

Modeling a Cost-Effective IPM Dissemination Strategy for Vegetables and Rice: An Example in South Asia

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ABSTRACT

Integrated Pest Management (IPM) technologies have proven to be effective at increasing agricultural productivity and have been credited for providing economic, health, and environmental benefits in many developing countries. In South Asia, population growth and the increasing demand for nutritious foods have put pressure on farmers to produce more food with a relatively inelastic supply of land. Productivity enhancing practices, like IPM, have helped some farmers to meet this demand; however, with over 50 million farmers in Bangladesh and Nepal it is difficult to reach them with information about new agricultural technologies. This study evaluates the current IPM dissemination strategy being implemented by the Bangladesh Department of Agricultural Extension (DAE) and uses a linear programming (LP) model to propose alternative strategies that may extend the total benefits from IPM technologies. Additionally, using data from a household survey, a bivariate probit model and a two-step endogenous participation model are used to identify factors that may influence both knowledge and adoption of IPM practices in three regions of Nepal. The results from the LP model suggest that more farmers could be effectively reached by reallocating funding that is currently used for interpersonal communications (i.e. extension agent visits and farmer field schools) to more widespread methods such as mass media and field days. The model also suggests that a dynamic dissemination strategy is necessary to encourage adoption of IPM technologies with differing characteristics and levels of complexity. The econometric analysis suggests that farmers with “network linkages” to agricultural information and inputs, such as membership in a farmer organization, are more likely to be aware of IPM and to adopt IPM practices. The survey data also suggest that farmers who are members of Marketing Planning Committees (MPC) may be more likely to adopt more IPM practices when compared to non-members. Overall, the study suggests that strategically disseminating IPM information is vital to promote the adoption of these technologies in South Asia.

DEDICATION

I dedicate my thesis to my parents, Ron and Cheryl Harris, to my sisters, Lindsey and Amy, and to my loving extended family. Thank you for all of the support and encouragement you have provided me throughout my years at Virginia Tech.

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CHAPTER I: INTRODUCTION

I.1 The Importance of Agricultural Innovations

Rapid population growth in developing countries continues to put pressure on agricultural production to meet the increasing need for affordable food. By 2025, the growing populations and rising incomes in these countries will cause demand to increase by 59% for cereals, 60% for roots and tubers, and 120% for meats when compared to the levels of demand in 2000 (De Janvry et al., 2001). Farmers in developing countries battle many obstacles including low yields, high production costs, a lack of production and market information, and high risk, among others. Research and innovations that help battle these obstacles are in demand and are imperative to the success of farmers in developing countries. However, it is difficult for the millions of farmers in less developed countries (LDC) to gain access to new information and technologies that could help them improve their production practices.

The productivity of farmers is directly related to their human capital (Feder et al., 2004). Human capital includes both intrinsic skills and those that have been learned through experience. Therefore, in order to maximize productivity farmers must enhance their own capital by gaining knowledge about new agricultural innovations. Many diffusion strategies have been used to disseminate agricultural information; however, the number of farmers that have been reached has been limited.

The benefits of using integrated pest management (IPM) practices have been given considerable attention in recent years. By employing a holistic approach, IPM integrates biological, cultural, and chemical controls of pests resulting in the decreased use of pesticides (Greene et al., 1985). The initial motivation for the development of IPM was to control the negative environmental and health effects of pesticide use; however, since its initiation, significant economic benefits have been realized by farmers who adopt the new practices.

It is important for IPM researchers to have an accurate estimate of the gains that are likely to result from the technologies that they develop. Research on the economic impact of IPM innovations is necessary so that researchers and extension personnel can concentrate on developing and disseminating the most beneficial techniques. In addition, impact assessments

allow the coordinators of agricultural extension programs to set goals and allocate budgets in a manner that maximizes the potential benefits of IPM practices in the hands of farmers.

Access to advancements in agricultural research is critical for the success of farmers in developing countries; however, the large number of farmers and the lack of functioning dissemination channels create a challenge for agricultural extension. This thesis examines the dissemination of agricultural technologies in South Asia, using Integrated Pest Management (IPM) technologies in Bangladesh and Nepal as examples.

I.2 Problem Statement

Agriculture accounts for most of the income in developing countries and employs the majority of the available labor. In Bangladesh, agriculture contributes one-third of the country's gross domestic product (GDP) and employs over half of the country's workforce (Bangladesh, 2008). In Nepal, approximately 76% of the population obtains income from agriculture and the industry contributes almost 40% to the GDP (Palikhe, 2002; Shrestha and Neupane, 2002). Production losses are a critical concern due to their tremendous economic impact. Crop loss due to pests is a major problem across both countries. In 2002, throughout Bangladesh, insect pests alone caused a 16% loss in rice yields, 11% of wheat, 20% of sugarcane, 25% of vegetables, 15% of jute, and 25% of pulse crops (Bangladesh, 2002a). In Nepal, pest infestations during production and storage result in an annual crop loss of 35% (Palikhe, 2002).

Unfortunately many farmers are unaware of new technologies and practices to help control pests and often resort to using heavy chemical pesticide applications. Over the past two decades pesticide use has increased rapidly as farmers work to combat infestations (Bangladesh, 2002a). Economic, environmental, and health implications are associated with the increased use of chemical controls. A 2009 Health Bulletin released in Bangladesh indicated that 7,438 people had died from pesticide poisoning in the previous year (Rory, 2010). Additionally, pesticides are quite expensive in developing countries and contribute to high input costs.

After being introduced in the 1960's, pesticide use has also increased rapidly in Nepal, especially in commercial production. Although the total amount of pesticides used throughout the country may be considered negligible compared to countries such as India, the misuse of

pesticides in the commercial sector has ignited concerns regarding their effects on environmental and human health (Atreya, 2007).

In addition to the economic implications of using these chemicals, the overuse and improper disposal of pesticides poses numerous health and environmental threats including: pesticide resistance, toxic residues in food, water, and soil, the elimination of natural pest enemies, and the disruption of the ecosystem (Palikhe, 2002). Commercial farms account for the majority of the misuse due to ignorance about the inherent danger of the chemicals and unfamiliarity with alternative pest control measures. High pesticide and insecticide applications have led to water contamination and the spread of diseases affecting the health of livestock, aquatic life, and humans (Rasul and Thapa, 2004).

Awareness and availability of alternative pest management practices is critical in order to alleviate some of the harmful effects of chemical applications. Aggressive marketing tactics used by pesticide dealers often overpower messages from agricultural extension personnel and may dissuade farmers, particularly untrained farmers, from seeking information about non-chemical pest control (Robinson et al., 2007). In an effort to increase their own sales and profits, some dealers may try to create the illusion that chemical treatments are the only effective solution to pest threats. Informing farmers of the benefits of non-chemical pest controls is imperative in order to break the cycle of chemical abuse.

Integrated pest management aims to improve productivity by promoting safe and effective pest management strategies across much of the developing world (Norton et al., 1999). IPM researchers develop technology “packages,” or groups of practices, that are introduced in specific regions to reduce crop loss due to a variety of pest problems. The packages that are developed are based on agro-ecological principles that are adaptable to a diverse range of agricultural situations (Thrupp and Altieri, 2001). In addition, the program aims to reduce the use of pesticides in order to create a more healthy and sustainable solution for pest control. The packages contain several pest management practices that vary in complexity and require different levels of training to implement them effectively.

IPM practices for rice were introduced in Bangladesh in 1981 (Bangladesh, 2002a). The Food and Agricultural Organization of the United Nations (FAO) trained officials from the

Department of Agricultural Extension so that they could then teach farmers how to incorporate IPM principles in crop production. In Nepal, IPM was not formally introduced until 1997 (Atreya, 2007). Farmer field schools (FFS) were utilized to educate over 16,000 farmers in the first five years of the program. Farmers were receptive to the alternative methods of pest management and the idea of “community IPM” quickly developed. “Community IPM is a strategy for sustainable agriculture development where farmers act on their own initiative and analysis, identify and resolve relevant pest and crop-related problems, conduct their own local IPM research and education, establish or adapt local organizations that enhance the influence of farmers in local decision making, employ problem solving and decision-making processes, create opportunities for all farmers in their communities to develop themselves, and promote a sustainable agricultural system,” (Atreya, 2007, p. 400).

