectively, compared to the control plots. The cost of cabbage and eggplant production varied greatly among the experiments as well as among study areas. Using the CRD, it was found that there was a significant difference in the effects resulting from the three treatments between the experimental and control groups. The adoption constraints for the IPM practices were also analyzed (Alponi 2003).

Mutuc (2003) analyzed the increase in calorie intake due to eggplant grafting. The purpose of this study was to show that a minimum data set could be used to assess the increase in the intake of calories in a productivity enhancing activity that increases the supply of a commodity. Eggplant grafting is an IPM practice that is being used in the Philippines on varieties that are highly susceptible to bacterial wilt. There are two experimental eggplant grafting sites, Nueva Ecija and Pangasinan. The economic surplus method was used, but this study moved beyond the basics and included other human indicators such as poverty and nutrition. The impact was evaluated for a 10 year time period between 2002 and 2011. The study found the yield changes, cost changes, price and supply schedules and the calorie intake changes as well as the net income impact per year for every year for each region. There was an increase in yields due to the grafting and that had positive effects on the calorie intake at all income levels. In Nueva Ecija in the 5% bacterial wilt case the total daily calorie intake per capita increased between 0.09 to 0.6 kilocalories, and in the 50% bacterial wilt case, the total daily calorie intake per capita increased between 0.9 to 6.0 kilocalories. In Pangasinan, the increases were between 0.07 and 0.22 and between 0.15 and 0.49 respectively (Mutuc 2003).

Rakshit (2008) conducted an ex-ante economic impact assessment of pheromone adoption by cucurbit farmers in Bangladesh. The analysis was conducted under two scenarios, the first when the pheromone is commercially available to farmers and the second when it is restricted by the government policy and is not fully commercially available. The pheromone is used in pheromone traps for capturing fruit flies in cucurbit fields. For the purposes of this study a survey was conducted, which provided farm and household level data, as well as information about knowledge on pesticides and information about government regulation. An economic surplus analysis using a closed economy model was conducted. Under the first scenario using maximum yield change of 0.5, the NPV was about $3.99 million and the IRR was 151%. Under the second scenario using 0.3 yield change, the NVP was $2.71 million and the IRR was 140%. A sensitivity analysis was also conducted by changing the demand and supply elasticity. The results ranged between $4.06 to $6.29 million under the first scenario (0.5 yield change) and $2.75 to $4.04 million under the first scenario (0.3 yield change). The respective IRR's ranged from151% to 165%, and from 140% to 151%, respectively for the first and second scenario. Under the first scenario, change of the supply elasticity from 0.5 to 0.3 yields an increase in the NPV of $2.3 million, while under the second scenario such an increase yields an increase in NPV of $1.33 million. An increase in demand elasticity from 0.4 to

0.6 resulted in an increase of $0.07 million of NPV of benefits, while under the second scenario it resulted in an increase of $0.04 million. The conclusion was that the model is not very sensitive to changes in the elasticity of demand, but it is sensitive to changes in the supply elasticity (Rakshit, 2008).

II.II.C. Eastern Europe

Daku (2002) analyzed the farm level and aggregate economic impacts of the olive IPM programs in Albania. Pesticide overuse has been present in Albania for a long period of time, although pesticide use declined in the post 1998 period due to the bad economic conditions. Daku (2002) pointed out that pesticide use will spike again because of farmers believe that pesticides increase their profits. According to Katsoyannos (1992), olive losses in the Mediterranean region were approximately 10 to 50 percent of the marketable production. Olives are susceptible to insects and diseases; one of the main problems is infestation by the olive fruit fly, *Bactrocera (Dacus) oleae (Gumelin)*, which is the main cause for high acidity in olives that lowers product quality. Daku (2002) developed olive crop budgets and utilized the economic surplus method, a baseline survey, and follow up survey. The baseline survey provided socioeconomic and other base data, while the follow up survey was used to estimate adoption. There were three scenarios: pesticide-based scenario, minimum-practice scenario, and do-nothing scenario. This study estimated net returns above total costs of $151.21/ha, $147.89/ha and $68.76/ha, respectively for the three scenarios. Six different IPM experiments were conducted, with each experiment showing positive net benefits. According to Daku (2002), all alternative IPM packages under the pesticide-based scenario and minimum-practice scenario are economically feasible and have positive net returns. Also these IPM packages are more profitable than the current practices. Over the next 30 years, the net IPM research benefits were projected to vary between $ 39 million (assuming farmers move from no spray to IPM practice directly) and $52 million (assuming farmers move from fill pesticide to IPM program). The producers will gain 45% of the net IPM benefits (Daku 2002).

II.II. D. Latin America

Cole, et al. (2002) assessed the impacts from pesticides on health in Highland Ecuadorian Potato Production. Potato production is very important in the highlands of Ecuador, but there is extensive pesticide use in the high risk commercial potato production. The IPM CRSP has worked on educating farmers in order to improve potato yield and also to decrease the harm to the environment and to farmers and consumers. Recent studies found that 87% of the farmers using pesticides in Ecuador wet their hands and 73% wet their back while applying fertilizer by backpack sprayer, which may have serious health effects. Farmer-field schools (FFS) which are based on farmer participatory education were working toward educating farmers about IPM practices that are safer, less costly and more productive. This study found that by using IPM practices, the amount of active ingredients, of fungicide applied for late blight decreased by 50%, insecticides use decreased by 75 % in the case of toxic carbofuran and 40% in the case of methamidophos. This resulted in a decrease in production costs from $104 to $80 per ton while maintaining the same level of productivity (Cole, et al. 2002).

Baez (2004) analyzed the potential economic benefits from plantain IPM adoption in the case of coastal rural households in Ecuador. According to the information from the last census of Ecuador, 80% of the coastal farmers and 60% of the highland farmers depend on agriculture as a primary source of their income (Project SICA/MAG, 2002). Plantain is a staple food in Ecuador, and the climate and the land are appropriate for plantain production. In 2004, Ecuador produced 8.2% of the total plantain production in Latin America and the Caribbean (FAO (2008)). In her thesis, Baez (2004) points out that plantain is susceptible to diseases and insects, which is one of the main obstacles toward its development as an Ecuadorian export. Starting in 1997, the IPM CRSP worked toward improving the life of the farmers and the overall population in Ecuador. The analysis of Baez (2004), indicated a high poverty rate among plantain farmers, as well as strong agricultural dependency. The economic surplus analysis, included a 15 year period discounted at 4%, when maximum adoption was achieved production increased by 17%, and in the case of IPM-F (IPM practices, no fungicide) the producers net benefits were approximately $49 million. In the second case IPM+F (IPM practice plus fungicide) the producers net benefits were approximately $46.5 million, and production increased by 16% if maximum adoption is achieved. For the same 15 year period at a 4% discount rate, the consumer benefits were $4.4 million in the IPM-F case and $4.2 million in the IPM+F case, market prices declined by 1.61% and 1.53%, respectively. The laborers net benefits in the same 15 year period at 4% discount rate were $ 9.5 million in the case of IPM-F, while in the case of IPM+F, the net benefits were 16 % lower. The gain to the poor, extremely-poor landless households and small farms was estimated to be approximately $6.1 in the 15 year period at a 4% discount rate (Baez 2004).

Table 1: Summary Table of benefits from the IPM CRSP impact studies[1]

	Country	Crop	Benefits / impacts / achievements
Africa			
East Africa Moyo, et al.(2007)	Uganda	Peanuts	Open economy: NPV ranging from $43.0 to $35.6 million Closed economy: NPV ranging from $41.1 to $34.0 million
Debass (2000)	Uganda	Beans Maize	NPV was about $ 202 million, IRR was 250% NPV was about $36 million, IRR was 250%
West Africa Nouhoheflin et al. (2009)	Mali		Closed Economy: NPV was about $11.64 million,IRR was 102%. NPV was about $10.3 million, IRR was 134%. NPV was about $1.5 million, IRR was 50%. Open Economy: NPV was about $12.4 million,IRR was 102%. NPV was about $10.9 million, IRR was 134%. NPV was about $1.6 million, IRR was 50%.
Asia			
Southeast,South Asia Mamaril and Norton(2006)	Philippines Vietnam ROW	Rice Rice Rice	Gains were $270 (range from $136-276) million Gains were $329 (range from $159-415)million Gains were $20 (range from $10-26) million
Southeast,South Asia Mishra (2003)	Bangladesh Philippines India	Eggplant Eggplant Eggplant	NPV gains range from $25 to $69 million NPV gains range from $19 to $53 million NPV gains range from $279 to 773 million
Southeast Asia Cuyno (1999)	Philippines	None-Health	Reduced risk to: human health and farm animals by 64% beneficial insects by 61% fish and other aquatic species by 62% birds by 60%
South Asia Alponi (2003)	Bangladesh	Vegetables: Eggplant Cabbage	Cabbage and eggplant yields were higher 10-50% and 13-61% respectively Eggplant seedlings mortality rate was 5-10% Cabbage seedlings mortality rate was 1-4%
Southeast Asia Mutuc (2003)	Philippines	Eggplant	Case 1: Nueva Ecija: Total daily calorie intake/capita increased b/w 0.09 to 0.6 kilocalories (5% bacterial wilt) and b/w 0.9 to 6.0 kilocalories (50% bacterial wilt) Case 2: Pangasinan Total daily calorie intake/capita increased b/w 0.07 and 0.22 kilocal. (5% bacterial wilt) and b/w 0.15 and 0.49 kilocal. (50% bacterialwilt)
South Asia Debass (2000)	Bangladesh	Birnjal (Eggplant) Cabbage	NPV was about $29million, the IRR was 684% NPV was about $26 million,the IRR was 696%
Rakshit (2008)	Bangladesh	Cucurbit Crops	NPV was about $3.99 million, IRR was 151%.
Latin America			
South America Cole et al. (2002)	Ecuador	Potato	Active fungicide ammount decreased by 50% Insecticide use decreased by 75% Production costs decreased from $104 to $80/t
South America Baez (2004)	Ecuador	Plantain	Producer, consumer and laborer net benefits range from $46.5 to $49 million, $4.2 to $4.4 million and $8 to $9.5 million, respectively.
Eastern Europe			
Daku (2002)	Albania	Olives	Net IPM research benefits varies between $39 and $52 million (assuming farmers move from no spray and fill pesticide to IPM program/ practice directly.

[1]The IPM CRSP impact studies included in the table were reviewed in Chapter II, section II only.

Chapter III. Methods

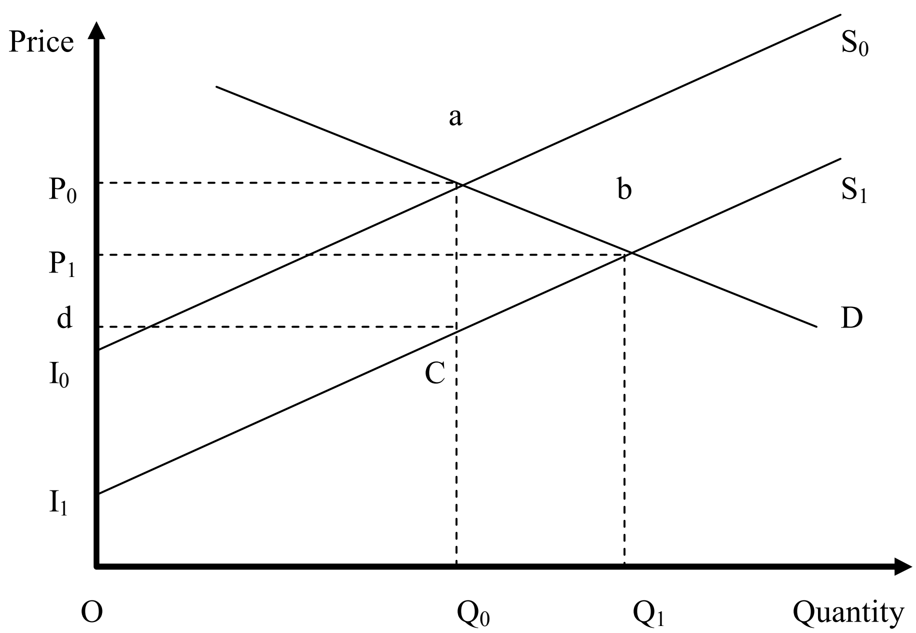
Many studies which evaluate the impacts of agricultural research use budgeting, economic surplus and benefit cost analysis. According to Alston, Norton, and Pardey (1998), calculating the change in economic surplus is one of the most common methods for welfare analysis or estimating returns in a partial equilibrium framework. This model can be used for ex-ante and ex-post analysis. The economic surplus model was used in many of the IPM CRSP impact assessments described above and will be used in others which follow in the next chapter.

The economic surplus method is used to measure the net returns at the market level from a research project or program, which shifts the supply curve out to the right. It is a very flexible method that also allows consideration of technology and price spillover effects. Technology spillover is when other countries are able to adopt and utilize the research benefits of one country (Alston, Norton, and Pardey, 1998). The economic surplus model can be used to measure the change in producer and consumer surplus as a result of a program (such as the IPM CRSP) and also the total or net welfare effect. Since one of the objectives of this thesis is to calculate the net present value of benefits resulting for the specific IPM programs using the economic surplus model is necessary. Using the economic surplus approach provides dollar values for the producer and consumer benefits resulting from the particular program that is being evaluated which is necessary and important for the decision making process. This section presents and explains the economic surplus model graphically and through mathematical formulas which were later used in Excel framework to calculate the producer and consumer surplus amounts in the cases of Albania, Ecuador and Uganda.

In figure 1, the area below the demand curve D above the price line P_0 is called consumer surplus (CS). It indicates how much some consumers are willing to pay above the current price to obtain the product. However, these consumers pay the current price and not what they would be willing to pay.

The area P_0I_0a, above the supply curve S_0, and below the price line is called producers surplus (PS). It indicates how much the producers are willing to accept below the current market price and represent the returns to fixed factors of production.

Figure 1: Consumer and Producer Surplus



Source: Alston, Norton, and Pardey (1998) p.209

According to Alston, Norton, and Pardey (1998, pp.41), the shift of supply from S_0 to S_1 is due to yield improving research or reduction in costs and adoption of the new technologies that result from the research. The goal of the IPM CRSP is to affect this shift in supply by affecting the production side thereby improving the life of farmers and the economy as a whole. The supply shift changes the consumer and producer surplus. The new CS is the area below the demand curve D but above the new price P_1 and the new PS is the area P_1I_1b, the new equilibrium point is b. The gain to consumers from the supply shift is the area P_0P_1ab and the gain to producers is the area $I_1P_1b - I_0P_0a$ (Alston, Norton, and Pardey 1998, pp.209). The net welfare effect may be either positive or negative depending on the elasticities of the supply and the demand. The total net welfare is the sum of the changes in producer and consumer surplus which in this case is the area $abI_1 I_0$. This case is a closed economy case.

$$\Delta CS = P_0 Q_0 Z (1 + 0.5Z\eta) \quad \text{(III.1)}$$

$$\Delta PS = P_0 Q_0 (K - Z) (1 + 0.5Z\eta) \quad \text{(III.2)}$$

$$\Delta TS = \Delta CS + \Delta PS = P_0 Q_0 K (1 + 0.5Z\eta) \quad \text{(III.3)}$$

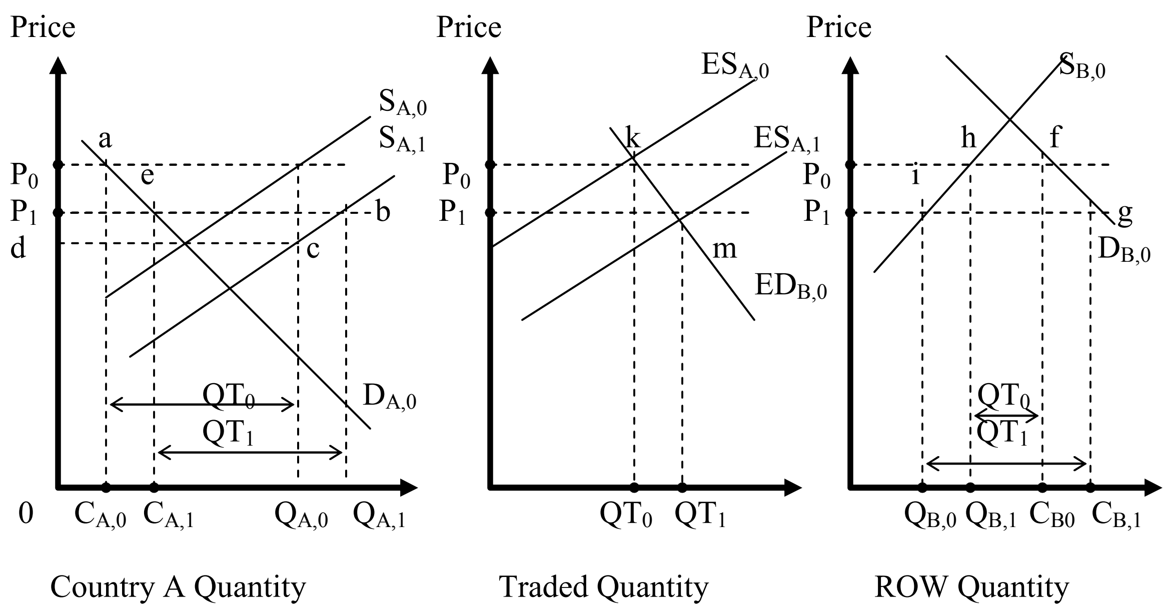
Where η is the absolute value of the elasticity of demand, and $\mathcal{E}$ is elasticity of supply.