A significant amount of research has been conducted to develop IPM technologies in South Asia, resulting in a reduced reliance on pesticides and increased crop yields. Vegetable crops have been given considerable attention because they contribute to a balanced diet. Although rice is the primary crop grown in both Bangladesh and Nepal, vegetables are extremely important as they provide essential nutrients for the vast population.

In Bangladesh nearly 100,000 farmers have been taught about IPM through intensive, season-long farmer field schools (FFS) (Bangladesh, 2002a). In turn, these farmers have reduced pesticide use dramatically, in some cases by nearly 80%. Implementing new IPM techniques has also increased yields by an average of 10%. Although these gains are substantial, the 100,000 farmers only comprise 0.27% of the nearly 37 million farmers in Bangladesh.

Although the IPM program has developed a wealth of information for farmers many are still unaware of new research and technological advances. The information gap between researchers and farmers is an enormous problem as it limits the production gains that can be obtained. Many tactics are used to disseminate information about IPM including mass media, field days, extension agent visits, and farmer field schools. Each tactic has its own benefits and drawbacks concerning efficacy, cost, and reach.

Farmers are often presented with IPM information using various forms of mass media, including pamphlets, newspapers, radio, and television. Mass media is the cheapest form of

information dissemination and has the potential to reach a large portion of a population (Bentley et al., 2003). Its use, however, encounters some constraints when trying to reach the entire population including low literacy levels and restricted access to media resources. In addition, mass media is inadequate when trying to disseminate complex technologies that must be coupled with training. Despite these constraints, mass media has the potential to effectively convey simple messages about IPM to a broad, diverse audience.

Field days, extension agent visits, and FFS are instructional and intensive strategies to disseminate information regarding IPM. Field days are organized events that provide IPM information to farmers through presentations and demonstrations about new technologies. Ranging in size, from 25 to 500 farmers, field days provide first hand exposure to pest management techniques that have proven effective in the area. This dissemination approach allows for relatively cost-effective diffusion of IPM information (Ricker-Gilbert et al., 2008), though the depth of training is limited by time and personnel. Extension agent visits on the other hand, are utilized to relay IPM on a more personal level. Although this dissemination tactic can help tailor an IPM package to each farmer's specific needs, the agents can only reach a limited number of farmers due to budget and time constraints.

The most intensive method of teaching farmers about IPM is through a farmer field school (FFS). FFS "help farmers develop their analytical skills, critical thinking, and creativity, and help them learn to make better decisions" (Feder et al., 2004 p.222). They are structured in weekly meetings of 20 to 25 farmers with an IPM trainer throughout a single crop growing season (approximately 8-12 weeks). The cost of training per farmer is the highest of any dissemination tactic; however, the goal is to have farmers leave the FFS and teach others about the strategies they have learned, thus effectively lowering the overall cost of disseminating information through this method. This continuing farmer to farmer information transfer is critical to ensure the cost-effectiveness of the FFS. Unfortunately, research has shown that while some informal diffusion does take place, often it is ineffective in conveying the intricacies of the IPM technology as well as in reaching a broad spectrum of farmers (Feder et al., 2004; Rola et al., 2002).

Farmer organizations also play an important role in the dissemination of agricultural information (Caviglia-Harris, 2003). More widespread IPM dissemination may be achieved by better utilizing existing farmer groups. Furthermore, many farmers access agricultural information and inputs through various networks and linkages. These connections, which will be referred to as “network linkages,” may also serve as communication channels to disseminate information about new agricultural technologies.

Cost-effective dissemination tactics must be utilized so that the expansion of IPM can be maximized within the funding constraints. The characteristics of IPM packages further complicate the task because the technologies differ in complexity. They require varying levels of training for the information to be adequately transferred to farmers. A multifaceted strategy of information dissemination must be developed in order to successfully reach farmers and teach them the skills and information necessary to maximize the gains offered by new IPM technologies.

In the past, researchers have claimed that farmers make the decision to adopt based on maximizing their expected utility or benefits (Adesina and Zinnah, 1993). However, it appears that pest management decisions are primarily made based on the perception that pesticide use is the most effective method of control and they are seldom based solely on economic rationale (Heong and Escalada, 1999). Information should be disseminated in a way that creates positive perceptions of IPM and encourages farmers to adopt new technologies for the many benefits they can provide.

Governments, non-governmental organizations (NGO's), universities, and private companies all play important roles in developing new technologies which can enhance productivity in LDC's. Shrinking budgets of these organizations mandate the use of fewer resources, requiring better allocation of the resources in a way that will be most effective at achieving the desired outcome (Bentley et al., 2003). Organizations employ economists to conduct research which reveals the effects of new technologies and their economic impact on a community, country, or region. The results of the economic studies are used in research priority-setting which allows organizations to allocate their resources most appropriately in accordance with their goals (Norton et al., 1992).

Until now, IPM has concentrated on participatory techniques to disburse technologies. Although in-depth training may provide a farmer with more knowledge, these training techniques have not enabled the spread of IPM information to the majority of farmers. In order for IPM technologies to spread successfully the research must be integrated with a more widespread diffusion process (Norton et al., 2005). Mass media has been proven to disseminate information rapidly across a broad audience at a relatively low cost (Heong and Escalada, 1999). Other diffusion mechanisms, however, are needed to convey information associated with complex technologies. Finding a dissemination strategy that is both effective and financially feasible is crucial to the success of IPM and the future productivity of farmers in South Asia.

I.3 Objectives

The objectives of this study differ between Bangladesh and Nepal based on the IPM data that were available in each country.

Bangladesh

The objective of the Bangladesh study is to identify the most cost-effective dissemination strategy for vegetable and rice IPM technologies. A combination of IPM dissemination methods implemented by the Department of Agricultural Extension (DAE) will be strategically selected based on costs and benefits within a set of specified constraints. This project is designed to (1) maximize economic benefits by selecting the most cost-effective IPM dissemination strategy to diffuse IPM technologies for four crops: eggplant, tomatoes, cucurbits, and rice; and (2) calculate the economic tradeoffs associated with reallocating the dissemination budget among various dissemination methods, IPM technologies, and crops. The results of this study could assist policy-makers by suggesting strategies to cost-effectively disseminate IPM technologies. The calculated tradeoffs can assist decision-makers as they allocate dissemination budgets in accordance with their goals.

Nepal

The objective of the Nepal study is to identify the factors that influence farmer awareness and adoption of IPM technologies. Furthermore, this study will outline the current IPM dissemination strategy being used in Nepal, as well as identify the sources and information

channels from which farmers learn about agricultural technologies. This project aims to aid future research efforts by providing an overview of the current status of IPM in Nepal and making suggestions for further examination and analysis.

I.4 Hypotheses

Nepal

- 1.) Farmers with network linkages to inputs and agricultural information will be more likely to have awareness about IPM technologies than farmers without network linkages.
- 2.) Farmers with network linkages will be more likely to adopt IPM technologies than farmers that are not associated with networks.

I.5 Procedures and Data Sources

Bangladesh

This study uses a linear programming (LP) model to identify a cost-effective strategy to disseminate IPM information for four crops in Bangladesh. The model maximizes the total economic surplus obtained from a specific extension strategy by aggregating the estimated surplus gained per dollar spent on disseminating IPM for each crop, practice, and dissemination method.

Economic surplus estimates were computed for each IPM practice to obtain the objective function coefficients for the LP model. The surplus calculations rely on the expert opinion of researchers at the Bangladesh Agricultural Research Institute (BARI), field-level enterprise budgets compiled with data from Bangladeshi farmers, production data from statistical databases and annual reports, and other studies conducted during the past 10 years. The adoption rate for each technology is estimated based on expert opinion from extension personnel and crop scientists. A field survey of 300 farmers in three regions of Bangladesh was also used to draw some conclusions about the current level of IPM knowledge and technology adoption. A copy of the survey is included in Appendix A and a map of the survey areas is provided in Appendix B.

The constraints of the model are constructed from budget information from the Department of Agricultural Extension (DAE) for each dissemination method by crop and IPM

practice. Data on the cost and number of farmers reached for each dissemination tactic were collected during interviews with government personnel and NGO staff who coordinate IPM extension programs across Bangladesh.

Nepal

A bivariate probit model and endogenous participation model were used to identify the factors that affect farmer awareness and adoption of IPM technologies for various vegetable crops. Data were obtained from a household-level survey conducted by IDE -Nepal in 2010. The data represent eighty vegetable farmers from three districts across the central and western regions of Nepal.

Information regarding the current structure of IPM research and dissemination was collected during a trip to Nepal in the summer of 2010. Interviews were conducted with personnel representing several governmental and private organizations that actively develop IPM technologies and/or disseminate IPM technologies to farmers throughout the country.

I.6 Organization of Thesis

This thesis is organized into five chapters. Chapter Two provides the context for the study by reviewing dissemination literature, providing background information about Bangladesh and Nepal, and describing the current IPM programs in each country. Chapter Three outlines the empirical strategy and methodology used to analyze the IPM dissemination strategies in the two countries. The results are presented in Chapter Four, followed by the summary, limitations, conclusions, and suggestions for future research in Chapter Five.

CHAPTER II: BACKGROUND

II.1 Introduction

Chapter Two provides the context for this study by reviewing literature about the process of dissemination, agricultural extension, and decision-making. This chapter also provides a general background about Bangladesh and Nepal, and describes the current strategies used by both public and private sectors to reach farmers with information about IPM. Additionally, commonly used IPM practices are described for each country.

II.2 Review of Dissemination Literature

II.2.1 Defining Dissemination

In his book, Diffusion of Innovations, Everett Rogers defines diffusion as “the process by which an innovation is communicated through certain channels over time among the members of a social system” (Rogers, 1995, p.5). The process of information dissemination is complicated by the risk and uncertainty involved in new techniques. Rogers proceeds to define uncertainty as “the degree to which a number of alternatives are perceived with respect to the occurrence of an event and the relative probability of these alternatives” (Rogers, 1995, p.6). Providing clearly detailed information and instruction about a new innovation reduces the uncertainty and leads to the ultimate goal of adoption of the technology or practice.

Often researchers use the term “diffusion” when they are referring to the spontaneous spread of new ideas and “dissemination” when referring to a planned flow of ideas. Based on the definitions outlined by Rogers (1995), this paper will use the terms “diffusion” and “dissemination” synonymously to reference both the spontaneous and planned spread of innovations and technologies.

II.2.2 Disseminating Agricultural Innovations – A Historical Perspective

Since Griliches' study on the adoption of hybrid corn in 1957, researchers have analyzed diffusion strategies to determine how farmers receive the information that leads to the adoption of new agricultural innovations (Marra et al., 2003). Following Griliches' study, Copp, Sill, and Brown released a pioneering paper focusing on the stages of decision-making in the context of adoption (Copp et al., 1958). They used a participatory appraisal approach to identify information channels from which dairy farmers gained knowledge regarding pest control, grass silage, and artificial hay drying. The information seeking behavior of the farmers was examined during each stage of the adoption process. The process was divided into five categories: (1) awareness, (2) interest, (3) acceptance, (4) trial, (5) and adoption.

The sources from which farmers received information about agricultural technologies were categorized into eight groups: (1) farm magazines/papers, (2) radio, (3) printed extension, (4) oral extension, (5) peer influence, (6) commercial media (printed and oral), (7) formal agricultural training, and (8) "other." The researchers found that more than one dissemination channel was commonly cited by the farmers as a source of agricultural information. No "one-to-one" relationships between the information sources and stages of the adoption process were found. However, correlations were identified between the sources and stages of the adoption process which supported the findings of past research (Copp et al., 1958). For example, mass media (magazines, radio, and printed extension) proved to be the most important information source at the *awareness stage*. On the other hand, during the *interest stage* face-to-face communication was cited more frequently while mass media was cited less. Peer influences became more important during the *acceptance stage* as farmers compared experiences with friends, neighbors, and relatives. Printed and oral extension sources again became crucial during the *trial stage* as farmers sought information about how to correctly apply new technologies. The study did not press farmers to cite information sources after the trial period; however, similar diffusion research conducted by Beal and Bohlen suggested that farmers continue to use peers and extension services to evaluate their results after adoption (Copp et al., 1958).

The researchers proceeded to evaluate the information channels based on institutional support, timing, farmer bias, availability, and local compatibility (Copp et al., 1958). Their

conclusions suggested that certain information sources, such as extension and farm magazines, reached widespread farmer audiences because they were supported and financed by large institutions that aimed to provide farmers with valuable agricultural resources. Early adopters could not rely on other farmers for information because the majority of farmers did not yet know of the new innovation. In addition, information transferred via informal diffusion (from person to person) was often biased by negative results and failed attempts at successful adoption. The availability of information was also identified as an important factor. Farm programs were usually broadcast only once over radio or television channels making it difficult to reach a large farming audience. In situations in which electronic media was limited, it was suggested that printed media could be more convenient and accessible to the agricultural community. Finally, information that was diffused by mass media was not often directed at a specific locality, which raised concerns about the effectiveness of the technology in differing environments. Farmers wanted assurance that the practice was suited for local conditions and that it would be beneficial to their farm operation.

Most of the conclusions of Cobb, Sill, and Brown are in line with more current research that has further examined the effectiveness of different dissemination methods in each stage of the decision-making process. Recent research has also concentrated on how diffusion methods affect farmer perceptions and the ultimate adoption of new technologies. Several studies have concluded that farmer perceptions indeed do have a significant effect on adoption (Adesina and Zinnah, 1993; Heong et al., 1998; Negatu and Parikh, 1999). Perceptions can be significantly different based on the method of dissemination used to communicate information about a particular practice. Studies focusing on IPM practices have made significant contributions to the literature regarding the diffusion and adoption of agricultural technologies. Several of these studies will be explored in the following sections.

II.2.3 The Process of Innovation Diffusion and Decision-Making

Rogers outlines four main elements in the diffusion of innovations which include: the innovation, communication channels, time, and a social system (Rogers, 1995). The innovation itself can exist in the form of a new idea, technology, or practice. Information about this innovation is transmitted to the public through communication channels over a period of time.

As people receive the new information they progress through a process defined by Rogers as the “innovation-decision process” which will be examined later in this section. The fourth element of diffusion, the social system, includes all of the people who are involved in a joint problem-solving effort. These people have similar goals and may have to overcome obstacles in order to accomplish them. Understanding the social system is also imperative in order to understand how communities may be affected by the dissemination of a new innovation (Rogers, 1995).

The ultimate goal of diffusion is to have a positive effect on adoption of a particular technology or practice. Rogers emphasizes several endogenous features of an innovation that are directly associated with the rate of successful adoption. These attributes include the benefit of the innovation relative to older technologies, the compatibility with current production practices, the complexity of the innovation, the ability to try the practice with low risk, and the observability of success (Rogers, 1995). Each of the five technology characteristics are closely related to the concept of risk (or perceived risk) which is considered a major factor influencing adoption (Abadi Ghadim et al., 2005; Fernandez-Cornejo et al., 1994; Marra et al., 2003). When designing a diffusion strategy the attributes of the innovation must be considered so that an appropriate and effective model can be created to accentuate the benefits of the new agricultural practice.

Farmers are assumed to be risk adverse (Feder, 1982). Therefore, to provide an advantage from its adoption, the new innovation must be perceived to be more beneficial and less risky than the preceding practice (Rogers, 1995). Economic profitability is often a common advantage offered by a new technology. The tradeoff that often occurs between profitability and risk can affect a farmer’s decision to adopt a technology based on the magnitude of the two factors and his or her attitude toward risk (Abadi Ghadim and Pannell, 1999). To determine the likelihood that a practice will be adopted it is helpful to review the other four innovation attributes previously defined by Rogers (Rogers, 1995). *Compatibility* refers to the degree to which the innovation is consistent with current values and past experiences. More compatible innovations create a lower perception of risk to the farmer, thus decreasing the uncertainty associated with adoption. Another attribute, *complexity*, is also linked with risk. The concepts behind less complex technologies are simpler to understand and are perceived as less risky because they are easier to correctly implement. Farmers will be hesitant to adopt innovations that require higher levels of training or comprehension. *Trialability* refers to the level of experimentation that can be

conducted with an innovation without having to fully adopt the technology. The trial period allows farmers to assess their perceived risk and estimate the likelihood of successfully incorporating the practice in their current operation. Trialability of agricultural innovations is crucial because it has proven to increase farmers' willingness to adopt a new technology (Abadi Ghadim and Pannell, 1999). Finally, the *observability*, or degree to which results are observable to the adopting farmer and neighbors, greatly affects the desirability of an innovation (Rogers, 1995). If an observing farmer can easily evaluate his neighbor's level of success he is more likely to adopt a technology that has provided positive results for his peers.