$Z = K\mathcal{E} / (\mathcal{E} + \eta)$, where Z is the price reduction from P_0 to P_1 due to the supply shift. While, K represents the vertical shift of the supply function expressed as a portion of the initial price (Alston, Norton, and Pardey, 1998, pp210). This closed economy economic surplus framework was used to calculate the producer and consumer surpluses in the cases of Albania and Uganda.

The closed economy case is simple to explain because it deals with a single market. However for some products, there is significant trade among countries. Countries that are large importers/exporters also can have the ability to affect the world market prices for the product with their production behavior, while small importers/exporters can not. In the case of an open economy, the Rest Of the World (ROW) is included in the economic surplus model. When research is done in a large exporting country, part of the benefits of that research may be transferred to the countries that import the product through price reductions (Alston, Norton, and Pardey 1998, pp.213). Price and technology spillovers are common in the case of a large exporting country. The spillovers lower world prices. When the countries importing the good are not able to adopt the new technology from the exporting country (A), then there is no technology spillover.

Figure 2: Research benefits, size, and distribution due to trade (large country exporter innovates, no technology spillover)

a) Country A: Large country (innovator) b) Excess supply, demand and trade c) ROW production, consumption and trade



Source: Alston, Norton, and Pardey (1998) p.215

In figure 2, Country A is the large innovating country, which has increased its supply due to the innovative technology. This supply increase results in excess supply for country A, which means the export quantity of that good has increased. The excess supply of country A is presented as $ES_{A,0}$ in panel b, the horizontal difference between the initial domestic supply $S_{A,0}$ and the initial demand $D_{A,0}$. The initial import demand is presented by $ED_{B,0}$ the horizontal difference between ROW's initial demand $D_{B,0}$ and initial supply $S_{B,0}$. Following Alston, Norton, and Pardey (1998, pp.214), the quantity produced in Country A is marked $Q_{A,0}$, the quantity consumed is marked $C_{A,0}$, and the quantity exported is marked by QT_0. The corresponding quantities in the ROW are marked by $Q_{B,0}$, $C_{B,0}$ and the quantity of imports QT_1. Due to the research, Country A benefits by the shift of supply to $S_{A,1}$, which consequently shifts the excess supply in panel b from $ES_{A,0}$ to $ES_{A,1}$, and the new equilibrium price is P_1. The quantities in country A shift. Consumption is $C_{A,0}$, production is $Q_{A,1}$ while export quantity is QT_1. In ROW, the corresponding quantities are $C_{B,1}$, $Q_{B,1}$ and the quantity of import is QT_1. Since country A is a large country, it affects world prices such they fall, and consumers in both countries and producers in country A benefit, while producers in ROW lose. The benefit for consumers in country A is presented in panel a by the consumer surplus area P_0aeP_1, while producers surplus is given by the area P_1bcd. The benefits to consumers in the ROW are given in panel c by the area P_0fgP_1, while producers' losses are presented by the area P_0hiP_1 (Alston, Norton, Pardey 1998, pp.214). Since consumers benefit in both cases and producers lose only in one case, it is evident that the net benefits are positive. However more specific calculations need to be done to calculate the exact net benefit. The domestic supply and demand and the ROW's supply and demand equations are used to calculate the percentage reduction in price. According to Alston, Norton, Pardey (1998, pp.217), the domestic ΔCS and ΔPS are calculated as follows:

$$\Delta CS_A = P_0\, C_{A,0}\, Z\, (1 + 0.5Z\eta_A) \qquad \text{(III.4)}$$

$$\Delta PS_A = P_0\, Q_{A,0}\, (K - Z)\, (1 + 0.5Z\varepsilon_A) \qquad \text{(III.5)}$$

$$\Delta TS_A = \Delta PS_A + \Delta CS_A \qquad \text{(III.6)}$$

where, η_A is the absolute values of elasticity of domestic demand and ε_A is the elasticity of domestic supply. The Z shift is different than in the case of the of small open or closed economy, $Z = \varepsilon_A * K / (\varepsilon_A + s_A * \eta_A + (1 - s_A) * \eta_B^E) = (P_1 - P_0) / P_0$, where η_B^E is the absolute value of the demand elasticity of ROW's excess demand (or export demand) and s_A is the fraction of production consumed in the domestic country.

$$\eta_B^E = (Q_{s,B} / Q_{x,A}) * \varepsilon_B + (Q_{d,B} / Q_{x,A}) * \eta_B \qquad \text{(III.7)}$$

where, $Q_{s,B}$ and $Q_{d,B}$ are the quantities supplied and demanded, respectively, in country B, and $Q_{x,A}$ is the exports of the commodity from country A. The ΔPS and ΔCS in ROW are calculated as follows (Alston, Norton, and Pardey 1998, pp.214):

$$\Delta CS_B = P_0\, C_{B,0}\, Z\, (1 + 0.5Z\eta_B) \qquad \text{(III.8)}$$

$$\Delta PS_B = P_0\, Q_{B,0}\, Z\, (1 + 0.5Z\, \varepsilon_B) \qquad \text{(III.9)}$$

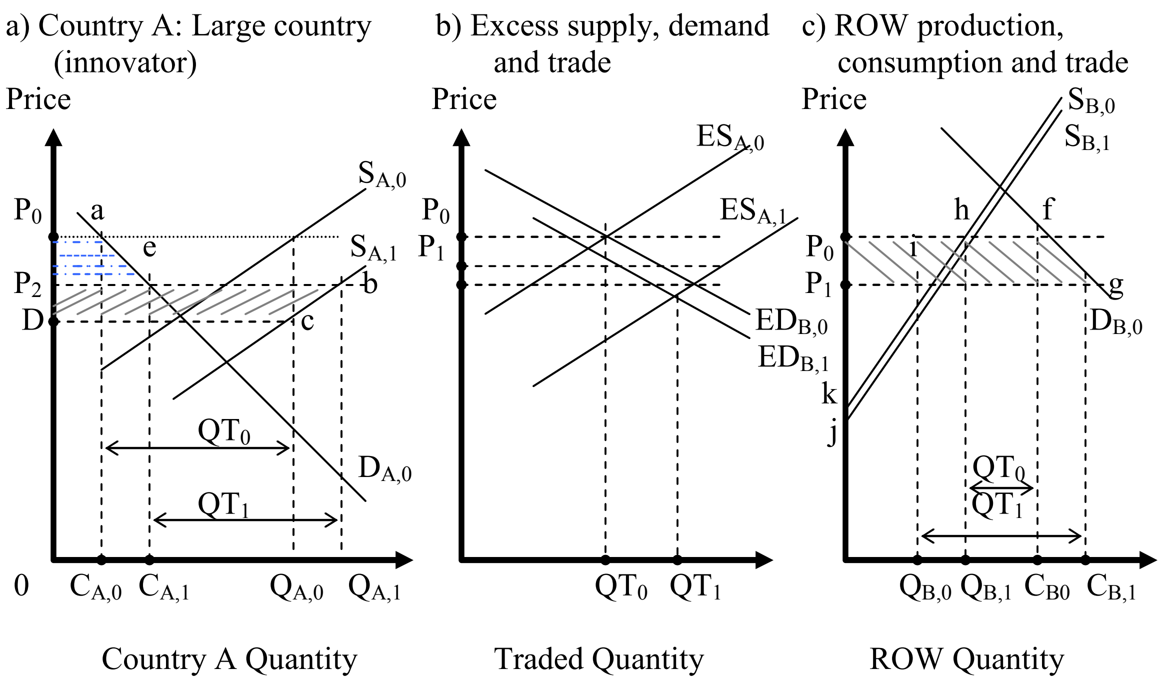
The ROW's net benefit is calculated by summing (III.8) and (III.9). Since the net benefit in ROW is positive and both the ΔCS_A and ΔPS_A are positive, then it can be concluded that the over all net benefit is positive:

$$\Delta TS_B = P_0\, Q_0\, K\, (1 + 0.5Z\eta_B^E) \qquad \text{(III.10)}$$

The large exporting country with no technology spillover framework was used to calculate the consumer and producer surplus in Ecuador, in chapter IV section II. The formulas explained above were imputed in an Excel spreadsheet after obtaining and imputing other required data such as prices, quantities, elasticites etc., which produced the producer and consumer surplus dollar amounts.

If the innovative country is the importing country, in the case above that would be ROW, and then Figure 2 would look different as well as the ΔPS and ΔCS. If there is a technology spillover then the outcome will also be different. Figure 3 presents a large innovative exporter country and the effects of the spillover. This case is important because it shows the effects of the technology spillover to both countries which affects the consumer and producer surplus values.

Figure 3: Research benefits size and distribution due to trade (large country exporter innovates, with technology spillover)



Source: Alston, Norton, and Pardey (1998) p.220

The difference between the cases presented in figures 2 and 3 is that the world price is lower in figure 3 due to the reduction in excess demand from $ED_{B,0}$ to $ED_{B,1}$ presented in panel b. The domestic country A still benefits from the research which lowers the world price, but the technology spillover hurts country A's exports because farmers in the ROW lower the world price even more by adopting the new technology. Country A's producers will benefit as long as the difference between P_0 and P_2 is smaller than the initial vertical supply shift in country A, which can be the case even when the technology is fully transferable (Alston, Norton, and Pardey 1998, pp.219). The producers in country A gain the area P_2bcd (panel a), the consumers gain area P_0aeP_2 (panel a), while the consumers in ROW gain area P_0fgP_2 (panel c). The ROW producers are net losers even though there is some adoption (Alston, Norton, and Pardey 1998, pp.219).

The economic surplus framework is simple and there are many factors that affect both the consumer and the producer sides, such as taxes, quotas, and other government regulations, that can also be included in the model.

III.I. Benefit-Cost Analysis (B-C)

B-C analysis is a popular quantitative method used by economists to discount the benefits and costs of alternative investments to a common time period. According to Steinemann, Apgar, and Brown (2005, pp.322) B-C analysis is a useful systematic framework for project evaluation. The benefits may include not only revenues to producers but also net benefits to consumers and environmental benefits. The costs in a B-C analysis are compared to the benefits of the investment (cost), but they may also include the costs to the environment which include emissions, environmental degradation, loss of natural resources, effects on human health etc. Measuring the benefits and costs to the environment is difficult and people tend to overlook and undervalue them. There are few different B-C methods such as net present value (NPV), benefit-cost ratio, internal rate of return (IRR) etc. In this section the NPV, B-C ratio and the IRR method are presented and explained in more details because these were used as a part of the economic surplus analysis in all three sections of chapter IV.

In order to evaluate the benefits and costs, they need to be placed in equivalent terms over time. The net present value (NPV) is one method used to discount benefits and costs to a present value (Steinemann, Apgar, and Brown 2005, pp.335).

$$NPV = \left[\sum_{t=0}^{n} \frac{B_t}{(1 + r)^t} \right] - \left[\sum_{t=0}^{n} \frac{C_t}{(1 + r)^t} \right] \qquad \text{(III.11)}$$

or

$$NPV = \Sigma B_{PV} - \Sigma C_{PV} \qquad \text{(III.12)}$$

where,

t = the time period

r = the discount rate

n = the life of the project

B_t = the benefits in time period t

C_t = the costs in time period t

ΣB_{PV} = the sum of all benefits in present value terms

ΣC_{PV} = the sum of all costs in present value terms

(Steinemann, Apgar, Brown 2005, pp.335).

According to Steinemann, Apgar, and Brown (2005, pp.336) the project is justified if the NPV > 0, while in the case of multiple projects where the NPV > 0 for all of them, the project with the highest NPV value is chosen. The NPV method was used in combination with the economic surplus method in order to obtain the net present value of benefits resulting from the specific IPM programs in all three cases (Albania, Ecuador and Uganda). The B-C method was also used by Cuyno (1999) to measure the economic impact of an IPM CRSP program on the health and environment in the Philippines. When combined with the economic surplus analysis described above, the benefits in the NPV formula are the surplus values over time and the costs are the research costs.

Another B-C method is the internal rate of return (IRR), which is the rate of return that sets the NPV of benefits minus costs to zero, by finding the appropriate discount rate (Steinemann, Apgar, and Brown 2005, pp.337).

$$\left[\sum_{t=0} \frac{B_t}{(1+r)^t}\right] = \left[\sum_{t=0} \frac{C_t}{(1+r)^t}\right] \qquad \text{(III.13)}$$

or

$$\Sigma B_{PV} = \Sigma C_{PV} \qquad \text{(III.14)}$$

According to Steinemann, Apgar, and Brown (2005, pp.338), an IRR greater than the discount rate (r) indicates that the project should be undertaken, because it yields a higher rate of return than the alternative. The IRR method was also used in combination with the economic surplus method in chapter IV. The IRR were calculated for the tomato IPM Program in Albania, the plantain IPM Program in Ecuador and the tomato IPM Program in Uganda.

III.II. Budgeting

Budgets are used in IPM CRSP impact studies to summarize the benefits and costs per hectare and these estimates are then used in the economic surplus analysis. Daku (2002) used budgets to summarize the expenses for each experiment and the costs and returns per acre to produce olives. An enterprise budget includes the value of output and cost of all inputs devoted to producing one kind of crop or livestock. The enterprise budget provides information about the profitability of each enterprise relative to the resources used, it also provides information about relative efficiency of various enterprises (Brown 1979). According to Daku (2002), an enterprise budget summarizes the costs and projected returns for a single enterprise, it also includes gross returns and variable and fixed costs. Each enterprise budget is customized to the specific crop and area setting, but it contains the same main parts.

Another type of budget is a partial budget. According to Brown (1979), the partial budget consists of four basic items:

Costs	Benefits
a) New costs	c) Costs saved
b) Revenue forgone	d) New revenue

If (c) + (d) > (a) + (b) the change is profitable, given that it is a feasible change.

According to Daku (2002) partial budgets can be developed for each IPM practice, which will help indentify the cost and revenue items that will change with the implementation of the new IPM practices. Daku (2002) points out that the partial budget is a partial application of marginal analysis.

Chapter IV. Results of the Additional Analysis of IPM CRSP Impacts

The IPM CRSP studies included in Chapter II were tailored to a specific country, crop, and/or experiment. In an attempt to include more recent impact analysis, a request was sent to each IPM CRSP site chair asking them to nominate additional IPM technologies for evaluation in their sites. This chapter includes additional economic surplus analyses that were conducted based on the responses received from Albania, Ecuador and Uganda. Scientist-questionnaires were sent to IPM CRSP site coordinators in: East Africa, West Africa, Southeast Asia, East Asia, Central Asia, Latin America and Eastern Europe. Each site that responded compiled their scientist responses and filled out an aggregate scientist-questionnaire for a specific crop, so one response per site was received. A sample questionnaire is presented in Appendix A. After receiving the responses, an economic surplus analysis was conducted for each crop/technology. The appropriate model was decided upon with respect to the type of market for that product (closed economy, small open economy, or large open economy). The choice of the appropriate economic surplus model is affected by the country's ability to affect world prices. After that the appropriate data from each questionnaire was entered in an Excel spreadsheet, the information on prices, quantities produced, exports, imports and consumption were found using FAOSTAT. The benefit time period was different for every project, depending on when the project started but the usual research timeframe used was 15 years. Therefore the data for each project was spread out over a 15 year time period. The elasticity of supply ε is problematic if linear supply and demand curves are used because when the function is inelastic at the equilibrium a negative intercept at the price axis is implied. Therefore various authors have criticized the use of linear supply curves with point elasticity of less than one (Alston, Norton, and Pardey 1998, pp.63). To avoid this type of problem and due to limited information about the actual supply elasticities, the supply elasticity was assumed to be 1 in the cases that were examined. A supply elasticity of 1 was also used in most of the previous studies for same products and countries. The demand elasticities were also obtained from previous studies.

A full list of the variables used in the economic surplus analyses as well as explanations about each variable are available in Appendix B. Using the formulas discussed in the chapter III, the total economic surplus was calculated first and than the NPV of the benefits was calculated, using a 5% discount rate.