The innovation-decision process is a step-wise process through which an individual learns about a new innovation and decides whether to incorporate it into his or her current practice. The process consists of five steps: (1) gaining the first knowledge of an innovation (*awareness* stage), (2) forming an attitude (*persuasion* stage), (3) deciding whether to adopt or reject the innovation (*decision* stage), (4) implementing the new idea (*implementation* stage), and (5) confirming the decision (*confirmation* stage) (Rogers, 1995). Other researchers have referred to the five stages with different terms such as interest, adoption, acceptance, trial, and evaluation (Copp et al., 1958; Feder et al., 2001). For the sake of uniformity, this paper will refer to the stages of the innovation-decision process as outlined by Rogers unless referring to a specific study.

The first stage, when farmers gain initial knowledge, is referred to as the *awareness* stage. During this stage an individual gains information about the existence of a new innovation and forms their first perceptions (Rogers, 1995). During the *persuasion* stage the individual's attitude toward the innovation is molded in either a positive or negative manner depending on the perceived benefits or drawbacks. The *decision* stage involves the individual's actions which lead to a decision to adopt or reject a new innovation. *Implementation* occurs based on the decision to adopt or reject. During this stage the innovation is either put into use or it is discarded. Finally, after the incorporation (or disposal) of the innovation the result is evaluated during the *confirmation* stage. During this final stage the individual seeks reinforcement of the decision to adopt or reject the technology based on initial results and feedback from peers and other agricultural professionals.

The success of the innovation-decision process depends on the number of farmers who successfully adopt the new technology. Adoption rates are slow at the start of diffusion but gain speed as more and more farmers are exposed to the new innovation and decide to adopt. Studies have grouped farmers into categories depending upon the length of time it takes them to adopt a new innovation (Rogers, 1995; Fernandez-Cornejo et al., 1993). In a study evaluating the adoption of IPM techniques by Florida vegetable growers, farmers were grouped into six categories: (1) innovators, (2) early adopters, (3) early majority, (4) late majority, (5) laggards, and (6) non-adopters (Fernandez-Cornejo et al., 1994). The innovators in this study represented the smallest minority (2.2%) as they were the farmers who were willing to assume risk and experiment with new technologies. Early adopters (12.2%) played a key role in the diffusion process because of their well respected status in the community and their representation of other farmers. Farmers who cautiously waited to evaluate the results of their peers formed the early majority (30.6%). Skeptical farmers waited for the majority of their neighbors to adopt before they also implemented the new pest management strategies; these farmers were categorized as the late majority (30.6%). Laggards (14.4%) were often more vulnerable to economic failure and therefore waited to adopt until they were certain that the technology would be successful. Finally the non-adopters (10%) never implemented the new IPM technology.

As researchers design diffusion models they must consider the four main elements of diffusion, the attributes of the innovation, the stages of the decision-making process, and the types of adopters which will be reached through the dissemination effort. It is imperative to use a mix of diffusion methods which can cater to each unique aspect of the innovation-decision process.

II.2.4 Informal Dissemination

Informal dissemination, or social learning, occurs when farmers learn from each other's experiences, decisions, and outcomes (Munshi, 2004). Although proponents of farmer field schools and other intensive extension methods rely on the notion that trained farmers will share the information with friends, many studies have shown that informal dissemination is inadequate to reach the majority of the population. Several hypotheses have been proposed as to why this informal diffusion fails.

Copp, Sill, and Brown raise concern about informal diffusion by suggesting that farmers receiving innovation information from peers are more likely to receive negative information about other farmers' failed attempts to successfully implement the new technology (Copp et al., 1958). An IPM study in Ecuador by Mauceri and others (2007) concluded that farmer-to-farmer diffusion is less effective than other dissemination strategies based on lower knowledge scores and adoption rates (Mauceri et al., 2007). The study found that FFS graduates share IPM information with 11 other farmers. Of these 11 individuals, some shared the information with peers however dissemination did not proceed further. Non-FFS farmers may lack the expertise to effectively transfer IPM knowledge. In addition, trust may play a vital role, as the study found that recipient farmers prefer to learn from knowledgeable trainers instead of neighboring farm operators.

An Indonesian study concluded that IPM knowledge did not significantly diffuse to members of other villages through informal diffusion (Feder et al., 2004). Many reasons have been cited for the failure of informal diffusion. Having a diverse, heterogeneous population may lower the level of social learning because people cannot assume that a technique that worked for their neighbor will also prove profitable for their farm (Munshi, 2004). Additionally, the high complexity of some IPM techniques may account for lower diffusion because they are not easily communicated in informal farmer-to-farmer discussion. One study concluded that simple technologies may be successfully disseminated through farmer-to-farmer diffusion, whereas, information about more complex technologies must be transferred via formal training (Ricker-Gilbert et al., 2008). The economic impacts of these conclusions are critical as they dramatically affect the cost-effectiveness of high input diffusion strategies and may threaten the sustainability of IPM dissemination efforts that rely on informal diffusion.

II.2.5 Disseminating IPM Technologies

Instead of releasing IPM practices one by one, multiple technologies are often released simultaneously to combat a variety of pest problems in what is referred to as an IPM "package." The technologies within the package frequently vary in complexity and aim to maximize interactions among the components through complementarity (Leathers and Smale, 1991). As with other agricultural technology packages, farmers rarely adopt 100% of the IPM innovations,

but instead choose to adopt each part of the package sequentially usually beginning with simple innovations and building in complexity over time (Byerlee and Polanco, 1986; Leathers and Smale, 1991). Researchers have identified several factors that explain sequential adoption including: profitability, riskiness, uncertainty, and capital and institutional constraints (Leathers and Smale, 1991). Using a Bayesian model Leathers and Smale concluded that “sequential adoption may be a rational choice for imperfectly informed farmers and need not be viewed as evidence of institutional shortcomings or farmers irrationality” (Leathers and Smale, 1991, p.741). The proper timing of adoption allows farmers to gain information about a technical package and assimilate it with their current practices to maximize their profitability (Ersado, 2004).

Farmers make IPM adoption decisions to maximize their expected utility or benefits (Mauceri et al., 2007). These pest management decisions are based on their beliefs and perceptions of pests and pesticide use, are rarely grounded with sound economic rationale, and seldom consider environmental or health hazards (Heong, 1998). Without scientific knowledge about yield losses caused by certain pests, farmers often overestimate damages and spray unnecessarily (Heong, 1999). Much of the problem is based on the extent to which farmers’ allow their beliefs to govern the practices that they utilize. A study conducted in the Philippines concluded that “farmers’ perceptions of insects, and insect damage and their control are important in their adoption of insect pest management practices” (Palis, 1998, p.606). The results of other studies have provided additional support in the assertion that farmer perceptions significantly influence pest management practices (Palis, 1998; Heong and Escalada, 1999). To simplify decision-making, farmers often use rules-of-thumb to decide when and how often to spray pesticides. Mass media has been used to diffuse particular IPM technologies to the farming population in an effort to change these beliefs. Mainly, media use has been employed to change perceptions and convey simple messages about IPM (Heong et al., 1998). Interpersonal diffusion strategies provide necessary support for the more technical aspects of IPM; however, they lack the ability to reach the masses.

An experimental study conducted in Vietnam showed that mass media could be effective in altering farmer attitudes toward insecticide use (Heong et al., 1998). Heong stated that insecticide applications are often unnecessary and often do not provide economic returns. The

study targeted 21,000 farming households located in two districts, Tan Tru and Tan Thanh, which are located in the Mekong Delta in southern Vietnam. The study evaluated the transmission of a simple message aimed at rice farmers: ‘Spraying insecticides for leaf folder control in the first 40 days after sowing is not needed’. The message was disseminated via 21,000 leaflets (one for each household), 4,000 posters, a radio drama (entitled ‘Well, I shall try’), nine billboards, and labeled vehicles. Data were collected through surveys in a pre-test-post-test design which consisted of a pre-test, the media experiment, a monitoring survey, and three post-tests. The pre-test, which collected data on farmer profiles, pest management knowledge, perceptions, attitudes, and practice, was conducted with 633 randomly selected farmers. This baseline information was used to measure the perception changes after the media campaign. In addition, the information was used to construct the most effective campaign by airing the radio drama on the most popular stations at times which farmers commonly listened.