IV.I. Tomato IPM Program in Albania

According to the Food and Agriculture Organization (FAO), tomatoes are the fourth most important agricultural product in Albania. In 2006, Albania produced 164,853 metric tons of tomatoes, the area harvested was 7,385 ha, and the yield per hectare was 22,323 kg/ha. On average from 2000 to 2005 Albania imported 6,121 metric tons of tomatoes and exported approximately 127 metric tons of tomatoes. Due to the small quantities of exports and imports Albania can be considered a closed economy with respect to the tomato market. The IPM CRSP has been working with Albanian producers to improve their tomato production practices. In order to manage the root-knot nematode (*Meloidoyne inconita*) problem, the IPM practice of soil solarization was used. The solarization process includes covering the soil with plastic-sheet after harvest and before planting the new seeds. This process destroys the pathogens in the soil that later can cause the root-knot nematode problem. According to Albanian scientists, a yield improvement of 50-200% occurred with IPM use compared to the untreated control, and 50% as compared to previous practice. A 50% yield change was assumed in the economic surplus analysis. The percent change in cost per hectare used in the economic surplus analysis was calculated using the data provided by the scientists. The cost change was estimated to be –0.39%. The scientists suggested that maximum adoption rate of 65-70% will be achieved by year 2014, which sounds optimistic. Past experience with adoption of improved practices suggests that a more reasonable adoption estimate would be about 25%. Currently 1.5% of the farmers have adopted the IPM practice and there are only 4ha of tomatoes grown under the IPM practice. A maximum adoption rate of 25% was assumed in our analysis. The price of tomatoes per ton was estimated by using average prices per ton of tomatoes for the years 2000-2002-2004 which were obtained from the FAOSTAT (2008). The quantities of tomatoes produced were obtained only for the green-houses and low-tunnels production in Albania because the scientists who responded to the scientist-survey indicated that they were answering the questions regarding green-house tomato production. The average quantity of tomatoes produced in green-houses and low-tunnels was averaged for each and than added together for the same time period as the prices. The average price was $308 per metric ton (FAOSTAT, 2008) and the average quantity was estimated to be 26,969 metric tons (Matotan Z., and Abacus, 2009). Varying the price and the quantity per year would not change the results since the annual variation is not large, therefore using average prices and quantities is recommended. The elasticity of supply was assumed to be 1, due to the factors described in the previous section. An additional factor supporting the assumption was the fact that tomato producers can divert land into tomato production relatively quickly. The elasticity of demand for tomatoes in Albania was -0.5 (Rickard and Sumner 2006). The economic surplus analysis was conducted for the time period 2007 to 2022. The costs reported by the Albanian scientists were for the years from 2007 to 2014, but the costs reported in 2014 were carried over until year 2022. The consumer and producer surplus analysis yielded positive values for all years. The benefits and costs of the IPM practice were discounted at 5% giving a NPV of approximately USD $8 million[2] over 15 years. The IRR was incalculable due to the large value of the benefits and very small value of the costs.

Due to the uncertainty of the assumptions, a sensitivity analysis was conducted. Scientists reported that the adoption rate will reach 65-70% by 2014. Consequently the adoption rates were changed in such a way that the highest value was 70% as the scientists had suggested initially. This change in the adoption rate increased the NPV to about USD $23 million[3] for the 15 year period.

In the second sensitivity analysis, the percent change in cost per hectare was changed to 25%. The responses received in the scientist-questionnaire regarding the cost per hectare may have been too low because scientists may have misinterpreted the question. Knowledge and practice suggest that -0.39% change in cost per hectare is too low, and that is why in the sensitivity analysis a 25% cost per hectare change was used. Another reason for the cost uncertainty may be the fact that only 4 hectares of tomato are currently

[2] Refer to Appendix C for the economic surplus analysis table
[3] Refer to Appendix D for the sensitivity analysis table

grown under the IPM practice, so there is little commercial experience with it, as farmers only started adopting the IPM practice in 2007. Changing the percent change in cost per hectare to 25% resulted in a decrease of the NVP to about USD $5 million over the 15 year period, with a 5% discount rate.

The following table summarizes the NPV of benefits produced by the economic surplus analysis of tomatoes in Albania.

Table 2: Summary of the results from the economics surplus analysis and sensitivity analysis for tomato IPM in Albania

	NVP
Original, max adoption rate = 25%	$8,358,811.98
	Sensitivity Analysis
Case 1 : Adoption rate change = 70%	$22,714,675.68
Case 2: Percent change in cost per hectare = 25%	$5,498,633.82

IV.II. Plantain IPM Program in Ecuador

For the time period 2001-2007, Ecuador was the third largest producer of plantain in South America (FAOSTAT, 2008a). According to the FAOSTAT (2008a), in 2006 Ecuador was the largest South American exporter of plantain, while in 2005 Ecuador was the second largest exporter after Columbia. In 2006 Ecuador exported 166,688 metric tons of plantain, which is approximately 30% of the world plantain exports. In 2006, South America exported 365,787 metric tons of plantain, which was approximately 67% of the world's plantain exports (FAOSTAT, 2008a). This trade implies that the appropriate model for the economic surplus analysis is a large exporting economy model. According to the Ecuadorian scientists, the IPM practice used is referred to as IPM management which includes sanitization of the crop, fertilization and population (of plantains) regulation, cultural practices and biological control. The scientists estimated the percent yield change per hectare to be 100% for farmers who adopt the complete set of IPM practices. The percent change in cost per hectare was estimated to be approximately 37%. The scientists also indicated that with IPM, the use of pesticides such as gliphosate and carbofuran is reduced. The plantain IPM project began in 1999 and thus far 5000 out of available 45,000 hectares of plantain are currently grown under the IPM practice suggested by the IPM CRSP, which is 11% of the available hectares. The scientists believe that so far 0.2% of the farmers have adopted the IPM practice but the adoption had started in the 4th year (2003). The percentage of hectares used did not equal the number of farmers who adopted the technology because of the uneven per farmer acre distribution. The maximum adoption was expected to reach 5% of the farmers, and was expected to be achieved in 5 years. The supply elasticity for plantain was assumed to be 1 based on the argument made by Alston, Norton, and Pardey (1998) in the beginning of this chapter. According to Baez (2004) the elasticity of demand for plantain was -0.3, indicating that plantain is a staple food in Ecuador. The large open economy model leads to the use of an excess-demand-supply framework. The calculation of η_B^E - absolute value of the demand elasticity of ROW's excess demand (or export demand) - requires the supply and demand elasticities for the ROW. The ROW's plantain elasticities of supply and demand are expected to be more elastic than the ones in the domestic country because the elasticities in the ROW are aggregated excess demand and supply of the rest of the trading countries. The ROW's plantain elasticity of supply η_B was assumed also to be 1, while ROW's demand elasticity was assumed to be -0.6 considering the information available for bananas (Baez 2004). Using the formula for the absolute value of the demand elasticity of ROW's excess demand (or export demand) η_B^E which was defined in section III formula III.7 yields a η_B^E of 167.89. The price and quantity produced used in the economic surplus analysis were averaged for the period from 2001 to 2003 and were USD $61 and 714,094 metric tons, respectively (FAO STAT 2008a). Since the large open economy model was used, another piece of information was needed, the quantities consumed domestically. These were obtained from FAO STAT (2008a), the consumption quantities were also averaged from 2001 to 2003. The average quantity consumed in Ecuador was 467,722 metric tons. The research and dissemination costs reported by the scientists are for the time period 1999-2006, however since no information was available for the costs after year 2006 which were $4,000. The costs from year 2006 were carried over until year 2013. Including these costs in the economic surplus analysis did not affect the results significantly, since the benefits from adoption of the IPM practices were much higher than the costs. Using the formulas from Chapter III regarding the open economy model, the economic surplus analysis resulted in a NPV of benefits over the 15 year period, discounted at 5%, of approximately USD $7 million[4] and the IRR was estimated to be 110%.

[4] The economic surplus analysis table for Plantain in Ecuador is in Appendix E

Sensitivity analysis was conducted by varying the yield change, which was initially reported to be 100%. Given the small number of current adopters mentioned above, a 100% yield change is optimistic, instead a 70% yield change was used for this sensitivity analysis which resulted in a NPV of benefits over the 15 year period, discounted at 5%, decreased to approximately USD $4 million and the IRR was 89%.

Table 3: Summary of the results from the economics surplus and the sensitivity analysis of the Plantain IPM Program in Ecuador

	NPV	IRR
Baseline Scenario - max yield change =100%	$6,502,488.75	110%
Reducing the yield change to 70%	$3,909,910.26	89%

IV.III. Tomato IPM Program in Uganda

The Ugandan scientists provided 3 different responses to the scientist questionnaire for 3 different combinations of IPM practices. The questionnaire which contained all the IPM practices combined together was used for the original economic surplus analysis. The 2 other questionnaires were used for sensitivity analysis.

According to FAOSTAT (2008b), in the period from 2002 to 2005, on average Uganda produced 11,200 metric tones of tomatoes and the area harvested for that period on average was 2,100 ha. The model used in the economic surplus analysis was a closed model because during the time period from 2002 to 2005, average exports of tomatoes in

Uganda were 19 metric tones and average imports were 15.5 metric tones, which in both cases is a very small amount for tomato to be considered as an important export crop. The scientists reported that the IPM practices applied on tomato production were a combination of staking, mulching, minimum pesticides, raisedbeds, and resistant variety. The percent yield change per hectare was reported to be 42%. According to the data provided by the scientists the percent change in cost per hectare was estimated to be 1%. The development of the IPM practices started in 2002, but the dissemination process began in 2004. Farmers started adopting the IPM practices in 2005, and currently 5% of all tomato growers have adopted the IPM practices. The maximum adoption is expected to be achieved by 2016, and according to the scientists the maximum adoption is expected to reach 70%. Knowledge and experience suggest that 70% adoption is an over-optimistic assumption, as in most cases the maximum adoption reaches approximately 25%. The 25% adoption rate was used in the baseline scenario analysis. The costs provided by the scientists are for the years 2002 to 2008. Since there is no information about the costs after 2008, the 2008 costs were carried out until 2016. Due to the unavailability of price data for tomatoes in Uganda, the price used in the economic surplus analysis was generated using tomato prices from nearby countries for the 2002-2005 period. The average price was estimated by averaging the prices in each of the four counties: Ethiopia, Kenya, Malawi and Mozambique for each year and then the averages from 2002, 2003, 2004 and 2005 were averaged again. The price obtained was approximately $195 per metric ton of tomatoes. Due to the lack of previous studies and according to the argument made by Alston, Norton, and Pardey (1998) in at the beginning of this chapter IV, the elasticity of supply was assumed to be 1. The elasticity of demand for tomatoes in Uganda was assumed to be -0.5. Using the formulas outlined in Chapter III, for the closed economy case, the NPV of benefits from adopting the IPM practices using a 5% discount rate was about USD $1 million, and the IRR was 169%.

Sensitivity analysis was conducted to consider the scientists' estimate that the maximum adoption will achieve 70%. The adoption rate ranged from 5% in 2008 to 70% in 2016, which yielded a NPV of about USD $2.5 million and IRR of 174%. The following table shows the results from the original analysis and the sensitivity analysis described above.

Table 4: Summary of the original and the two sensitivity analysis for the Tomato IPM Program in Uganda

	NPV	IRR
Original scenario, max adoption rate = 25%	$1,004,378.93	169%
Percent change in cost per ha = 25%	$584,266.01	133%
Maximum adoption rate = 70%	$2,504,050.86	174%

Based on the scientists' data, the percentage change in cost per acre was estimated to be 1%. Sensitivity analysis was also conducted by changing the percent change in cost per hectare from 1% to 25%, ceteris paribus. Changing the percent change in cost per hectare to 25% decreased the NPV to about USD $0.58 million (5% discount rate) and the IRR to 133% when the maximum adoption of 25% was achieved.

The following sensitivity analyses (case 1 and 2) were based on the 2 other[5] questionnaires.

Case 1: The scientists reported the combination of practices to be: mulching, minimum pesticides, raisedbeds and resistant variety. The yield change in this case was reported to be 25%, instead of the 42% in the initial (original) analysis. The percent change in cost per hectare also changed from 1%, the new percent change in cost per acre was estimated to be -0.5%. The maximum adoption was again expected to be 70%. However, as in the original analysis a 25% adoption rate was used, based on knowledge and previous experience. The costs for development and dissemination changed per year but the same procedure was applied in which the 2008 costs were carried out until 2016. The new analysis at 5% discount rate, yielded NPV of approximately USD $0.03 million and IRR was 43% when adoption reaches a maximum of 25%.

Case 2: The combination of IPM practices in this case was: staking, minimum pesticides, raisedbeds and MT56. The new combination resulted in a 30% yield change and a new percent change in cost per hectare. The change in cost per hectare went from 1% in the original scenario to 0.25%. The maximum adoption was again expected to reach 70% but based on the previously mentioned assumptions a 25% adoption rate was used. The development and dissemination costs changed again but the same practice was applied, the costs from year 2008 were carried to 2016. The new changes resulted in a new NPV of approximately $0.8 million (at 5% discount rate) and IRR of 270% when the adoption

[5] For more information please refer to the beginning of section: Tomato IPM Program in Uganda.

rate was maximum 25%. The table below is used to summarize the effects from case 1 and case 2:

Table 5: Summary of the case 1 and case 2 economic surplus analyses conducted in the case of the Tomato IPM Program in Uganda

	NPV	IRR
	Maximum Adoption ≤ 25%	
Case 1[1]	$29,721.91	43%
Case 2[2]	837,665.57	270%

[1] The analysis is based on the scientist-questionnaire contatining the following mix of IPM practices: mulching, minimum pesticides, raisedbeds and resistant variety (including MT56).

[2] The analysis is based on the scientist-questionnaire contatining the following mix of IPM practices: staking, minimum pesticides, raisedbeds and MT56.

Chapter V. Factors Determining Adoption of IPM Technologies in Bangladesh

An adoption analysis is necessary to describe and measure the adoption of IPM technologies, which can provide important policy information that can lead to improvement of farmers' lives. The objective of chapter V is to determine the factors that affect adoption of IPM technologies in Bangladesh, using survey data from four districts. The chapter includes the following sub-sections: basic background information about Bangladesh, technology adoption discussion and literature review, description the econometric model, description of the variables in the econometric model, and results and conclusions.

V.I. Basic Background Information

Bangladesh is located in the southern part of Asia. It is bordered by India, Myanmar and the Bay of Bengal. Bangladesh is one of the world's most populous nations with 158.6 million citizens. In 2007 the gross domestic product (GDP) was reported to be $67.7 billion dollars, while GPD per capita was approximately USD $426, the average annual GDP growth was reported to be 6.5% (World Bank 2008). Life expectancy at birth in 2007 in Bangladesh was 64 years, and the literacy rate was 47% (World Bank 2008). In 2007, the agriculture sector was estimated to be 18.9% of GDP, and the agricultural annual growth was estimated to be 3.2%. Rakshit (2008) describes Bangladesh as an overpopulated country, heavily dependent on agriculture, with high seasonal unemployment among farm workers, which leads to a generally low standard of living in most areas. According to the US Department of State (2008), 62.3% of the work force in Bangladesh which is about 60.3 million people, works in agricultural jobs. Numerous world organizations have been working to improve the lives of people in Bangladesh, including the IPM CRSP. There are various ways to improve farmers' lives in Bangladesh using IPM CRSP techniques and approaches, such as developing resistant varieties, educating farmers though FFS's, etc. Impact analyses regarding different agriculture related aspects in Bangladesh have been conducted by Rakshit (2008), Victoria (2007), Mishra (2003), Alponi (2003), Debass (2000) and others. One way to improve the lives of farmers in most developing countries is through adoption of innovative agricultural technologies. Considering the fact that the majority of the population in LDCs depends on agricultural production, new technologies may provide an opportunity to increase production and income significantly (Feder, Just, and Zilberman 1985).

V.II. Technology adoption discussion and literature review of IPM adoption

Technology adoption has been studied extensively over the years, and different authors have defined technology differently. In general a new technology can be defined as a new way of production. New technologies are usually associated with risk, uncertainty and distrust in the minds of farmers, which are obstacles to adoption. According to Feder, Just and Zilberman (1985), other constraints to adoption of innovative technologies are the "lack of credit, limited access to information, inadequate farm size, inadequate incentives associated with farm tenure arrangements, insufficient human capital, absence of equipment to relieve labor shortages (thus preventing timeliness of operations), chaotic supply of complementary inputs (such as seed, chemicals, and water), and inappropriate transportation infrastructure." Economists often associate technology improvement with increase of productivity, decrease of labor and increase of leisure. In agriculture, technologies have been introduced as packages containing several components such high yield varieties (HYV), fertilizers and corresponding land preparation (Feder, Just and Zilberman 1985).

Feder, Just, and Zilberman (1985) also point out that before defining adoption it is important to distinguish between individual (farm-level) and aggregate adoption, defining final adoption at the level of the individual farmer as the “degree of use of a new technology in long-run equilibrium when the farmer has full information about the new technology and its potential” while the aggregate level of adoption is measured by the aggregate use of technology within a specific geographic area.

Mauceri (2004) analyzed the adoption of IPM technologies in the case of potato production in Carchi, Ecuador, using an ordered probit model. The variables used in the adoption analysis were: age, farm size, education, family size, number of family members 14 years and older, landholdings per capita, pesticide health impact on the farmer and the family, FFS attendance, information access though field days, pamphlets and exposure to FFS participants. The study found that, apart from information factors the only socio-economic factor that was significant was household size, and it impacted IPM adoption negatively. The data were obtained through a farmers’ survey, however the sample was non-random and small which limited the analysis. Mauceri (2004) also looked at the cost-benefit of various information diffusion methods, and the extent of adoption in addition to analyzing the determinants and constraints to adoption. The study found that FFSs are cost-effective and require little if any additional capital but are not the most cost effective dissemination techniques. (Mauceri 2004)

Bonabana-Wabi (2002) analyzed the factors affecting adoption of IPM technologies in the Kumi district, Eastern Uganda. In addition, she also analyzed the relative contribution of each factor affecting IPM adoption and the level of adoption of eight IPM technologies. The study analyzed the adoption of eight IPM technologies on cowpea, sorghum and groundnuts in Kumi. Low adoption (< 25%) was found with five technologies, while high adoption (> 75%) was found with three technologies. Using univariate and multivariate logit models, the eight practices were analyzed and it was found that information access positively affects adoption of IPM technologies. It was also found that social factors do not affect sorghum technology adoption, except *celosia* (an exotic legume that reduces striga) which was positively affected, and in that case males were more likely to adopt the technique of intercropping sorgum with *celosia* than females. Farm experience was found to positively affect timely planting of cowpea. Some of the significant economic factors found by the study to affect adoption were the farm labor availability and disease incidence, which affect adoption of *celosia* and other Striga chasers, negatively (Striga chasers such *Celosia* reduce Striga emergence in sorghum). In the sorghum crop rotation model, adoption of crop rotation was found to reduce weed problems. In the cowpea case, it was found that intercropping was used as both a land-saving technology and a pest management strategy. (Bonabana-Wabbi 2002)

De Souza Filho, Young, and Burton (1999) analyzed the factors influencing adoption of sustainable agricultural technologies in Espitito Santo, Brasil, using an alternative approach called discrete econometric framework (duration analysis).The study found that access to information (through membership in farmers organizations, NGO presentations, pamphlets etc.) positively affects adoption, and also increases the awareness of negative effects due to pesticide use. In this study farm size was found to affect adoption negatively. It was also found that an increase in output prices and rural wages relative to prices of external inputs decreases the speed of diffusion of sustainable agricultural technologies (De Souza Filho, Young, and Burton 1999).

Another study by Chaves and Riley (2001) determined the factors influencing integrated pest management adoption to combat coffee berry borer on Colombian farms. The factors affecting adoption were said to be social, economic, environmental and institutional. A logistic regression analysis was used to determine the impact of different factors, but first some standard non-linear curves were fitted and contrasted to the uptake data for each of the four chosen IPM recommendations for coffee berry borer control. Since the different factors were analyzed at different times upon the uptake of the recommendations singly and in combination, there were different scenarios. The study found education to be an important influential factor positively affecting adoption under all scenarios, while the size of coffee plots was found to be important in all cases in most of the years, and wealth was also found to be an influential factor affecting adoption.

V. III. The econometric model: an ordered probit

The dependent variable in the following adoption analysis can take four values 1, 2, 3 and 4, indicating different levels of adoption. Due to the ordered nature of the dependent variable the model used was an ordered probit model. The ordinary least squares (OLS) models are not the adequate estimators for these types of cases because they are not necessarily consistent in the probability discrete choice framework. The OLS estimator measures the change in the dependent variable given one unit change in the independent variable and could offer results that are negative or exceed the maximum value. The ordered probit model ensures a result that lies within the interval of interest (Wooldridge 2006). The ordered probit model was also used by Mauceri (2004), while Feder and Umali (1993) also suggested the use of the logit/probit models for technology adoption analysis. The ordered probit requires a dependent variable that, as suggested by the name, is ordered, which means that the assigned values are no longer arbitrary but are rather ordered responses taking on values {0, 1, 2….J} (Wooldridge 2002).

In their study, Mullen, Norton and Reaves (1997) pointed out that adoption can be defined by level, while Mauceri (2004) used the level defined adoption approach (ordered probit model) in the adoption analysis.

The dependent variable in this analysis, was also defined by levels: none, low, medium and high which correspond respectively to 1, 2, 3, and 4.

1 - indicated no adoption, meaning that none of the IPM practices were used by that particular farmer.

2 - indicated low adoption, meaning that one of the IPM practices was adopted by the particular farmer.

3 – indicated medium adoption, meaning that two IPM practices were adopted.

4 - indicated high adoption, meaning that three of more practices were adopted by the particular farmer.

The dependent variable was created by looking at seven different variables, which referred to the usage of IPM practices, and using the above guidelines. The practices used to define the dependent variable were: resistant variety, biological control, burning sawdust, poultry refuse, mustard/neem oil cake, mashed sweet gourd traps and pheromones. The sawdust, poultry refuse and mustard/neem oil cake are soil amendments (bedding). Except for the resistant variety and biological control, each other practice was considered as a separate dummy variable. The biological control and resistant variety belonged in one variable regarding the control of the most important pest to that farmer. There was another category for the second most important pest to the farmers. The farmers were asked whether they used pesticides, biological control, resistant variety or other practices, regarding their most important and second most important pest. Finally, there were seven individual variables: the control of the most important pest (pesticides, biological control, resistant variety or other practices), the control of the second most important pest (pesticides, biological control, resistant variety or other practices), burning sawdust, poultry refuse, mustard/neem oil cake, mashed sweet gourd traps and pheromones. Looking at the seven variables, if the farmer used only one practice a 2 was registered, which indicated low IPM adoption, if any two practices were used a 3 was registered, which indicated medium level of IPM adoption etc.

According to Wooldridge (2002, pp.504), a latent variable model can be used to derive the ordered probit model, where y^* is determined by

$$y^* = \mathbf{x}\,\boldsymbol{\beta} + e, \qquad e \mid \mathbf{x} \sim \text{Normal}(0,1) \qquad \text{(V. 1)}$$

where $\boldsymbol{\beta}$ is K x 1 and $\mathbf{x}$ does not contain a constant.

$$y = 0 \qquad \text{if } y^* \leq \alpha_1$$

$$y = 1 \qquad \text{if } \alpha_1 < y^* \leq \alpha_2$$

$$\text{(V. 2)}$$

$$y = J \qquad \text{if } y^* > \alpha_J$$

where $\alpha_1 < \alpha_2 \ldots < \alpha_J$ are the cut points or threshold parameters. The number of threshold parameters depends on the number of values taken by y, for instance if the values of y are 0, 1 and 2 than there will be two cut points α_1 and α_2. In the case of the adoption analysis of IPM adoption in Bangladesh, y takes on the values 1, 2, 3 and 4, resulting in three cut points α_1, α_2 and α_3.

Given the standard normal assumption for e, the conditional distribution of y given x can be derived by calculating each response probability:

$$P(y = 0 \mid x) = P(y^* \leq \alpha_1 \mid x) = P(\mathbf{x}\,\boldsymbol{\beta} + e \leq \alpha_1 \mid \mathbf{x}) = \boldsymbol{\Phi}(\alpha_1 - \mathbf{x}\,\boldsymbol{\beta})$$

$$P(y = 1 \mid x) = P(\alpha_1 < y^* \leq \alpha_2 \mid x) = \boldsymbol{\Phi}(\alpha_2 - \mathbf{x}\,\boldsymbol{\beta}) - \boldsymbol{\Phi}(\alpha_1 - \mathbf{x}\,\boldsymbol{\beta})$$

.   .   .

.   .   .   (V. 3)

.   .   .

$P(y = J - 1 \mid x) = P(\alpha_{J-1} < y^* \leq \alpha_J \mid x) = \mathbf{\Phi(\alpha_J - x\beta) - \Phi(\alpha_{J-1} - x\beta)}$

$P(y = J \mid x) = P(y^* > \alpha_J \mid x) = 1 - \mathbf{\Phi(\alpha_J - x\beta)}$

These probabilities sum to unity. If J= 1 that results in a binary probit model. The α and $\boldsymbol{\beta}$ parameters can be estimated using maximum likelihood estimation (MLE). (Wooldridge 2002, pp.505)

The MLE estimation is based on the distribution of y given x, the Var (β) is directly adjusted for the presence of herersokedasticity (Wooldridge 2006). According to Wooldridge (2002) the presence of heteroskedasticity in Var ($e \mid \mathbf{x}$) changes the functional form entirely $P(y = 1 \mid \mathbf{x}) = E(y \mid \mathbf{x})$ indicating that probit would be inconsistent when $\boldsymbol{\beta}$ is heteroskedastic although it makes little sense to care about the consistent estimation of $\boldsymbol{\beta}$ when $P(y = 1 \mid \mathbf{x}) \neq \Phi(\alpha, \boldsymbol{\beta})$. Another problem that Wooldridge (2002) pointed out in the latent variable models was the normality assumption. If the assumption does not hold, it means that $G(z) \neq \Phi(z)$ and therefore $P(y = 1 \mid \mathbf{x}) \neq \Phi(\alpha, \boldsymbol{\beta})$ which is a functional form problem. In order to obtain more flexible functional forms for $P(y = 1 \mid \mathbf{x})$, the assumptions on e could be relaxed.

MLE is the particular value of parameters that creates the greatest probability of observing the sample (Wooldridge 2006). Considering the ordered probit functional form for the probability of success, taking the log of the both sides yields the log-likelihood function (Wooldridge 2002, pp.505):

$$\ell_i(\alpha, \boldsymbol{\beta}) = 1[y_i = 0] \log[\boldsymbol{\Phi}(\alpha_1 - \mathbf{x}\boldsymbol{\beta}) + 1[y_i = 1] \log[\boldsymbol{\Phi}(\alpha_2 - \mathbf{x}\boldsymbol{\beta}) - \boldsymbol{\Phi}(\alpha_1 - \mathbf{x}\boldsymbol{\beta})] + \ldots + 1[y_i = J] \log[1 - \boldsymbol{\Phi}(\alpha_J - \mathbf{x}\boldsymbol{\beta})] \quad \text{(V. 4)}$$

This log-likelihood function measures the probability of observing the sample data we have. By maximizing the log-likelihood function, the probability of observing the sample data is being maximized. The log-likelihood function is always negative.

The signs of y^* in the model indicate positive or negative impacts on the probability of IPM adoption in the case of Bangladesh. According to equation V.4 the probabilities in the case of Bangladesh can be written as follows:

$P(y = 1 \mid x) = P(y^* \leq \alpha_1 \mid x) = P(\mathbf{x}\boldsymbol{\beta} + e \leq \alpha_1 \mid \mathbf{x})$

$P(y = 2 \mid x) = P(\alpha_1 < y^* \leq \alpha_2 \mid x) = P(\alpha_1 < \mathbf{x}\boldsymbol{\beta} + e \leq \alpha_2 \mid \mathbf{x})$

$P(y = 3 \mid x) = P(\alpha_2 < y^* \leq \alpha_3 \mid x) = P(\alpha_2 < \mathbf{x}\boldsymbol{\beta} + e \leq \alpha_3 \mid \mathbf{x})$

$P(y = 4 \mid x) = P(y^* \geq \alpha_4 \mid x) = P(\mathbf{x}\boldsymbol{\beta} + e \geq \alpha_4 \mid \mathbf{x})$

where the y values 1, 2, 3 and 4 are the corresponding values of the dependent variable indicating none, low, medium and high adoption, respectively.

V. IV. Determinants affecting adoption

Different models have been applied to look at determinants of adoption. Rauniyar and Goode (1996) point out that adoption process is complex and requires accounting for numerous social, economic, cultural, and institutional determinants. The determinants of adoption included in the present model belong in three main categories: socio-demographic, economic, and institutional characteristics. The same categories were used by Mauceri (1999) and Wabbi-Bonabana (2002).

The adoption analysis is based on Bangladesh survey data, collected in the summer of 2006 and used by Rakshit (2008) who conducted an IPM impact assessment study of pheromone adoption for cucurbit crops in Bangladesh. However an adoption analysis was not conducted. The four districts of Jessore, Comilla, Chittagong and Norsingdi, were chosen because they are intensive vegetable growing regions (Rakshit 2008). The survey sample consisted of 300 Bangladeshi farmers, who ranged in age from 14 to 70 years, with 8 percent below the age of 20, and an average age of approximately 38 years. Eighty five percent of the farmers reported having experienced (or a family member having experienced) a health problem due to pesticide use. Also according to the survey data, 17 percent of the farmers were female, all of them in the Norsingdi district. Land holdings ranged between .23 and 66 acres, with an average of 3.18 acres, and 60% of the farmers owned less than 2 acres of land. In Bangladesh, land holdings are represented in decimals (tenth of an acre) instead of acres due to the small size of land holdings. Even though the survey used the decimal marking system, land holdings were converted to acres for the purpose of the adoption analysis. Only five farmers reported owning more than 20 acres of land which for a country as poor as Bangladesh is not very likely so those numbers were thrown out of the analysis data as an outliers. About 77% of the farmers responded that they had received IPM training, and 44% of them reported losses greater than 30% due to annual vegetable yield loss due to pests. The number of working family members (14 years or older) ranged from 0 to 13 members, with an average of about 3 family members. About 24 % of the farmers reported the number of working members to be greater than 4. The average level of education was approximately 5 years, ranging from 0 to 16 years. Bangladeshi primary school education is 5 years, but according to the USAID (2009) it takes Bangladeshi children 6.6 years to complete it. In this sample, approximately 40% of the surveyed farmers reported having education greater or equal to 7 years, meaning they had at least primary school. According to the reported usage of IPM practices, about 29 percent of the respondents were high adopters, while 20 percent were medium adopters. The IPM practices used to define the dependent variable were discussed in the previous section of this chapter.

i. Category I. Socio-demographic Characteristics

District – Farmer's district

The variable "district" was a dummy. Each of the four different Bangladeshi districts: Jessore, Comilla, Chittagong and Norsingdi, was represented by one variable: **District1, District2, District3 and District4**, respectively. These distinguished the district to which each farmer belongs. The coefficients on this variable (**District1, District2, District3 and District4**) indicated the variation between districts which could be used to increase adoption and/or improve policy in the low adoption districts. Feder and Slade (1984) used a binary district variable in the logit analysis of factors affecting the probability of knowledge and adoption. For the purpose of this adoption analysis the four districts were converted in four different dummy variables. Each dummy variable corresponds to one district, however one district had to be dropped because of the dummy variable trap.

Age – Farmer's age

Age is expected to negatively affect adoption. Older and more experienced farmers may be less likely to experiment with new technologies while younger farmers are less risk averse and more likely to adopt new techniques. Mauceri (2004) included age in the ordered probit model, pointing out that younger farmers are still in the process of learning the best management techniques. Adesina et al. (2000) found age to be negatively related to adoption of ally cropping. Chaves and Riley (2001) found age to be negatively correlated and very influential factor in the adoption of IPM for coffee berry borer on Colombian farms.

Female – Farmer's Gender (Female=1, Male=0)

Female is a binary variable distinguishing between male and female farmers. Gender analysis has been an important part of IPM CRSP research. "Yet there are many obstacles to incorporating women in IPM programs around the world, ranging from traditional culture to the fact that gender influences access to resources such as land, labor, education and credit—all important to the adoption of IPM" (IPM CRSP, 2008c). Mauceri (2004) and Bonabana-Wabbi (2002), both found that the farmer's gender (male of female) was not a significant variable affecting technology adoption, in addition Bonabana-Wabbi (2002) also suggests that the effects of the variable are indeterminate. Rauniyar and Goode (1996) also found the effects of this variable to be indeterminate.

Educ - Level of farmer's education

Educ is a continuous variable that represent the number of years of education. More educated farmers were expected to be more open to adoption of innovative technologies, such IPM technologies. Feder, and Slade (1984) categorized education along with experience, as a part of human capital, and point out that a higher endowments of human capital affects productivity positively. Chaves, and Riley (2001), found that higher levels of education were associated with higher adoption. Another study found that education was not a significant variable affecting adoption of technologies (Feder and Umali 1993). A study by Rauniyar and Goode (1996) hypothesized a positive sign for the education variable based on the fact that higher human capital should increase adoption.