After the IPM information was disseminated using the various types of mass media, 97% of the target population was aware of the campaign within two months. Farmers cited the leaflet (89%), radio drama (72%), poster (69%), demonstration plots (43%), friends (34%), and billboards (34%) as their source of IPM information. Fifty-six percent of farmers said that they conducted the experiment after receiving the information from the media. Over the study period insecticide sprays were greatly reduced from an average of 3.35 sprays per season to 1.56 within the first 18 months. However, the types of insecticides used were relatively unchanged, as were the insecticide targets and the perceived health effects of pesticide use. These results suggest that mass media has the power to alter loosely held beliefs, however, struggles to change perceptions which are ingrained in a society.

A survey conducted in 12 surrounding districts 25 months into the study revealed that farmer beliefs outside of the immediate study area had also changed. This result is indicative of the reach that can be obtained by mass media channels. In the first post-test 77% of the farmers who were aware of the campaign (n=400) said that they had shared the information with family and 67% had discussed it with other farmers. Overall the dissemination of a simple IPM message was successful. During the post-tests, 97% of farmers who were surveyed said that they would continue disuse of insecticide sprays during the first 40 days of the following season.

Governments in surrounding provinces were inspired by the media campaign employed in the project sites and launched 15 programs using the approach (Heong, 1998).

Heong also used a FFS training program that had been conducted two years prior in the same province to make some comparisons between the trained and untrained farmers in his study. The FFS had reached 2.2% of the households in the study site, whereas the media campaign had reached 97%. One hundred fourteen of the farmers in Heong's post-test had been trained in the FFS program. By comparing their results with untrained farmers several observations were made. The results showed that FFS trained farmers sprayed less, but not significantly less, than farmers who had only been exposed to the media campaign. Heong suggests that although mass media was adequate to diffuse the simple message, FFS training further reinforced the belief that spraying was not necessary for leaf folders.

As Rogers stated, the complexity of an innovation directly influences its adoption (Rogers, 1995). IPM packages are unique because the incorporated technologies frequently vary in complexity. Many IPM technologies require knowledge and skill in order to implement them successfully (Mauceri et al., 2007). Others are rather simple and can be implemented without training, such as the Vietnam study message: "Don't spray in the first 40 days." The varying levels of complexity make diffusion through one dissemination method highly unsuccessful.

With IPM technologies a multi-faceted diffusion strategy is crucial when trying to influence adoption. Mass media has been proven to successfully disseminate simple technologies (Heong et al., 1998). On the other hand, extension agent visits and FFS are more efficient at conveying information about more complex innovations. There is a critical need for further research concerning the most effective and affordable multi-media diffusion strategies. In addition, as Feder and others have pointed out previous studies have not concentrated on the *time* element of the diffusion process (Feder et al., 2004). These studies have not accounted for the length of exposure of certain diffusion methods, making it difficult to evaluate the effectiveness of dissemination strategies and the impact of farmer-to-farmer diffusion. Research is needed to examine how current resources can be best utilized to reach farmers in developing countries. Although information dissemination is not a cure-all for production limitations it can greatly

improve production by increasing farmers' human capital, lowering risk and uncertainty, and allowing farmers to take advantage of the most recent research advances.

II.3 Bangladesh

II.3.1 Introduction

Bangladesh, located in Southern Asia, borders the Bay of Bengal and lies between India and Burma, as illustrated in Figure 2.1. It is a developing country struggling to grow out of poverty. The country is characterized by a high population density, low per capita income, and a large rural sector. Between 1970 and 2007 Bangladesh's Human Development Index (HDI) which measures overall well-being based on health, education, and income, increased by 1.87% annually (Human Development Index, 2009a). Currently, Bangladesh is ranked 146th (out of 182 countries) in the HDI rankings.

Figure 2.1: Map of Bangladesh



Source: CIA World Fact Book, 2011

(a) Location of Bangladesh



Source: CIA World Fact Book, 2011

(b) Map of Bangladesh

II.3.2 Geography

In its entirety, the country encompasses an area of nearly 144,000 square kilometers – slightly smaller than the state of Iowa (CIA, 2011a). It has a tropical climate with mild winters (October to March), hot and humid summers (March to June), and a warm and rainy monsoon season (June to October). The terrain is mainly flat, low-lying flood plains with the highest point being only 1,230 meters above sea level. The flat terrain and heavy rain create a great

vulnerability for major flooding. Nearly a third of the country floods during each monsoon season.

II.3.3 Demographics and Culture

Bangladesh has a population of 158 million and a growth rate of 1.29% (CIA, 2011a). The population density is quite high with 1,097 people living in one square kilometer (CIA, 2011a). Both the birth rate, measured by the number of births per 1,000 people in the population, and the death rate, measured by the number of deaths per 1,000 people, have been declining in recent years and are currently 22.9 and 5.8, respectively (CIA, 2011a). The fertility rate, measured by the average number of children born per woman, has also been decreasing and is currently 2.6 children. Twenty-eight percent of the population lives in urban areas and the country is experiencing an increase in urban dwellers by an annual rate of 3.1%. Seventy percent of the urban population, however, lives in slums (PRB, 2010). The life expectancy in Bangladesh is just over 69 years old (CIA, 2011a).

The majority of Bangladeshi people are Muslim (89.5%), with the next most common religion being Hindu (9.6%), and a very small minority (0.9%) of other religions (CIA, 2011a). Bangla, or Bengali as it is commonly called, is the official language with English being the second most prevalent. Bangladeshi people, on average, only attend school for 8 years (2004 est.) contributing to the low literacy rate of 48% (2001 est.).

II.3.4 Economy

Bangladesh has a GDP of nearly \$100 billion (CIA, 2011a). The service sector contributes 52.9% to the GDP, followed by industry (28.7%) and agriculture (18.4%). Although agriculture does not comprise the majority of the GDP, it does dominate employment. Industrial production includes cotton textiles, jute, garments, tea processing, and newsprint. The agricultural sector is dominated by rice, jute, tea, wheat, sugarcane, potatoes, tobacco, and pulses.

Bangladeshi exports have grown by 3.3% in the last year (The World Bank, 2009) and are valued at \$15.4 billion. Exports are dominated by garments, jute, leather, frozen fish, and

seafood. The U.S. (21%), Germany (13.2%), the UK (8.6%), France (6.3%), and the Netherlands (4.7%) are the largest export clients. Overall however, Bangladesh is a net importer with annual imports being valued at nearly \$21.5 billion. The country imports machinery, chemicals, iron, steel, textiles, and foodstuffs. China (14.7%), India (14.7%), Kuwait (7.5%), and Singapore (7.1%) are the largest suppliers for Bangladesh.

In 2010 the inflation rate was approximately 8.9% and the exchange rate fluctuated around 69 taka per US dollar. Foreign investments totaled US\$653 million in 2007 (The World Bank, 2009). During the same year, the total external debt stocks were approximately US\$ 22 billion.

II.3.5 Technology and Communications

The use of cell phones has been increasing rapidly in recent years and currently there are approximately 50 million cellular phones in use (CIA, 2011a). More people use mobile phones than fixed telephone lines. There are 15 television broadcast stations (1999 est.) and 68,224 internet hosts. Only a small percentage of the population (0.39%) uses the internet.

II.3.6 Poverty

Bangladesh is one of the world's poorest countries with 40% of its people living below the poverty line (CIA, 2011a). Since the livelihoods of most of the population depend on agriculture they are susceptible to low incomes during times of bad weather. About 20% of rural households live in extreme poverty with little land to cultivate in hopes of producing food or generating money (IFAD, 2007). Women are frequently hindered by poverty more so than men because of labor discrimination and inadequate nutrition. It has been determined that there are a disproportionate number of households headed by women who remain extremely poor (IFAD, 2007).

The extremely impoverished population is also vulnerable to sanitation problems which can lead to disease and health issues. Eighty percent of the country has access to improved water sources (PRB, 2010) and only 44% of the population uses adequate sanitation (1999 est.). Forty-

three percent of children under the age of 5 are underweight and 30% of the entire population is considered malnourished (2004 est.).