Work - Number of family working members

Work, is a continuous variable which represents the number of working members (14 years and older) in the family. This variable measured the labor availability which is a factor in adoption (Mauceri 2004). A study by De Souza Filho, Young, and Burton (1999) found the variable to be significant and positively affecting the adoption of IPM technologies. Another study however, found that family size was negatively correlated with adoption in the case of alley farming by farmers in the forest zone of southwest Cameroon (Adesina et al 2000).

Expr - Farming experience

Exper, is a continuous variable that represents the years of farming experience. According to Feder and Slade (1984), farm experience along with education could be represented as human capital which positively impacts adoption. However in this case, experience is expected to negatively affect adoption, because more experienced farmers may already have picked profitable practices and would be averse toward change.

ii. Category II. Economic Characteristics

FarmInc - The share (low or high) of farm income from total annual income

FarmInc, is included as a dummy variable, which shows the importance of farming for that particular farmer. It is expected to affect adoption negatively. If the share of farm income is high (≥ 50%) farmers were expected to be more risk averse and less likely to try new technologies. Farmers with a low share of farm income (<50%) are expected to be more open to adopting new technologies in order to increase their returns.

Fland - Total size of Farm Land (including own, rented, sharecropped etc. land)

Fland, is a continuous variable measuring the total land holdings in acres. Mauceri (2004) used per capita measure of the land size and found that the variable had no significant impact on adoption while the signs in the different model adaptations were conflicting. Mauceri (2004) pointed out that the difference in the signs may be due to the nature of the IPM technology, larger farms are expected to adopt more capital intensive technologies while smaller farms are expected to adopt more labor intensive technologies. In another study farm size was found to be negatively correlated with adoption (De Souza Filho, Young, and Burton 1999).

iii. Category III. Institutional Characteristics

Exten – distance (km) to the nearest extension agent.

Exten, is defined as a continuous variable measuring the distance in kilometers to the nearest extension agent. The correlation with adoption is expected to be negative. Adesina et al (2000) found positive correlation between adoption and farmers' having contacts with extension. According to Bonabana-Wabbi (2002) extension contacts are positively related to adoption.

Aware – Awareness of pesticide alternatives

Aware is a dummy variable that indicates whether the farmer is aware of the pesticide alternatives. It is expected that farmers who are aware of the pesticide alternatives will be higher adopters than the ones that are not aware.

IPM – Access to IPM training

IPM is a binary variable that provides information about access to IPM training. This variable was expected to positively impact the adoption of IPM technologies. Numerous studies have found that the access to information has a positive impact on adoption (Mauceri (2004), Bonabana-Wabbi (2002), De Souza Filho, Young, and Burton (1999)).

The following table provides a statistical summary of all variables that are discussed above and later included in the econometric model.

Table 6: Statistical summary of variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Category I. Socio-demographic Characteristics					
District1	275	0.2363636	0.4256226	0	1
District2	275	0.2618182	0.4404257	0	1
District3	275	0.3163636	0.4659045	0	1
District4	275	0.1854545	0.3893745	0	1
Age	275	37.68364	12.20229	14	70
Female	275	0.1672727	0.3738996	0	1
Educ	270	5.118519	3.960872	0	16
Work	275	3.265455	1.919571	0	13
Category II. Economic Characteristics					
FarmInc	275	0.706	0.3440909	0	1
Fland	270	2.447839	2.634234	0.23	18.4
Category III. Institutional Characteristics					
IPM	268	0.7947761	0.4046207	0	1
Exten	267	4.508577	4.501065	0	24
Aware	270	0.7740741	0.4189672	0	1
Dependent variable					
Adoption Level	273	2.659341	1.162083	1	4

V.V. Results and Conclusions

The ordered probit model was used to examine the impacts of independent variables on ordered categories of adoption.

Table 7: Summary of the models' results

Variables	Model 1		Model 2	
	Coeffcient	Sig.	Coeffcient	Sig.
District2	0.82934	0.001***		
District3	0.39245	0.089**		
District4	0.36498	0.558		
Age	0.00014	0.982	0.00161	0.793
Female	1.05229	0.079*	0.75417	0.008***
Educ	0.04786	0.015**	0.03791	0.050**
Work	0.05739	0.139	0.02864	0.443
FarmInc	0.40345	0.176	0.22352	0.424
Fland	-0.00940	0.766	-0.00757	0.801
Exten	-0.01228	0.617	-0.03921	0.021**
IPM	0.53253	0.013**	0.62835	0.003***
Aware	0.90055	0.000***	0.85382	0.000***
n = 248			n = 248	
Pseudo R^2= 0.1438			Pseudo R^2= 0.1255	

* Indicates significance at the 10% level

** Indicates significance at the 5% level

*** Indicates significance at the 1% level

Table 7 summarizes two different models. The sign of the coefficient in the coefficient columns shows the type of impact, positive or negative, by the particular variable. According to Borooah (2002, pp.24) the impact on intermediate outcomes can not be inferred, which means that is it impossible to say whether the probability of no adoption is higher or lower than low level of adoption, or if the probability of medium adoption is lower or higher than the probability of high level of IPM adoption.

Model 1 includes the full set of variables from which District2, and Aware were statistically significant at the 1% significance level, while District3, Educ, and IPM was significant at 5% and Female was statistically significant at 10%. The variable District1 was dropped to avoid the “dummy variable trap.” The variable District2 had a positive sign, which implied that farmers in District2 had higher probability to be high IPM adopters and lower probability of no or low IPM adoption then farmers from District1, ceteris paribus. The implication of District2 was that if all other characteristics were similar except the district than District2 farmers were more likely to be high IPM adopters. The implication was not that all Distric2 farmers were higher IPM adopters then farmers from all the other districts. The sign of the Dirtrict3 variable is the same as District2 therefore the implication is the same. The variable Female, implies that female farmers have a higher probability of being high adopters and a lower probability of being low adopters, compared to male farmers, ceteris paribus. The variable Educ, implies who have higher education have a higher probability of being high adopters and a lower probability of being low adopters, compared to farmers that have lower level of education, ceteris paribus. The variable IPM implies that farmers who have had IPM training have a higher probability of being high adopters and a lower probability of being low adopters compared to farmers that haven’t had IPM training, ceteris paribus. The variable Aware, implies that farmers who are aware of pesticide alternatives have a higher probability of being high adopters and a lower probability of being low adopters, than farmers who are aware, ceteris paribus.

Model 2 includes the same set of variables as model 1 with the exception of the District variable which was dropped. The district variables (District1, District2, District3 and District4) were excluded from model 2 in order to examine the effect of only other variables. Another reason for excluding the district variable was that all of the female farmers belonged only in District4 which is possible to have impacted the levels of significance and the signs of these two as well as the other variables in model 1. In the new model the variable Female, IPM and Aware, were significant at the 1% level while the variables Educ and Exten were significant at the 5% significance level. The coefficients' signs in this model remained the same as in model 1 but the level of significance of the variables Female and IPM increased. The variable Extn which was not significant in model 1 is statistically significant in model 2 at the 5% significance level. The variable Extn has a negative sign and it implies that farmers who are further away for an extension agent have a higher probability of being low or no adopter while farmers that are closer to an extension agent have a higher probability of being medium of high adopters of IPM technologies, ceteris paribus.

Outliers are present in the variable Fland. Five farmers reported owning more than 20 acres of land, considering the fact that Bangladesh is one of the poorest nations in the world, owning as much land is almost impossible. The outliers were removed from the data before the analysis was conducted.

VI. Conclusion and Limitations

There are three different sections in this thesis. The first section is the literature review, the second section is the economic surplus analysis (Albania, Ecuador, Uganda) and the third section is the adoption analysis (Bangladesh). Consequently, the conclusions are be grouped in three categories.

Based on the results from past IPM CRSP impact studies reviewed in the literature review section it can be concluded that the IPM CRSP technologies have resulted in positive economic impacts. Previous studies provided information on poverty reduction for a peanut IPM program in Uganda, nutritional benefits of grafting eggplant for bacterial wilt in the Philippines, and the environmental benefits of onion IPM in the Philippines. Please refer to Table 1, for summary of benefits from previous IPM CRSP impact studies.

The conclusion from the economic surplus analysis (Albania, Ecuador and Uganda) is that IPM technologies have resulted in positive NPV and positive returns to investment in all three cases. These findings are similar to the findings of past IPM CRSP impact studies.

Under the base scenario the NPV of the tomato IPM Program in Albania was approximately USD $8 million. Increasing the rate of adoption increased the NPV to about USD $22 million[6] for the 15 year period. In the second sensitivity analysis, the

[6] Refer to Appendix C for the sensitivity analysis table

percent change in cost per hectare rose to 25% which resulted in a decrease of the NVP to about USD $5 million over the 15 year period, at a 5% discount rate.

Under the baseline scenario for the Plantain IPM Program in Ecuador, the NPV was found to be approximately USD $7 million over 15 years at a 5% discount rate. The IRR was 110%. Reducing the yield change to 70% resulted in a lower NPV of benefits of approximately USD $4 million and an IRR's of 89%.

Under the base scenario for the Tomato IPM Program in Uganda, it was found that the NPV of benefits from adopting the IPM practices using a 5% discount rate was about USD $1 million, and the IRR was 169%. Increasing the adoption rate to 70% yielded a NPV of about $ 2.5 million and IRR of 174%. Changing the percent change in cost per hectare to 25% decreased the NPV to about USD $0.58 million (5% discount rate) and the IRR to 133% when the maximum adoption of 25% was achieved. Based on the different combination of practices Case1 and Case2 scenarios were conducted. The Case1 scenario yielded NPV of approximately $0.03 million and IRR was 43% when adoption reaches a maximum of 25%. The Case2 scenario resulted in a new NPV of approximately $0.8 million (at 5% discount rate) and IRR of 270% when the adoption rate was 25%.

The analysis on adoption of IPM technologies in Bangladesh is the last section. The conclusion from this section is that the institutional factors are particularly important and significant for the adoption of IPM technologies. In this study the impact of the variables in both models was found to be consistent, while some studies had found opposing indeterminate impacts due to changes in the coefficients sign throughout the different models. As expected the level of education, being a female farmer, IPM training and the awareness of pesticide alternatives were found to be significant factors positively affecting the adoption of IPM technologies. The age variable was expected to have a negative impact on the level of IPM adoption, but the models demonstrated that age had a positive impact. The impact of the age variable was not statistically significant.

VI.I. Implications for further research

Some of the IPM CRSP impact studies were conducted in languages other than English. Even though this thesis attempted to include most of the available IPM CRSP impact studies, there still are and will be other studies that have not been included. Some studies are currently in progress, while others are conducted in remote areas of the world and are not published etc.

With regard to the economic surplus analysis, one implication for further research is to include one example from all the site areas. This thesis included three different examples from three different sites. If all IPM CRSP sites had responded to the scientist-questionnaire, the results would have provided a better picture of the current situation in the different parts of the world.

Adoption analyses provide useful and necessary information that helps in the process of IPM technology dissemination. The adoption analysis of IPM technologies in Bangladesh was based on a survey conducted for assessing the adoption of pheromones for cucurbit crops. More accurate results could be obtained if the survey was conducted specifically for assessing the adoption factors for IPM technologies. The results would also be more accurate if the whole country (Bangladesh) was surveyed. However, surveying the whole country is time consuming and costly and therefore only the major vegetable areas were surveyed.

The IPM CRSP has been helpful and beneficial to farmers around the world. Further up-to-date research is necessary to measure the impacts of the IPM CRSP.

References:

Adesina, A.A., D. Mbila, G.B. Nkamleu, and D. Endamana. 2000. "Econometric analysis of the determinants of adoption of alley farming by farmers in the forest zone of southwest Cameroon." *Agriculture, Ecosystems & Environment* 80(3): 255-265.

Alwang J.A., Weller S.C., Sanchez G.E., Calderon L., Edwards C.R., Hamilton S., Williams R., Ellis M., Suarez C., Barrera V., Crissman C., Norton G W. 2005. "Developing IPM Packages in Latin America." In G.W. Norton, E.A. Heinrichs, G.C. Luther, and M.E. Irwin eds. *Globalizing integrated pest management: A participatory research process.* Ames IA: Blackwell Publishing. pp. 71-94.

Antle, J.M. and S.M. Capalbo. 1995. *Measurement and Evaluation of the Impacts of Agricultural Chemical Use: A Framework for Analysis. In Impact of Pesticides on Farmer Health and the Rice Environment.* P.L. Pingali and P.A. Roger, eds. Norwell, MA, Kluwer Academic Publishers, 1995.

Alponi, A.J. "Adoption of IPM technology in Vegetables and its relative advantages over farmers practices in some selected areas of Bangladesh." MS thesis. Bangladesh Agricultural University. 2003

Alston, J.M., G.W.Norton., and P.G. Pardey. 1998. *Science under Scarcity*, CAB International

Baez, C. "Potential Economic Benefits from Plantain Integrated Pest Management Adoption: The Case of Coastal Rural Households in Ecuador." Ms thesis, Virginia Polytechnic Institute and State University. 2004

Borooah, V. K. 2002. *Logit and probit: Ordered and multinomial models*. Thousand Oaks, CA: Sage Publications.

Brown, M.L. 1979. *Farm Budgets: From Farm Income Analysis to Agricultural Project Analysis*, World Bank staff occasional papers, no. 29. Baltimore: Published for the World Bank [by] the Johns Hopkins University Press.

Chaves, B., and J. Riley. 2001 "Determination of factors influencing integrated pest management adoption in coffee berry borer in Colombian farms." *Agriculture, Ecosystems & Environment* 87,(2): 159-177.

Cole, D.C., S. Sherwood, C. Crissman, V. Barrera, and P. Espinosa. 2002. "Pesticides and Health in Highland Ecuadorian Potato Production: Assessing Impacts and Developing Responses." *International Journal of Occupational and Environmental Health* 8(3): 182-190.

Cuyno, L.C.M. 1999. "An economic evaluation of the health and environmental benefits of the IPM program (IPM CRSP) in the Philippines." PhD dissertation, Virginia Polytechnic Institute and State University.

Daku, L.S. 2002. "Assessing Farm-level and Aggregate Economic Impacts of Olive Integrated Pest Management Programs in Albania: An Ex-Ante Analysis." PhD dissertation, Virginia Polytechnic Institute and State University.

Debass, T. 2000. "Economic Impact Assessment of IPM CRSP Activities in Bangladesh and Uganda: A GIS Application." MS thesis, Virginia Polytechnic Institute and State University.

De Souza-Filho, H. M., T. Young, and M. P. Burton. 1999. "Factors Influencing the Adoption of Sustainable Agricultural Technologies Evidence from the State of

Espírito Santo, Brazil.” *Technological Forecasting and Social Change* 60: 97-112.
EPA, Environmental Protection Agency. (2007). What is IPM. Retrieved 02/25/08, from http://www.epa.gov/pesticides/ipm/brochure/whatipm.htm
Erbaugh J.M., J.Caldwell, S. Kyamanywa, K.T. Gamby, and K. Moore. 2005. “Developing IPM Packages in Africa.” In G.W. Norton, E.A. Heinrichs, G.C. Luther, and M.E. Irwin eds. *Globalizing integrated pest management: A participatory research process.* Ames IA: Blackwell Publishing. pp. 51-69.
FAOSTAT. (2008) Food and Agricultural Organization Statistical Data Base: FAOSTAT Albania: Tomatoes.” Retrieved 09/15/08 from http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor
__________.(2008a). Food and Agricultural Organization Statistical Data Base: FAOSTAT Ecuador: Plantains. Retrieved 08/04/08, from http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567.
__________. (2008b). Food and Agricultural Organization Statistical Data Base: FAOSTAT Uganda: Tomatoes.” Retrieved 09/20/08 from http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor
FAO. (2008). Major Food and Agricultural Commodities and Producers: Albania. Retrieved 18/15/08, from http://www.fao.org/es/ess/top/country.html?lang=en&country=3
Feder G., R.E. Just, and D. Zilberman. 1985. "Adoption of Agricultural Innovations in Developing Countries: A Survey." *Economic Development and Cultural Change* 33(2): 255-298.
Feder G., and R. Slade. 1984. "The Acquisition of Information and the Adoption of New Technology." *Amer. J. of Agri. Econ.* 66(3): 312-320.
Feder, G. and D. L. Umali. 1993. ”The Adoption of Agricultural Innovations A Review.” *Technological Forecasting and Social Change* 43: 215-239.
IPM CRSP. (2008). IPM CRSP Countries at a Glance. Retrieved 09/08/08, from http://www.oired.vt.edu/ipmcrsp/IPM_2008/Countries.htm.
__________. (2008a). What do we do. Retrieved 02/23/2008, from http://www.oired.vt.edu/ipmcrsp/IPM_2008/What_We_Do/what_is_ipm.htm
__________. (2008b). IPM CRSP IPM Goals and Objectives. Retrieved 09/08/08, from http://www.oired.vt.edu/ipmcrsp/IPM_2008/What_We_Do/goals.htm
__________. (2008c). "What do we do: Gender and IPM." Retrieved 02/23/2008, from: http://www.oired.vt.edu/ipmcrsp/IPM_2008/What_We_Do/gender.htm
Katsoyannos, P. 1992. Olive Pests and Their Control in the Near East. United Nations, Food and Agriculture Organization: Plant Production and Protection Paper No. 115. Rome.
Lawrence J., S. Tolin, C. Edwards, S. Fleischer, D.M. Jackson, D. Clarke-Harris, S. McDonald, K. Dalip, and P. Chung. 2005. “Developing IPM Packages in the Caribbean.” In G.W. Norton, E.A. Heinrichs, G.C. Luther, and M.E. Irwin eds. *Globalizing integrated pest management: A participatory research process.* Ames IA: Blackwell Publishing. pp. 95-119.
Mamaril, C.B. and G.W. Norton. 2006. "Economic evaluation of transgenic pest resistant rice in the Philippines and Vietnam." *Quarterly Journal of International Agriculture* 45(2): 127-144.

Matonan Z., and Abacus. (2009). Country Report Albania. Retrieved on April 30, 2009 from: http://www.povrce.com/index.cgi?P=gen&A=FAO&HTM=10091

McDonald, S.A., B. Nault, and S.A. Tolin 2004. "Efficacy of Stylet-Oil® in suppressing the spread of TEV infections in a 'Scotch Bonnet' pepper (*Capsicum chinense* Jacquin) in field in Jamaica." *Tropical Agriculture* 81(1): 54-60.

Miller S.A., Karim A.M.N.R., Baltazar A.M., Rajotte., Norton G.W. 2005. "Developing IPM Packages in Asia." In G.W. Norton, E.A. Heinrichs, G.C. Luther, and M.E. Irwin eds. *Globalizing integrated pest management: A participatory research process.* Ames IA: Blackwell Publishing. pp. 27-50.

Mishra, S. 2003. "An Ex-Ante Economic Impact Assessment of Bt Eggplant in Bangladesh, the Philippines and India." MS thesis, Virginia Polytechnic Institute and State University.

Moyo, S., G.W. Norton, J. Alwang, I. Rhinehart, and C.M. Deom. 2007. "Peanut Research and Poverty Reduction: Impacts of Variety Improvement to Control Peanut Viruses in Uganda." *Amer. J. Agri. Econ*. 89: 448-460.

Mullen, J.D., G.W. Norton, and D.W. Reaves. 1997. "Economic Analysis of Environmental Benefits of Integrated Pest Management." *Journal of Agricultural and Applied Economics* 29(2): 243-253.

Mutuc, M.M.E. 2003. "Increase in Calorie Intake Due to Eggplant Grafting: Proof of Concept With the Use of Minimum Datasets." MS thesis, Virginia Polytechnic Institute and State University.

Nouhoheflin T, O. Coulibaly, S. Soumare, and G.W. Norton. 2009. "Tomato Baseline Survey and Impact Assessment of Research to Reduce Tomato Viruses in Mali." Unpublished Manuscript, Department of Agricultural and Applied Economics, Virginia Tech

Norton G.W., K. Moore, D. Quishpe, V. Barrera, T. Debass, S. Moyo, and D.B. Taylor. 2005. "Evaluating Socio-Economic Impacts of IPM." In G.W. Norton, E.A. Heinrichs, G.C. Luther, and M.E. Irwin eds. *Globalizing integrated pest management: A participatory research process.* Ames IA: Blackwell Publishing. pp. 241.

Norton, G.W., and J. Mullen. 1994. "Economic Evaluation of Integrated Pest Management Programs: A Literature Review." MS thesis, Virginia Polytechnic Institute and State University.

Pfeifer D., J. Tedeschini, L. Daku, M. Hasani, R. Uka, B. Stamo, and B. Ferraj. 2005. "Developing IPM Packages in Eastern Europe: Participatory IPM Research in Albanian Olives." In G.W. Norton, E.A. Heinrichs, G.C. Luther, and M.E. Irwin eds. *Globalizing integrated pest management: A participatory research process.* Ames IA: Blackwell Publishing. pp. 27-50.

Project SICA/MAC. (2002). III Censo Nacional Agropecuario. Retrieved from http://www.sica.gov.ec/censo/index.htm

Rakshit, A. 2008. "Integrated Pest Management in Bangladesh: An Impact Assessment of Pheromone Adoption for Cucurbit Crops." MS thesis, Virginia Polytechnic Institute and State University.

Rauniyar, G. P., and F. M. Goode. 1996. "Managing Green Revolution Technology: An Analysis of a Differential Practice Combination in Swaziland." *Economic Development and Cultural Change* 44(2): 413-437.

Rickard. B.J., and D. A. Sumner. "EU Support Reductions Would Benefit California Tomato Growers and Processors." *California Agriculture*. 60 (Oct.-Dec. 2006): 207-210

Steinemann, A.C., W.C. Apgar, H.J. Brown. 2005. *Microeconomics for Public Decisions,* Thomson South-Western.

USAID. (2007). "Agriculture." Retrieved 02/23/08, from http://www.usaid.gov/our_work/agriculture/

USAID. (2009). "USAID Mission in Bangladesh: Education." Retrieved 02/06/09 from http://www.usaid.gov/bd/programs/education.html

US Department of State. 2008. *Background Note: Bangladesh*. Retrieved 11/18/08, from http://www.state.gov/r/pa/ei/bgn/3452.htm

Victoria, M.V. 2007. "Agricultural Technology in Bangladesh: A Study on non-farm Labor and adoption by Gender." MS thesis, Virginia Polytechnic Institute and State University.

World Bank. (2008). Bangladesh: Data and Statistics - Poverty at a Glance. Retrieved 11/18/08, from http://devdata.worldbank.org/AAG/bgd_aag.pdf.

Weller, S.C., G.E. Sanchez, C.R. Edwards, and G.H. Sullivan. 2002. "IPM CRSP success in NTAE crops leads to sustainable trade for developing countries." *Sustainable Development International* 5: 135 - 138

Wooldridge, J. M. 2002. *Econometric analysis of cross section and panel data*. Cambridge, Mass: MIT Press.

Wooldridge, J. M. 2006. *Introductory econometrics: A modern approach*. Mason, OH: Thomson/South-Western.

Appendix A: A sample scientist-questionnaire.

Scientist Questionnaire (Albania)

Commodity: Tomato

Respondent(s)

Name(s): ___________________________

Date: ____________________________

Specialty: ________________________

Years of experience on tomato: _______

Please describe the IPM practice(s) on tomato:

____

____

____

1. What is the percent yield change (**if any**) per hectare (compared to previous practice) for farmers who adopt the tomato IPM practice(s) developed by the IPM CRSP_______%

2. What is your estimate of the percent change in cost per hectare (if any) for each of the following production inputs for farmers who adopt the tomato IPM practices?

	Most Likely Cost Change				
Input	**Share of total costs**	Decrease	No Change	Increase	**Percent Change**
Labor					
Pesticides					
Seeds and fertilizer					
Other					

3. If pesticide use was reduced, which pesticides?_________________________________

4. Approximately how many hectares of tomato are currently grown under the tomato IPM practice(s)? ________, **or** what percent of all tomato growers do you believe have adopted the IPM practices?_________

5. (a) In what year did farmers first start adopting the new tomato IPM practices?______
   (b) When do you think maximum adoption will be reached?_________
   (c) What do you believe will be the maximum percent of farmers who adopt the tomato IPM practices?___________

6. Roughly what were the costs (000$) involved in developing the tomato IPM practice(s) (by year) and in extending (disseminating) the technologies to farmers?

Year:								
Costs to Develop the IPM practices								
Costs to Disseminate the IPM practices								

7. (a) What is your estimate of the percent of tomatoes in the country that is produced by women?_______%
   (b) Do women adopt the IPM practices technologies at the same rate as men? yes ____, no_____.
   (c) If no, please describe the difference (roughly how much higher or lower) _________________________________and why it occurs: ______________________
   ____

Appendix B: The variables used in the economic surplus analysis (Alston, Norton, and Pardey 1998, Page 380)

The following information is included in the economic surplus analysis:

Column A: Year: The time frame of the project is considered to be 15 years, the starting and ending year defer per project. The time frame is provided by the scientist questionnaires.

Column B: Elasticity of supply (ε): is a measure of responsiveness of quantity supplied to price changes. The supply elasticity as well as the demand elasticity below are approximations, the correct procedure would be to vary the elasticites with the changes in price and quantity. Data on the supply elasticity is hard to calculate, therefore the estimates are borrowed from other relevant studies about the same crop and country.

Column C: Elasticity of demand (η): is the measure of responsiveness of quantity demanded to price changes, in this analysis η used in absolute terms. The demand supply elasticity is also hard to estimate therefore the values are borrowed from other relevant studies about the same crop and country.

Column D: Proportionate yield change: is the percentage yield change per hectare. It measures the percentage changes in yield per hectare due to adopting the new IPM practice. It is obtained from the specific scientist questionnaires.

Column E: Gross proportionate reduction in marginal cost per ton of output: Column D / Column B, converts the proportional yield change to proportionate gross reduction in marginal cost per ton of output.

Column F: Proportionate change in variable input cost per hectare, if any, to achieve the expected yield change.

Column G: Proportionate change in variable input cost per ton: Column F / (1 + Column D), the proportionate input cost change per hectare is converted to the proportionate input cost change per ton.

Column H: Net change: Column E – Column G, provides the net effects of the variable input changes associated with the yield change resulting in the maximum potential net change in marginal cost per ton of output.

Column I: Probability of success: measures the probability that the research will achieve the yield change in column D.

Column J: Adoption rate: Provides the adoption rate relative to the years from the commencement of research.

Column K: Proportionate supply shift per year of the K shift: Column H * Column I * Column J, gives the proportionate shift down of the supply curve.

Column L: Proportionate reduction in price or Z shift relative to it's initial value, due to the supply shift: in the case of closed economy the Z shift is obtained (Column B * Column K) / (Column B + Column C). In the large open economy case Z is obtained (Column B * Column K) / (Column B + s_A * Column C + (1 - s_A)*η_B^E). Note s_A and η_B^E are defined in chapter III.

Column M: Price: is the average price, the time over which prices are averaged differs for each economic surplus analysis depending on the time frame and the data available from FAO STAT.

Column N: Quantity: is the average quantity over a period of time which differs depending on the project and the FAO STAT data availability. In the case of Ecuador (large open economy) there is an additional column on quantity of plantain consumed domestically, which is necessary information for calculating the consumer surplus.

Column O: Producer surplus: (Column M * Column N) * (Column K – Column L) * (1 + 0.5 Column L * Column C).

Column P: Consumer surplus: In the closed economy case (Column 12 * Column 13 * Column 14) * (1 + 0.5 Column 12 * Column 3), in the open economy case (Column 12 * Column 13 * Column Consumption Quantity * (1 + 0.5 Column L * Column C)

Column Q: Total surplus: It adds the producer and consumer surplus: Column O + Column P

Column R: Cost: the annual research cost corresponding to the yield change, it is reported by the scientists in the questionnaire.

Column S: Benefits: it gives the difference between the total surplus and the cost: Column Q – Column R.

Column T: Net present value (NPV) is calculated using the Excel embedded formula, using 0.05 or 5 % discount rate.

Column 2 Internal rate of return (IRR): which is calculated using the Excel embedded formula for IRR.

Appendix C: The economic surplus analysis Excel table for Tomatoes – Albania

Tomatoes - Albania
Closed Economy

YEAR	Suply Elasticity ε	Demand Elasticity η	YIELD CHANGE	GROSS PROPOR. COST CHANGE	PROPOR. I. COST CHANGE PER HA.	PROPOR. I. COST CHANGE PER TON	NET CHANGE	PROB OF SUCCESS	ADOPT RATE	K	Z	PRICE $/ton	QUANTITY metric tons/year	PS	CS	TS	COST $ U.S	BENEFITS	NPV
2007	1	0.5	0.5	0.5	-0.0039	-0.0026	0.5026	1	0.015	0.007539	0.005026	308.59	26,969.87	20,941.05	41,882.11	62,823.16	1,650.00	61,173.16	$8,358,811.98
2008	1	0.5	0.5	0.5	-0.0039	-0.0026	0.5026	1	0.060	0.030156	0.020104	308.59	26,969.87	84,079.57	168,159.13	252,238.70	2,300.00	249,938.70	
2009	1	0.5	0.5	0.5	-0.0039	-0.0026	0.5026	1	0.090	0.045234	0.030156	308.59	26,969.87	126,434.70	252,869.41	379,304.11	2,500.00	376,804.11	
2010	1	0.5	0.5	0.5	-0.0039	-0.0026	0.5026	1	0.130	0.065338	0.043559	308.59	26,969.87	183,235.25	366,470.50	549,705.76	2,800.00	546,905.76	
2011	1	0.5	0.5	0.5	-0.0039	-0.0026	0.5026	1	0.180	0.090468	0.060312	308.59	26,969.87	254,761.53	509,523.05	764,284.58	3,000.00	761,284.58	
2012	1	0.5	0.5	0.5	-0.0039	-0.0026	0.5026	1	0.200	0.100520	0.067013	308.59	26,969.87	283,535.55	567,071.10	850,606.65	3,500.00	847,106.65	
2013	1	0.5	0.5	0.5	-0.0039	-0.0026	0.5026	1	0.230	0.115598	0.077065	308.59	26,969.87	326,871.79	653,743.57	980,615.36	3,500.00	977,115.36	
2014	1	0.5	0.5	0.5	-0.0039	-0.0026	0.5026	1	0.250	0.125650	0.083767	308.59	26,969.87	355,879.41	711,758.81	1,067,638.22	3,500.00	1,064,138.22	
2015	1	0.5	0.5	0.5	-0.0039	-0.0026	0.5026	1	0.250	0.125650	0.083767	308.59	26,969.87	355,879.41	711,758.81	1,067,638.22	3,500.00	1,064,138.22	
2016	1	0.5	0.5	0.5	-0.0039	-0.0026	0.5026	1	0.250	0.125650	0.083767	308.59	26,969.87	355,879.41	711,758.81	1,067,638.22	3,500.00	1,064,138.22	
2017	1	0.5	0.5	0.5	-0.0039	-0.0026	0.5026	1	0.250	0.125650	0.083767	308.59	26,969.87	355,879.41	711,758.81	1,067,638.22	3,500.00	1,064,138.22	
2018	1	0.5	0.5	0.5	-0.0039	-0.0026	0.5026	1	0.250	0.125650	0.083767	308.59	26,969.87	355,879.41	711,758.81	1,067,638.22	3,500.00	1,064,138.22	
2019	1	0.5	0.5	0.5	-0.0039	-0.0026	0.5026	1	0.250	0.125650	0.083767	308.59	26,969.87	355,879.41	711,758.81	1,067,638.22	3,500.00	1,064,138.22	
2020	1	0.5	0.5	0.5	-0.0039	-0.0026	0.5026	1	0.250	0.125650	0.083767	308.59	26,969.87	355,879.41	711,758.81	1,067,638.22	3,500.00	1,064,138.22	
2021	1	0.5	0.5	0.5	-0.0039	-0.0026	0.5026	1	0.250	0.125650	0.083767	308.59	26,969.87	355,879.41	711,758.81	1,067,638.22	3,500.00	1,064,138.22	
2022	1	0.5	0.5	0.5	-0.0039	-0.0026	0.5026	1	0.250	0.125650	0.083767	308.59	26,969.87	355,879.41	711,758.81	1,067,638.22	3,500.00	1,064,138.22	