The extreme and unpredictable weather can be blamed for some of the vulnerability of Bangladeshi people. Flooding in rural areas destroys crops and homes and along with them, the livelihood of millions. In addition, the high pressure on the land creates erosion problems that only contribute to the detrimental flooding. Food security, unpredictable incomes, and a lack of adequate institutions also contribute to the issue of poverty throughout the country. Since 1990, Bangladesh has made progress by reducing the number of people living under the poverty line by 1% per year.

II.3.7 Agricultural Overview

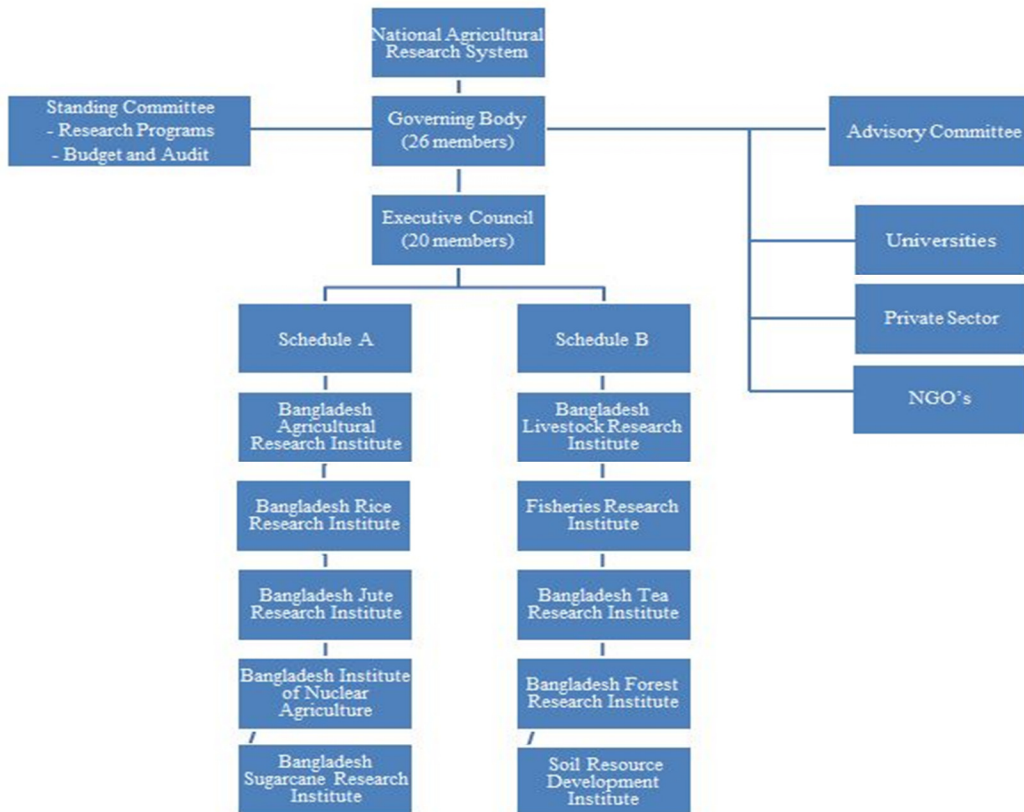
Agriculture is the lifeline for the majority of Bangladeshi people. There are 14.7 million agricultural households, which is about 51% of the total number of households in Bangladesh (Bangladesh, 2008). Although this number has increased since 1983, the percentage of agricultural households has been decreasing as more people migrate to urban centers. However, it is not only rural landowners who depend on agriculture. Nearly two-thirds of the workforce depends on agriculture as an income source (including wages) or for subsistence farming, and every person in Bangladesh depends on the success of agriculture to provide affordable food for the growing population.

Although agricultural production is extremely susceptible to flood damage, farmers have been able to increase the food grain production significantly through improved irrigation, fertilizer use, and rural credit networks. Total food grain production in Bangladesh rose from 10 million tons in 1971 to over 31.3 million tons in 2006 (Bangladesh, 2002a). The country produces a cereal yield of 3,816 kg/hectare. Rice is the principle crop with 28.1 million metric tons produced (Bangladesh, 2007). Despite increased agricultural production Bangladesh must still import some food products which comprise of 15.6% of all merchandise imports (IFAD, 2007).

II.3.8 National Agricultural Research System

The Bangladesh Ministry of Agriculture (MoA) established the National Agricultural Research System (NARS) as the umbrella organization under which agricultural research is conducted by public and private groups (Bangladesh, 2002b). Figure 2.2 depicts the organizational hierarchy of NARS. The Bangladesh Agricultural Research Council (BARC) is the apex of the system and works to coordinate research efforts and encourage collaboration and resource integration among agricultural research teams. A governing body of 26 members headed by the Minister of Agriculture establishes the policies that guide BARC when are then relayed to the Executive Council that oversees ten agricultural research institutes. Universities, private sector firms, and NGO's are also integrated in the research system and often collaborate directly with BARC or with the agricultural institutes.

Figure 2.2: Organization of NARS



Source: Adapted from www.barc.gov.bd

II.3.9 Agricultural Extension and IPM

During a 2010 research trip, quantitative and qualitative data were collected regarding the extension of IPM information. Unless otherwise cited, the information in the following sections was collected during meetings with representatives from public and private extension organizations.

In Bangladesh, agricultural extension responsibilities are shared by both the private and public sectors. The public sector, namely the Department of Agricultural Extension (DAE), serves as the primary source for production and market information for farmers. The production practices and information that they provide to farmers is developed by Bangladesh research centers and universities, as well as international partners. The Bangladesh Agricultural Research Institute (BARI) and the Bangladesh Rice Research Institute (BRRI) develop effective IPM practices. The DAE works closely with BARI and BRRI scientists to develop extension programs that will provide farmers with the most up-to-date information about production technologies. Additionally, the DAE provides market information by announcing the daily prices for a range of agricultural goods. Numerous NGO's assist in the effort by targeting groups of farmers and providing more specific information based on the group's individual goals. For example, in Bangladesh, the Mennonite Central Committee (MCC) works closely with BARI to teach farmers about IPM. They specifically concentrate on vegetable IPM and have helped to establish other local NGO's as input suppliers selling IPM products.

Department of Agricultural Extension (DAE)

The DAE is divided into two parts, the Agricultural Information Service (AIS) and the Agricultural Extension Component (AEC). The AIS manages the mass media communication across Bangladesh using both paper and electronic media to reach farmers. The AEC, on the other hand, is involved with interpersonal types of communication, such as field days, extension agent visits, and farmer field schools.

The AIS extends agricultural information using paper media in the forms of magazines, newspapers, pamphlets, and books. In 1941 a major agricultural magazine called "Krishikatha" was established for farmers. It has grown substantially and currently there are approximately 45,000 magazines distributed monthly across the country, including 40,000 direct subscriptions.

The magazines cost 15-20 taka (~\$0.25 USD) to produce, but are subsidized for farmers. A farmer subscription can be purchased for 40 taka (~\$0.58 USD) per year or the farmer can purchase the magazines monthly at a rate of 4 taka (~\$0.06 USD). Agricultural newsletters are also printed regularly, however they target agricultural officials instead of farmers and only 1,000 are distributed each month. Periodically books and pamphlets are produced regarding a specific crop or new technology. Pamphlets are more commonly distributed to farmers while the books are used as reference material for extension officers and highly educated farmers. Between 20,000 and 30,000 pamphlets are printed for a particular topic at an average cost of 5 taka (~\$0.07 USD) each. These pamphlets are free to farmers and are usually distributed over the course of two years when a farmer requests additional information about a crop or practice. Rarely are the pamphlets widely distributed to farmers at one time.

The use of electronic media is growing rapidly as an increasing number of farmers have access to radios, televisions, and cell phones. Television has surpassed radio communications as the primary electronic source of agricultural information. Agricultural news is televised daily from the major news broadcast stations. Additionally, the DAE began broadcasting an agricultural TV program in 1978 called *Mati O Manush*, directly translated, “Earth and Man.” A new program airs each week at six different times and focuses on a particular issue faced by farmers. Pest management is a common issue for the program and IPM techniques are often discussed. Between March and July, IPM was the primary focus in 15 out of 53 episodes. The total budget for a 25 minute broadcast is 25,000 taka (~\$362.32 USD).

The National Agricultural Radio Program was established in 1966 and now encompasses ten regional radio stations. The stations are run by the Ministry of Information but are staffed by DAE personnel. The Ministry of Agriculture has a committee that coordinates the radio broadcasts. The committee tries to be proactive with current issues; however, to avoid exposing farmers to risky technologies they tend to promote proven technologies instead of dedicating time to new practices.

Increasing internet access is also changing the extension system. Recently, AIS launched a new website, www.ais.gov.bd, which provides production and market information to farmers. Additionally in the last two years, AIS has been working with the Danish Government on a

project to establish Agricultural Information and Communication Centers (AICC) in rural areas of Bangladesh. An AICC consists of a television, phone, computer, fax machine, printer, and internet modem. IPM clubs and other farmer organizations are being targeted as recipients of these facilities. Currently, 20 information centers have been established with the goal of setting up 200 additional AICC's in the next two years.

Recently, AIS received the prestigious Bangabondhu National Agriculture Award for their extension activities using mass media. They were specifically commended for their creative use of information technology, "e-agriculture," documentary films, and video conferences with farmers.

Concentrating on more interpersonal communication channels, the AEC focuses on providing hands-on IPM training to farmers. Currently there are approximately 12,640 extension agents, known as Sub Assistant Agricultural Officers (SAAO). One SAAO serves 6-7 villages or about 900 farm households. Officers visit farmers directly and also offer short course trainings to approximately 1,200 leading farmers throughout the year. By selecting successful, influential farmers to participate in trainings the AEC hopes that the trained farmers will return to their villages and share the information that they learned with others through informal diffusion. SAAO officers reached approximately 11 million farmer households per year. The average salary of an SAAO officer is approximately USD \$3,200 per year.

Farmer field schools can be led by agricultural officers or leader farmers. In 2009, the AEC conducted 2,313 FFS. The FFS model in Bangladesh has evolved over the past several years to include gender specific trainings. Twenty-five households are represented in each FFS by one male and one female participant. The farmers attend both joint and gender-specific sessions throughout a growing season. Rice technologies are targeted towards men while vegetable technologies are aimed at women. Although the basic curriculum is established by the AEC, each group has the opportunity to customize the FFS based on problems they are facing and specific needs of the participants. FFS cover a wide range of production topics. Due to its importance in production, pest management comprises about 25% of the total FFS curriculum.

Field days are held in conjunction with the ceremonial graduation of each FFS group. Community officials and other farmers are invited to celebrate the conclusion of each FFS and

view the IPM plots that were maintained throughout the growing season. Ranging in size from 50-500 people, field days provide the AEC with an opportunity to reach a large number of farmers and show them examples of how the agricultural technologies have been successful through demonstrations.

II.3.10 IPM Clubs

Currently there are over 16,000 IPM clubs across Bangladesh like the one shown in Figure 2.3. During a FFS the farmers are encouraged to form an IPM club that will continue to function after the participants have graduated from the FFS. A club is eligible to apply for government support and they are often targeted by extension agents so that an agent can share agricultural information with many farmers at once. The clubs range in size but are usually have around 50-100 members.

Figure 2.3: IPM Club and AICC in Bangladesh



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II.3.11 Private Sector

Private sector NGO's and businesses also work diligently to extend IPM information to farmers. NGO's such as the Mennonite Central Committee (MCC) and Grameen Krishak Shahauk Shangtha (GKSS) conduct trainings and field days to teach IPM practices. Additionally, companies such as Ispahani and Safe Agriculture Bangladesh Ltd. (SABL) extend IPM technologies through advertisements and training to promote sales. Both the NGO's and input suppliers frequently work with BARI and BRRI to develop the most effective practices.

Mennonite Central Committee

The Mennonite Central Committee (MCC) is an international NGO dedicated to addressing basic needs and promoting peace. MCC began working in Bangladesh in 1970 (MCC, 2009). Through the Research and Extension Activity Partners (REAP) Project they work with local partner organizations to promote sustainable rural development.

Collaborating with 13 local NGO's, MCC actively disseminates IPM information to over 10,000 farmers each year through mass media channels, demonstrations, and field days. During 2009-2010 MCC carried out 119 demonstrations in five districts focusing on seven IPM practices for vegetable crops. MCC has also been instrumental in supporting the growth of smaller NGO's such as GKSS.

Grameen Krishak Shahauk Shangtha

Grameen Krishak Shahauk Shangtha (GKSS) (translated as the Rural Farmer Assistance Committee) is a local NGO that works with MCC and BARI to produce compost materials to sell to farmers while providing valuable agricultural extension services. The organization began small scale production in 2008 and was established as a large scale compost producer in 2009. They currently sell three products – vermicompost, Tricho-compost, and Tricho-leachate – to farmer, retailers, and government agricultural programs. GKSS has produced over 62 tons of Tricho-compost, an organic fertilizer developed by IPM CRSP-BARI (see Section II.3.13). Compared to the previous year, sales in 2010 have continued to increase and they have been producing about 15 metric tons of Tricho-compost each month. Additionally, GKSS produces about 1.5 metric tons of Tricho-leachate (trade named "Tricho-Power") on a monthly basis. Tricho-compost and Tricho-leachate are then sold to farmers for 15tk/kg and 60tk/100ml, respectively.

Information about these technologies is disseminated to farmers through media and interpersonal activities. GKSS uses print media in two daily newspapers – The Daily Jonokantha and The Daily Karotowa – and they advertise the technologies on two television channels – Baishakhi Channel and ATN Bangla Channel. The organization also works to train farmers about organic fertilizers and encourages the adoption of these practices through farmer field days, yard meetings, field demonstrations, and short-course trainings that have reached over 2000 farmers. Additionally, they hold technical orientation courses for DAE SAAO extension agents.

Ispahani Biotech

Ispahani has been operating in South Asia since 1820 across a number of sectors including tea, food products, textiles, jute, poultry and transportation (Ispahani Biotech, 2010). In 2007, Ispahani expanded into the agricultural sector by establishing Ispahani Seeds and Ispahani Biotech. While the former concentrated on providing farmers with high quality seed inputs, Ispahani Biotech was established to research environmentally friendly agricultural technologies, such as IPM.

Since April 2009, Ispahani Biotech has been commercially selling biopesticides, pheromones, and bio-control agents. The company sells three main types of pheromones: “jhilik” targeting cucurbit fruit flies, “chamak” targeting eggplant fruit and shoot borer, and “mukti” targeting fruit flies. Additionally, they market four beneficial insects: Trichogramma, Bracon, Lady Bird Beetles, and Green Lace Wings. Although commercial production was only established two years ago, Ispahani has experienced an exponential increase in product demand from farmers. Sales from the first six months of 2010 were over 4.2 million taka (~\$60,870) – three times higher than the total sales from 2009.

Ispahani collaborates with government and NGO’s to research IPM technologies and reach farmers with information about new products and practices. Ispahani Biotech currently works with BARI to develop effective IPM tools and hopes to build a similar relationship with the DAE, BRRI, and the Bangladesh Agricultural University.

Recently the government of Bangladesh officially approved the registration of biopesticides and pheromones making it easier to import and sell these products. Ispahani is now working to establish more marketing activities including print and electronic media

advertisements, workshops, training programs, and participation at agricultural fairs across the country. Ispahani hopes that by making the farmers aware of new technologies and showing the effectiveness of IPM they can encourage more widespread IPM adoption, both to provide a market for their products and to encourage more sustainable and healthy production methods.

Safe Agriculture Bangladesh Ltd.

Established in 2005, Safe Agriculture Bangladesh Limited (SABL) is a commercial provider of bio-control agents and pheromones. They collaborate with BARI and local NGO's to target their products to farmers' needs and to educate farmers about their products. The company prints advertisements in local papers as well as distributing leaflets, posters, and banners throughout the country. Additionally, SABL organizes multimedia field programs where they use a projector and screen to play a video made in cooperation with Mati O Manush. In 2009, approximately 250,000 farmers were reached using these media methods at an average cost of four taka per farmer (~\$0.06). With the approval of a formalized registration process for pheromones the company is planning to scale up their awareness campaign by running advertisements on the Bangladesh TV (BTV) channel, using more mass media, and strengthening their relationships with organizations that are involved with IPM across the country.