Appendix D: Sensitivity analysis Excel table for Tomatoes – Albania

CASE 1

Tomatoes - Albania
Closed Economy

YEAR	Suply Elasticity ε	Demand Elasticity η	YIELD CHANGE	PROPOR. COST CHANGE	I. COST CHANGE PER HA.	I. COST CHANGE PER TON	NET CHANGE	PROB OF SUCCESS	ADOPT RATE	K	Z	PRICE $/ton	QUANTITY metric tons/year	TS	CS	PS	COST $ U.S	BENEFIT	NPV
2007	1	0.5	0.5	0.5	-0.0039	-0.0026	0.5026	1	0.015	0.007539	0.005026	308.59	26,969.87	62,823.16	41,882.11	20,941.05	1,650.00	61,173.16	$22,714,675.68
2008	1	0.5	0.5	0.5	-0.0039	-0.0026	0.5026	1	0.100	0.050260	0.033507	308.59	26,969.87	421,799.41	281,199.60	140,599.80	2,300.00	419,499.41	
2009	1	0.5	0.5	0.5	-0.0039	-0.0026	0.5026	1	0.200	0.100520	0.067013	308.59	26,969.87	850,606.65	567,071.10	283,535.55	2,500.00	848,106.65	
2010	1	0.5	0.5	0.5	-0.0039	-0.0026	0.5026	1	0.300	0.150780	0.100520	308.59	26,969.87	1,286,421.75	857,614.50	428,807.25	2,800.00	1,283,621.75	
2011	1	0.5	0.5	0.5	-0.0039	-0.0026	0.5026	1	0.400	0.201040	0.134027	308.59	26,969.87	1,729,244.68	1,152,829.79	576,414.89	3,000.00	1,726,244.68	
2012	1	0.5	0.5	0.5	-0.0039	-0.0026	0.5026	1	0.500	0.251300	0.167533	308.59	26,969.87	2,179,075.46	1,452,716.97	726,358.49	3,500.00	2,175,575.46	
2013	1	0.5	0.5	0.5	-0.0039	-0.0026	0.5026	1	0.600	0.301560	0.201040	308.59	26,969.87	2,635,914.09	1,757,276.06	878,638.03	3,500.00	2,632,414.09	
2014	1	0.5	0.5	0.5	-0.0039	-0.0026	0.5026	1	0.700	0.351820	0.234547	308.59	26,969.87	3,099,760.55	2,066,507.03	1,033,253.52	3,500.00	3,096,260.55	
2015	1	0.5	0.5	0.5	-0.0039	-0.0026	0.5026	1	0.700	0.351820	0.234547	308.59	26,969.87	3,099,760.55	2,066,507.03	1,033,253.52	3,500.00	3,096,260.55	
2016	1	0.5	0.5	0.5	-0.0039	-0.0026	0.5026	1	0.700	0.351820	0.234547	308.59	26,969.87	3,099,760.55	2,066,507.03	1,033,253.52	3,500.00	3,096,260.55	
2017	1	0.5	0.5	0.5	-0.0039	-0.0026	0.5026	1	0.700	0.351820	0.234547	308.59	26,969.87	3,099,760.55	2,066,507.03	1,033,253.52	3,500.00	3,096,260.55	
2018	1	0.5	0.5	0.5	-0.0039	-0.0026	0.5026	1	0.700	0.351820	0.234547	308.59	26,969.87	3,099,760.55	2,066,507.03	1,033,253.52	3,500.00	3,096,260.55	
2019	1	0.5	0.5	0.5	-0.0039	-0.0026	0.5026	1	0.700	0.351820	0.234547	308.59	26,969.87	3,099,760.55	2,066,507.03	1,033,253.52	3,500.00	3,096,260.55	
2020	1	0.5	0.5	0.5	-0.0039	-0.0026	0.5026	1	0.700	0.351820	0.234547	308.59	26,969.87	3,099,760.55	2,066,507.03	1,033,253.52	3,500.00	3,096,260.55	
2021	1	0.5	0.5	0.5	-0.0039	-0.0026	0.5026	1	0.700	0.351820	0.234547	308.59	26,969.87	3,099,760.55	2,066,507.03	1,033,253.52	3,500.00	3,096,260.55	
2022	1	0.5	0.5	0.5	-0.0039	-0.0026	0.5026	1	0.700	0.351820	0.234547	308.59	26,969.87	3,099,760.55	2,066,507.03	1,033,253.52	3,500.00	3,096,260.55	

CASE 2

Tomatoes - Albania
Closed Economy

YEAR	Suply Elasticity ε	Demand Elasticity η	YIELD CHANGE	GROSS PROPOR. COST CHANGE	PROPOR. I. COST CHANGE PER HA.	PROPOR. I. COST CHANGE PER TON	NET CHANGE	PROB OF SUCCESS	ADOPT RATE	K	Z	PRICE $/ton	QUANTITY metric tons/year	TS	CS	PS	COST $ U.S	BENEFIT	NPV
2007	1	0.5	0.5	0.5	0.25	0.166667	0.333333	1	0.015	0.005000	0.003333	308.59	26969.87	41,647.84	27,765.23	13,882.61	1,650.00	39,997.84	$5,498,633.82
2008	1	0.5	0.5	0.5	0.25	0.166667	0.333333	1	0.060	0.020000	0.013333	308.59	26969.87	167,007.48	111,338.32	55,669.16	2,300.00	164,707.48	
2009	1	0.5	0.5	0.5	0.25	0.166667	0.333333	1	0.090	0.030000	0.020000	308.59	26969.87	250,927.35	167,284.90	83,642.45	2,500.00	248,427.35	
2010	1	0.5	0.5	0.5	0.25	0.166667	0.333333	1	0.130	0.043333	0.028889	308.59	26969.87	363,252.06	242,168.04	121,084.02	2,800.00	360,452.06	
2011	1	0.5	0.5	0.5	0.25	0.166667	0.333333	1	0.180	0.060000	0.040000	308.59	26969.87	504,351.50	336,234.33	168,117.17	3,000.00	501,351.50	
2012	1	0.5	0.5	0.5	0.25	0.166667	0.333333	1	0.200	0.066667	0.044444	308.59	26969.87	561,007.04	374,004.70	187,002.35	3,500.00	557,507.04	
2013	1	0.5	0.5	0.5	0.25	0.166667	0.333333	1	0.230	0.076667	0.051111	308.59	26969.87	646,221.55	430,814.37	215,407.18	3,500.00	642,721.55	
2014	1	0.5	0.5	0.5	0.25	0.166667	0.333333	1	0.250	0.083333	0.055556	308.59	26969.87	703,185.34	468,790.23	234,395.11	3,500.00	699,685.34	
2015	1	0.5	0.5	0.5	0.25	0.166667	0.333333	1	0.250	0.083333	0.055556	308.59	26969.87	703,185.34	468,790.23	234,395.11	3,500.00	699,685.34	
2016	1	0.5	0.5	0.5	0.25	0.166667	0.333333	1	0.250	0.083333	0.055556	308.59	26969.87	703,185.34	468,790.23	234,395.11	3,500.00	699,685.34	
2017	1	0.5	0.5	0.5	0.25	0.166667	0.333333	1	0.250	0.083333	0.055556	308.59	26969.87	703,185.34	468,790.23	234,395.11	3,500.00	699,685.34	
2018	1	0.5	0.5	0.5	0.25	0.166667	0.333333	1	0.250	0.083333	0.055556	308.59	26969.87	703,185.34	468,790.23	234,395.11	3,500.00	699,685.34	
2019	1	0.5	0.5	0.5	0.25	0.166667	0.333333	1	0.250	0.083333	0.055556	308.59	26969.87	703,185.34	468,790.23	234,395.11	3,500.00	699,685.34	
2020	1	0.5	0.5	0.5	0.25	0.166667	0.333333	1	0.250	0.083333	0.055556	308.59	26969.87	703,185.34	468,790.23	234,395.11	3,500.00	699,685.34	
2021	1	0.5	0.5	0.5	0.25	0.166667	0.333333	1	0.250	0.083333	0.055556	308.59	26969.87	703,185.34	468,790.23	234,395.11	3,500.00	699,685.34	
2022	1	0.5	0.5	0.5	0.25	0.166667	0.333333	1	0.250	0.083333	0.055556	308.59	26969.87	703,185.34	468,790.23	234,395.11	3,500.00	699,685.34	

Appendix E: Economic Surplus analysis Excel table for Plantain – Ecuador

Plantain - Ecuador

YEAR	Suply Elasticity $\mathcal{E}_A$	Demand Elasticity η_A	% YIELD CHANG	GROSS PROPOR. COST CHANGE	PROPOR. I. COST CHANGE PER HA.	PROPOR. I. COST CHANGE PER TON	NET CHANGE	PROB OF SUCCESS	ADOPT RATE	K	Z	PRICE	QUANTITY Produced	QUANTITY Consumed	CS	PS	TS	COST $ U.S	BENEFIT	NPV	IRR
1999	1	0.3	1	1	0.3688	0.1844	0.8156	1	0	0	0	53.3333	801,379.33	467,722.33	0.00	0.00	0.00	26,000.00	-26,000.00	$6,502,488.75	110%
2000	1	0.3	1	1	0.3688	0.1844	0.8156	1	0	0	0	53.3333	801,379.33	467,722.33	0.00	0.00	0.00	23,000.00	-23,000.00		
2001	1	0.3	1	1	0.3688	0.1844	0.8156	1	0	0	0	53.3333	801,379.33	467,722.33	0.00	0.00	0.00	21,000.00	-21,000.00		
2002	1	0.3	1	1	0.3688	0.1844	0.8156	1	0	0	0	53.3333	801,379.33	467,722.33	0.00	0.00	0.00	41,500.00	-41,500.00		
2003	1	0.3	1	1	0.3688	0.1844	0.8156	1	0.01	0.00816	0.00014	53.3333	801,379.33	467,722.33	3,441.44	342,716.65	346,158.08	25,000.00	321,158.08		
2004	1	0.3	1	1	0.3688	0.1844	0.8156	1	0.015	0.01223	0.00021	53.3333	801,379.33	467,722.33	5,162.21	514,092.70	519,254.91	20,000.00	499,254.91		
2005	1	0.3	1	1	0.3688	0.1844	0.8156	1	0.02	0.01631	0.00028	53.3333	801,379.33	467,722.33	6,883.02	685,480.57	692,363.58	14,000.00	678,363.58		
2006	1	0.3	1	1	0.3688	0.1844	0.8156	1	0.022	0.01794	0.0003	53.3333	801,379.33	467,722.33	7,571.35	754,039.02	761,610.38	4,000.00	757,610.38		
2007	1	0.3	1	1	0.3688	0.1844	0.8156	1	0.028	0.02284	0.00039	53.3333	801,379.33	467,722.33	9,636.38	959,725.74	969,362.13	4,000.00	965,362.13		
2008	1	0.3	1	1	0.3688	0.1844	0.8156	1	0.03	0.02447	0.00041	53.3333	801,379.33	467,722.33	10,324.74	1,028,291.77	1,038,616.51	4,000.00	1,034,616.51		
2009	1	0.3	1	1	0.3688	0.1844	0.8156	1	0.032	0.0261	0.00044	53.3333	801,379.33	467,722.33	11,013.10	1,096,859.68	1,107,872.78	4,000.00	1,103,872.78		
2010	1	0.3	1	1	0.3688	0.1844	0.8156	1	0.038	0.03099	0.00052	53.3333	801,379.33	467,722.33	13,078.22	1,302,574.76	1,315,652.98	4,000.00	1,311,652.98		
2011	1	0.3	1	1	0.3688	0.1844	0.8156	1	0.04	0.03262	0.00055	53.3333	801,379.33	467,722.33	13,766.60	1,371,150.24	1,384,916.85	4,000.00	1,380,916.85		
2012	1	0.3	1	1	0.3688	0.1844	0.8156	1	0.045	0.0367	0.00062	53.3333	801,379.33	467,722.33	15,487.59	1,542,597.21	1,558,084.80	4,000.00	1,554,084.80		
2013	1	0.3	1	1	0.3688	0.1844	0.8156	1	0.05	0.04078	0.00069	53.3333	801,379.33	467,722.33	17,208.61	1,714,055.99	1,731,264.61	4,000.00	1,727,264.61		

Appendix F: Sensitivity Analysis Excel table for Plantain, Ecuador

Plantain - Ecuador

YEAR	Suply Elasticity $\mathcal{E}$	Demand Elasticity η	% YIELD CHANGE	GROSS PROPOR COST CHANGE	PROPOR I. COST CHANGE PER HA.	PROPOR. I. COST CHANGE PER TON	NET CHANGE	PROB OF SUCCESS	ADOPT RATE	K	Z	PRICE	QUANTITY Produced	QUANTITY Consumed	CS	PS	TS	COST $ U.S	BENEFIT	NPV	IRR
1999	1	0.3	0.7	0.7	0.3688	0.21694	0.48306	1	0	0	0	61.667	714094.333	467,722.33	0.00	0.00	0.00	26,000.00	-26,000.00	$3,909,910.26	89%
2000	1	0.3	0.7	0.7	0.3688	0.21694	0.48306	1	0	0	0	61.667	714094.333	467,722.33	0.00	0.00	0.00	23,000.00	-23,000.00		
2001	1	0.3	0.7	0.7	0.3688	0.21694	0.48306	1	0	0	0	61.667	714094.333	467,722.33	0.00	0.00	0.00	21,000.00	-21,000.00		
2002	1	0.3	0.7	0.7	0.3688	0.21694	0.48306	1	0	0	0	61.667	714094.333	467,722.33	0.00	0.00	0.00	41,500.00	-41,500.00		
2003	1	0.3	0.7	0.7	0.3688	0.21694	0.48306	1	0.01	0.00483	8.17E-05	61.667	714094.333	467,722.33	2,356.74	209,129.35	211,486.08	25,000.00	186,486.08		
2004	1	0.3	0.7	0.7	0.3688	0.21694	0.48306	1	0.015	0.00725	0.000123	61.667	714094.333	467,722.33	3,535.12	313,700.43	317,235.55	20,000.00	297,235.55		
2005	1	0.3	0.7	0.7	0.3688	0.21694	0.48306	1	0.02	0.00966	0.000163	61.667	714094.333	467,722.33	4,713.53	418,275.78	422,989.31	14,000.00	408,989.31		
2006	1	0.3	0.7	0.7	0.3688	0.21694	0.48306	1	0.022	0.01063	0.00018	61.667	714094.333	467,722.33	5,184.89	460,107.12	465,292.01	4,000.00	461,292.01		
2007	1	0.3	0.7	0.7	0.3688	0.21694	0.48306	1	0.028	0.01353	0.000229	61.667	714094.333	467,722.33	6,599.00	585,605.23	592,204.23	4,000.00	588,204.23		
2008	1	0.3	0.7	0.7	0.3688	0.21694	0.48306	1	0.03	0.01449	0.000245	61.667	714094.333	467,722.33	7,070.38	627,439.30	634,509.68	4,000.00	630,509.68		
2009	1	0.3	0.7	0.7	0.3688	0.21694	0.48306	1	0.032	0.01546	0.000261	61.667	714094.333	467,722.33	7,541.76	669,274.06	676,815.81	4,000.00	672,815.81		
2010	1	0.3	0.7	0.7	0.3688	0.21694	0.48306	1	0.038	0.01836	0.00031	61.667	714094.333	467,722.33	8,955.90	794,782.42	803,738.32	4,000.00	799,738.32		
2011	1	0.3	0.7	0.7	0.3688	0.21694	0.48306	1	0.04	0.01932	0.000327	61.667	714094.333	467,722.33	9,427.29	836,619.91	846,047.19	4,000.00	842,047.19		
2012	1	0.3	0.7	0.7	0.3688	0.21694	0.48306	1	0.045	0.02174	0.000368	61.667	714094.333	467,722.33	10,605.76	941,216.62	951,822.38	4,000.00	947,822.38		
2013	1	0.3	0.7	0.7	0.3688	0.21694	0.48306	1	0.05	0.02415	0.000409	61.667	714094.333	467,722.33	11,784.25	1,045,817.60	1,057,601.86	4,000.00	1,053,601.86		

Appendix G: Economic Surplus Analysis Excel table for Tomatoes, Uganda

Uganda - Tomatoes
Closed Economy Example

YEAR	Suply Elasticity ε	Demand Elasticity η	YIELD CHANGE	GROSS PROPOR. COST CHANGE	PROPOR. I. COST CHANGE PER HA.	PROPOR. I. COST CHANGE PER TON	NET CHANG	PROB OF SUCCESS	ADOPT RATE	K	Z	PRICE *	QUANTITY *	TS	CS	PS	COST	BENEFIT	NPV	IRR
2002	1.00	0.50	0.42	0.42	0.01	0.007	0.413	1.00	0.00	0.000	0.000	194.55	14,000.00	0.00	0.00	0.00	1,000.00	-1,000.00	1,004,378.93	169%
2003	1.00	0.50	0.42	0.42	0.01	0.007	0.413	1.00	0.00	0.000	0.000	194.55	14,000.00	0.00	0.00	0.00	700.00	-700.00		
2004	1.00	0.50	0.42	0.42	0.01	0.007	0.413	1.00	0.00	0.000	0.000	194.55	14,000.00	0.00	0.00	0.00	1,850.00	-1,850.00		
2005	1.00	0.50	0.42	0.42	0.01	0.007	0.413	1.00	0.01	0.004	0.003	194.55	14,000.00	11,255.18	7,503.45	3,751.73	1,740.00	9,515.18		
2006	1.00	0.50	0.42	0.42	0.01	0.007	0.413	1.00	0.02	0.008	0.006	194.55	14,000.00	22,525.85	15,017.23	7,508.62	1,620.00	20,905.85		
2007	1.00	0.50	0.42	0.42	0.01	0.007	0.413	1.00	0.04	0.017	0.011	194.55	14,000.00	45,113.62	30,075.75	15,037.87	1,650.00	43,463.62		
2008	1.00	0.50	0.42	0.42	0.01	0.007	0.413	1.00	0.05	0.021	0.014	194.55	14,000.00	56,430.74	37,620.49	18,810.25	1,400.00	55,030.74		
2009	1.00	0.50	0.42	0.42	0.01	0.007	0.413	1.00	0.08	0.033	0.022	194.55	14,000.00	90,474.97	60,316.64	30,158.32	1,400.00	89,074.97		
2010	1.00	0.50	0.42	0.42	0.01	0.007	0.413	1.00	0.10	0.041	0.028	194.55	14,000.00	113,248.53	75,499.02	37,749.51	1,400.00	111,848.53		
2011	1.00	0.50	0.42	0.42	0.01	0.007	0.413	1.00	0.13	0.054	0.036	194.55	14,000.00	147,525.00	98,350.00	49,175.00	1,400.00	146,125.00		
2012	1.00	0.50	0.42	0.42	0.01	0.007	0.413	1.00	0.18	0.074	0.050	194.55	14,000.00	204,962.09	136,641.39	68,320.70	1,400.00	203,562.09		
2013	1.00	0.50	0.42	0.42	0.01	0.007	0.413	1.00	0.22	0.091	0.061	194.55	14,000.00	251,190.44	167,460.30	83,730.15	1,400.00	249,790.44		
2014	1.00	0.50	0.42	0.42	0.01	0.007	0.413	1.00	0.25	0.103	0.069	194.55	14,000.00	286,024.27	190,682.85	95,341.42	1,400.00	284,624.27		
2015	1.00	0.50	0.42	0.42	0.01	0.007	0.413	1.00	0.25	0.103	0.069	194.55	14,000.00	286,024.27	190,682.85	95,341.42	1,400.00	284,624.27		
2016	1.00	0.50	0.42	0.42	0.01	0.007	0.413	1.00	0.25	0.103	0.069	194.55	14,000.00	286,024.27	190,682.85	95,341.42	1,400.00	284,624.27		

Appendix H: Sensitivity Analysis Excel table for Tomatoes, Uganda

Uganda - Tomatoes
Closed Economy Example

YEAR	Suply Elasticity ε	Demand Elasticity η	YIELD CHANGE	GROSS PROPOR. COST CHANGE	PROPOR. I. COST CHANGE PER HA.	PROPOR. I. COST CHANGE PER TON	NET CHANG	PROB OF SUCCESS	ADOPT RATE	K	Z	PRICE	QUANTITY	TS	CS	PS	COST	BENEFIT	NPV	IRR
2002	1.00	0.50	0.42	0.42	0.01	0.007	0.413	1.00	0.00	0.000	0.000	194.55	14,000.00	0.00	0.00	0.00	1,000.00	-1,000.00	2,504,050.86	174%
2003	1.00	0.50	0.42	0.42	0.01	0.007	0.413	1.00	0.00	0.000	0.000	194.55	14,000.00	0.00	0.00	0.00	700.00	-700.00		
2004	1.00	0.50	0.42	0.42	0.01	0.007	0.413	1.00	0.00	0.000	0.000	194.55	14,000.00	0.00	0.00	0.00	1,850.00	-1,850.00		
2005	1.00	0.50	0.42	0.42	0.01	0.007	0.413	1.00	0.01	0.004	0.003	194.55	14,000.00	11,255.18	7,503.45	3,751.73	1,740.00	9,515.18		
2006	1.00	0.50	0.42	0.42	0.01	0.007	0.413	1.00	0.02	0.008	0.006	194.55	14,000.00	22,525.85	15,017.23	7,508.62	1,620.00	20,905.85		
2007	1.00	0.50	0.42	0.42	0.01	0.007	0.413	1.00	0.04	0.017	0.011	194.55	14,000.00	45,113.62	30,075.75	15,037.87	1,650.00	43,463.62		
2008	1.00	0.50	0.42	0.42	0.01	0.007	0.413	1.00	0.05	0.021	0.014	194.55	14,000.00	56,430.74	37,620.49	18,810.25	1,400.00	55,030.74		
2009	1.00	0.50	0.42	0.42	0.01	0.007	0.413	1.00	0.10	0.041	0.028	194.55	14,000.00	113,248.53	75,499.02	37,749.51	1,400.00	111,848.53		
2010	1.00	0.50	0.42	0.42	0.01	0.007	0.413	1.00	0.20	0.083	0.055	194.55	14,000.00	228,045.30	152,030.20	76,015.10	1,400.00	226,645.30		
2011	1.00	0.50	0.42	0.42	0.01	0.007	0.413	1.00	0.30	0.124	0.083	194.55	14,000.00	344,390.31	229,593.54	114,796.77	1,400.00	342,990.31		
2012	1.00	0.50	0.42	0.42	0.01	0.007	0.413	1.00	0.50	0.206	0.138	194.55	14,000.00	581,725.04	387,816.70	193,908.35	1,400.00	580,325.04		
2013	1.00	0.50	0.42	0.42	0.01	0.007	0.413	1.00	0.60	0.248	0.165	194.55	14,000.00	702,714.77	468,476.51	234,238.26	1,400.00	701,314.77		
2014	1.00	0.50	0.42	0.42	0.01	0.007	0.413	1.00	0.70	0.289	0.193	194.55	14,000.00	825,252.74	550,168.49	275,084.25	1,400.00	823,852.74		
2015	1.00	0.50	0.42	0.42	0.01	0.007	0.413	1.00	0.70	0.289	0.193	194.55	14,000.00	825,252.74	550,168.49	275,084.25	1,400.00	823,852.74		
2016	1.00	0.50	0.42	0.42	0.01	0.007	0.413	1.00	0.70	0.289	0.193	194.55	14,000.00	825,252.74	550,168.49	275,084.25	1,400.00	823,852.74		

Uganda - Tomatoes
Closed Economy Example

YEAR	Suply Elasticity ε	Demand Elasticity η	YIELD CHANGE	GROSS PROPOR. COST CHANGE	PROPOR. I. COST CHANGE PER HA.	PROPOR. I. COST CHANGE PER TON	NET CHANG	PROB OF SUCCESS	ADOPT RATE	K	Z	PRICE *	QUANTITY *	TS	CS	PS	COST	BENEFIT	NPV	IRR
2002	1.00	0.50	0.42	0.42	0.25	0.176	0.244	1.00	0.00	0.000	0.000	194.55	14,000.00	0.00	0.00	0.00	1,000.00	-1,000.00	584,266.01	133%
2003	1.00	0.50	0.42	0.42	0.25	0.176	0.244	1.00	0.00	0.000	0.000	194.55	14,000.00	0.00	0.00	0.00	700.00	-700.00		
2004	1.00	0.50	0.42	0.42	0.25	0.176	0.244	1.00	0.00	0.000	0.000	194.55	14,000.00	0.00	0.00	0.00	1,850.00	-1,850.00		
2005	1.00	0.50	0.42	0.42	0.25	0.176	0.244	1.00	0.01	0.002	0.002	194.55	14,000.00	6,646.82	4,431.22	2,215.61	1,740.00	4,906.82		
2006	1.00	0.50	0.42	0.42	0.25	0.176	0.244	1.00	0.02	0.005	0.003	194.55	14,000.00	13,299.05	8,866.03	4,433.02	1,620.00	11,679.05		
2007	1.00	0.50	0.42	0.42	0.25	0.176	0.244	1.00	0.04	0.010	0.007	194.55	14,000.00	26,619.71	17,746.47	8,873.24	1,650.00	24,969.71		
2008	1.00	0.50	0.42	0.42	0.25	0.176	0.244	1.00	0.05	0.012	0.008	194.55	14,000.00	33,288.15	22,192.10	11,096.05	1,400.00	31,888.15		
2009	1.00	0.50	0.42	0.42	0.25	0.176	0.244	1.00	0.08	0.020	0.013	194.55	14,000.00	53,325.87	35,550.58	17,775.29	1,400.00	51,925.87		
2010	1.00	0.50	0.42	0.42	0.25	0.176	0.244	1.00	0.10	0.024	0.016	194.55	14,000.00	66,711.36	44,474.24	22,237.12	1,400.00	65,311.36		
2011	1.00	0.50	0.42	0.42	0.25	0.176	0.244	1.00	0.13	0.032	0.021	194.55	14,000.00	86,830.12	57,886.75	28,943.37	1,400.00	85,430.12		
2012	1.00	0.50	0.42	0.42	0.25	0.176	0.244	1.00	0.18	0.044	0.029	194.55	14,000.00	120,469.44	80,312.96	40,156.48	1,400.00	119,069.44		
2013	1.00	0.50	0.42	0.42	0.25	0.176	0.244	1.00	0.22	0.054	0.036	194.55	14,000.00	147,478.14	98,318.76	49,159.38	1,400.00	146,078.14		
2014	1.00	0.50	0.42	0.42	0.25	0.176	0.244	1.00	0.25	0.061	0.041	194.55	14,000.00	167,791.39	111,860.93	55,930.46	1,400.00	166,391.39		
2015	1.00	0.50	0.42	0.42	0.25	0.176	0.244	1.00	0.25	0.061	0.041	194.55	14,000.00	167,791.39	111,860.93	55,930.46	1,400.00	166,391.39		
2016	1.00	0.50	0.42	0.42	0.25	0.176	0.244	1.00	0.25	0.061	0.041	194.55	14,000.00	167,791.39	111,860.93	55,930.46	1,400.00	166,391.39		

Uganda - Tomatoes
Closed Economy Example

YEAR	Suply Elasticity ε	Demand Elasticity η	YIELD CHANGE	GROSS PROPOR. COST CHANGE	PROPOR. I. COST CHANGE PER HA.	PROPOR. I. COST CHANGE PER TON	NET CHANGI	PROB OF SUCCESS	ADOPT RATE	K	Z	PRICE *	QUANTITY *	TS	CS	PS	COST	BENEFIT	NPV	IRR
2002	1.00	0.50	0.25	0.01	-0.005	-0.004	0.014	1.00	0.00	0.000	0.000	194.55	14,000.00	0.00	0.00	0.00	765.00	-765.00	29,721.91	43%
2003	1.00	0.50	0.25	0.01	-0.005	-0.004	0.014	1.00	0.00	0.000	0.000	194.55	14,000.00	0.00	0.00	0.00	670.00	-670.00		
2004	1.00	0.50	0.25	0.01	-0.005	-0.004	0.014	1.00	0.00	0.000	0.000	194.55	14,000.00	0.00	0.00	0.00	1,230.00	-1,230.00		
2005	1.00	0.50	0.25	0.01	-0.005	-0.004	0.014	1.00	0.02	0.000	0.000	194.55	14,000.00	762.65	508.43	254.22	1,500.00	-737.35		
2006	1.00	0.50	0.25	0.01	-0.005	-0.004	0.014	1.00	0.05	0.001	0.000	194.55	14,000.00	1,906.76	1,271.18	635.59	1,170.00	736.76		
2007	1.00	0.50	0.25	0.01	-0.005	-0.004	0.014	1.00	0.08	0.001	0.001	194.55	14,000.00	3,051.04	2,034.02	1,017.01	1,250.00	1,801.04		
2008	1.00	0.50	0.25	0.01	-0.005	-0.004	0.014	1.00	0.10	0.001	0.001	194.55	14,000.00	3,813.97	2,542.65	1,271.32	1,275.00	2,538.97		
2009	1.00	0.50	0.25	0.01	-0.005	-0.004	0.014	1.00	0.13	0.002	0.001	194.55	14,000.00	4,958.51	3,305.67	1,652.84	1,275.00	3,683.51		
2010	1.00	0.50	0.25	0.01	-0.005	-0.004	0.014	1.00	0.15	0.002	0.001	194.55	14,000.00	5,721.62	3,814.42	1,907.21	1,275.00	4,446.62		
2011	1.00	0.50	0.25	0.01	-0.005	-0.004	0.014	1.00	0.18	0.003	0.002	194.55	14,000.00	6,866.43	4,577.62	2,288.81	1,275.00	5,591.43		
2012	1.00	0.50	0.25	0.01	-0.005	-0.004	0.014	1.00	0.20	0.003	0.002	194.55	14,000.00	7,629.72	5,086.48	2,543.24	1,275.00	6,354.72		
2013	1.00	0.50	0.25	0.01	-0.005	-0.004	0.014	1.00	0.22	0.003	0.002	194.55	14,000.00	8,393.09	5,595.39	2,797.70	1,275.00	7,118.09		
2014	1.00	0.50	0.25	0.01	-0.005	-0.004	0.014	1.00	0.25	0.004	0.002	194.55	14,000.00	9,538.27	6,358.84	3,179.42	1,275.00	8,263.27		
2015	1.00	0.50	0.25	0.01	-0.005	-0.004	0.014	1.00	0.25	0.004	0.002	194.55	14,000.00	9,538.27	6,358.84	3,179.42	1,275.00	8,263.27		
2016	1.00	0.50	0.25	0.01	-0.005	-0.004	0.014	1.00	0.25	0.004	0.002	194.55	14,000.00	9,538.27	6,358.84	3,179.42	1,275.00	8,263.27		

Uganda - Tomatoes
Closed Economy Example

YEAR	Suply Elasticity ε	Demand Elasticity η	YIELD CHANGE	GROSS PROPOR. COST CHANGE	PROPOR. I. COST CHANGE PER HA.	PROPOR. I. COST CHANGE PER TON	NET CHANGE	PROB OF SUCCESS	ADOPT RATE	K	Z	PRICE *	QUANTITY *	TS	CS	PS	COST	BENEFIT	NPV	IRR
2002	1.00	0.50	0.30	0.30	0.0025	0.001923	0.298077	1.00	0.00	0.000	0.000	194.55	14,000.00	0.00	0.00	0.00	485.00	-485.00	837,665.57	270%
2003	1.00	0.50	0.30	0.30	0.0025	0.001923	0.298077	1.00	0.00	0.000	0.000	194.55	14,000.00	0.00	0.00	0.00	290.00	-290.00		
2004	1.00	0.50	0.30	0.30	0.0025	0.001923	0.298077	1.00	0.00	0.000	0.000	194.55	14,000.00	0.00	0.00	0.00	320.00	-320.00		
2005	1.00	0.50	0.30	0.30	0.0025	0.001923	0.298077	1.00	0.02	0.006	0.004	194.55	14,000.00	16,253.16	10,835.44	5,417.72	600.00	15,653.16		
2006	1.00	0.50	0.30	0.30	0.0025	0.001923	0.298077	1.00	0.04	0.012	0.008	194.55	14,000.00	32,538.58	21,692.39	10,846.19	510.00	32,028.58		
2007	1.00	0.50	0.30	0.30	0.0025	0.001923	0.298077	1.00	0.06	0.018	0.012	194.55	14,000.00	48,856.27	32,570.85	16,285.42	650.00	48,206.27		
2008	1.00	0.50	0.30	0.30	0.0025	0.001923	0.298077	1.00	0.08	0.024	0.016	194.55	14,000.00	65,206.23	43,470.82	21,735.41	725.00	64,481.23		
2009	1.00	0.50	0.30	0.30	0.0025	0.001923	0.298077	1.00	0.10	0.030	0.020	194.55	14,000.00	81,588.45	54,392.30	27,196.15	725.00	80,863.45		
2010	1.00	0.50	0.30	0.30	0.0025	0.001923	0.298077	1.00	0.13	0.039	0.026	194.55	14,000.00	106,222.28	70,814.85	35,407.43	725.00	105,497.28		
2011	1.00	0.50	0.30	0.30	0.0025	0.001923	0.298077	1.00	0.18	0.054	0.036	194.55	14,000.00	147,439.99	98,293.33	49,146.66	725.00	146,714.99		
2012	1.00	0.50	0.30	0.30	0.0025	0.001923	0.298077	1.00	0.20	0.060	0.040	194.55	14,000.00	163,983.54	109,322.36	54,661.18	725.00	163,258.54		
2013	1.00	0.50	0.30	0.30	0.0025	0.001923	0.298077	1.00	0.22	0.066	0.044	194.55	14,000.00	180,559.36	120,372.91	60,186.45	725.00	179,834.36		
2014	1.00	0.50	0.30	0.30	0.0025	0.001923	0.298077	1.00	0.25	0.075	0.050	194.55	14,000.00	205,483.58	136,989.06	68,494.53	725.00	204,758.58		
2015	1.00	0.50	0.30	0.30	0.0025	0.001923	0.298077	1.00	0.25	0.075	0.050	194.55	14,000.00	205,483.58	136,989.06	68,494.53	725.00	204,758.58		
2016	1.00	0.50	0.30	0.30	0.0025	0.001923	0.298077	1.00	0.25	0.075	0.050	194.55	14,000.00	205,483.58	136,989.06	68,494.53	725.00	204,758.58		