Currently SABL sells four bio-control agents: Trichogramma, Green Lace Wings, Bracon, and Lady Bird Beetles. They also have a line of four pheromone lures suited to control pests that feed on fruits, vegetables, and rice: Cuelure, Leucinodes orbonalis, Scirpophaga incertulas, and Bactrocera dorsalis. In the future, the company hopes to expand their line of products to include more biological controls and bio-fertilizers. In the first six months of 2010, the company made over 4.7 million taka in sales (~\$68,116) – almost three times the amount of sales from 2009.

II.3.12 Pesticide Use

From 1974 – 1979 the Government of Bangladesh provided farmers with a 50% subsidy on pesticides (Bangladesh, 2002a). Although pesticide usage initially declined after this policy was revoked in 1979, the use of pesticides has increased consistently during the past three

decades. During the period from 1997-2008, pesticide consumption increased 328.4% across Bangladesh and per hectare pesticide application increased by almost 600% (Ispahani Biotech, 2010). In 2008, over 48,000 metric tons of pesticides were consumed. Although the majority of total pesticides is applied on rice because of its extensive production, vegetables receive the highest amount of pesticide per application and the highest application frequency (Ispahani Biotech, 2010).

Figure 2.4: Farmer applying pesticides to field in Bangladesh



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According to a 2010 survey, non-IPM farmers applied pesticides as many as 25 times on eggplant, 20 times on tomato, and 18 times on cucurbit crops (Muniappan, 2010). Pesticide applications often contribute up to 35% of total production costs for fruits and vegetables (Karim, 2009). Furthermore, vegetables are not processed like rice; therefore, pesticide residues pose a greater danger to families consuming chemical-treated produce.

II.3.13 IPM Technologies

Incorporating IPM into a production system involves adopting a sustainable and environment-friendly management strategy to reduce pests. The strategy usually involves incorporating several methods for maximum pest control. For each crop an IPM package has been designed to most effectively control for a variety of pests. These methods vary in complexity, cost, and associated risk. Additionally, the technologies differ between regions. When a farmer is introduced to IPM, the entire package is usually described. Often the farmer will test the feasibility of IPM by adopting the simplest practice, which is usually the less risky than more complex practices. If the simple technologies are effective and profitable, the farmer may adopt increasingly complex technologies and eventually incorporate the entire package into his production activities.

Soil Amendments

Environments with high temperatures and humidity are prime locations for soil-borne fungal pathogens (Rahman et al., 2004). Pathogens infect seedlings and result in diseases such as foot rot, damping off, and stem rot that may destroy the plant or severely stunt its growth. Several additives can be applied to the soil to help control these diseases. Poultry refuse (PR) and mustard oil cake (MOC) are two commonly used soil amendments that greatly reduce the damage caused by soil-borne pathogens.

Poultry refuse, applied at the rate of 3-5 tons per hectare, releases organic acids that kill soil-inhabiting pathogens and improve the fertility of the soil (Rahman et al., 2004). Mustard oil cake works in the same manner and should be applied at a rate of 300-500 kilograms per hectare. Both treatments should be applied to the seedbed at least three weeks before planting. Field trials have shown that farmers applying PR and MOC can obtain yields that are 1.5 times higher than using traditional controls such as cow dung.

Tricho-Compost

Many scientists would classify Tricho-compost as a type of soil amendment; however, because the compost is formulated with *Trichoderma harzianum*, a type of fungi that inhabits soil, it is differentiated in this study. Tricho-compost is composed of set proportions of eight key ingredients: cow dung, molasses, maize bran, sawdust, poultry refuse, water hyacinth, ash, and a

Trichoderma harzianum spore suspension mixture. After combining the first seven ingredients, the compost is sprayed with a liquid Trichoderma solution and mixed. The compost is stored in cement structures to decompose for 35-50 days. As decomposition takes place a liquid leachate, known as Tricho-leachate, runs down the sides of the compost house and is collected. The leachate can be sold to farmers and sprayed on the fields or it can be used to add *Trichoderma harzianum* to another batch of compost.

Figure 2.5: Tricho-compost and Tricho-leachate Production



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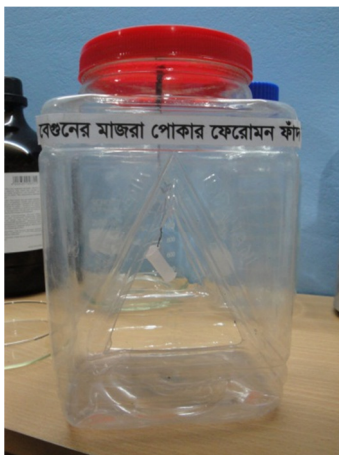
The compost is sun dried and bagged for sale. The recommended application rate is three metric tons per hectare. Farmers can buy Tricho-compost for 15tk/kg (~\$0.22 USD) and purchase Tricho-leachate (trade name = Tricho Power) for 60tk/100ml (~\$0.87 USD). In field trials, the application of Tricho-compost on tomatoes reduced root knot nematode (RKN) infestations by 46% to 63% and decreased the number of plant-feeding nematodes by 34% to 67%. Furthermore, the average yields of treated plots increased by 16.4% to 25.3% (Muniappan et al., 2010). When applied to eggplant the yield increased from 22.5% to 35.6% and reduced the number of harmful nematodes by 31% to 71%.

Pheromone Traps

Pheromone traps are commonly used in cucurbit and eggplant production. Figure 2.6a shows a pheromone trap that was constructed by cutting a triangular opening in opposite sides of a container, filling the bottom of the container with 2 inches of soapy water, and attaching a sex pheromone lure so that it hangs in the center of the opening. Synthetic sex pheromones have proven to be highly effective at attracting fruit flies and other insects which then enter the trap and drown in the soapy water (Nasiruddin et al., 2004). Various hormones may be used in the trap depending on its purpose. ‘Cuelure’ is a synthetic sex pheromone that attracts the male fruit flies. Although other attractants have been used in the past, such as mashed sweet gourd (MSG), synthetic hormones have proven to be the most effective and manageable lures. Cuelure lures catch up to 18 times more fruit flies than MSG and reducing crop damage by 70% (Steed, 2010).

A single trap can be purchased for 25 taka (~\$0.36 USD), but farmers are encouraged to save money by constructing the trap out of old containers. ESFB lures costs about 20 taka (~\$0.29 USD), should be arranged at a rate of 100 lures per hectare, and should be replaced every 6-8 weeks. Cucurbit fruit fly lures costs 22 taka (~\$0.32 USD), should be applied at a rate of 80 lures per hectare, and last for the entire three month growing season.

Figure 2.6: Pheromone Traps



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(a) Pheromone trap



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(b) Pheromone traps in test plot

Biological Controls

As a component of IPM, biological control involves managing pests with natural enemies (Shelton, 2010). Natural enemies of insect pests are commonly called bio-control agents or beneficial insects, and include predators, parasitoids, and pathogens. When successful, biological controls suppress pest populations below the economic threshold. Although biological controls have been used for decades in the U.S. its use in Bangladesh has been limited. BARI has worked with several private firms to develop a market for biological controls so that farmers can benefit from this method of non-chemical pest control. Trichogramma, Bracon, Green Lace Wig, and Lady Bug Beetles are the most common beneficial insects used in Bangladesh.

Figure 2.7: Mass Rearing of Trichogramma



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Trichogramma are small parasitic wasps that attack over 200 species of moths (Islam, 2010). Trichogramma should be released at a rate of one gram per hectare three times each season for previously treated fields. In the first year of application, Trichogramma should be released five times at 10-15 day intervals. One gram contains about 40,000 to 50,000 Trichogramma and costs approximately 150 taka (~\$2.17 USD).

The larval parasitoid, *Bracon hebetor* feeds on the larvae of many insect pests. *Bracon* should be applied at a rate of 800-1200 insects per hectare and released 4-5 times at 10-15 day intervals throughout the season. A single release costs about 150 taka (~\$2.17 USD).

Green Lace Wing is used as a predator in its larval stage. As the larvae grow they consume small insects including caterpillars, small beetles, leafhoppers, thrips, and small flies. Green Lace Wing should be released five times per season at a rate of 800-1000 eggs. 800 eggs cost approximately 250 taka (~\$3.62 USD).

Lady bugs (*Menochilus sexmaculatus*), also known as Ladybird Beetles, naturally proliferate when farmers stop spraying chemical pesticides, thus resulting in a relatively low market demand. However, if natural populations are inadequate for pest control, farmers can purchase lady bugs from companies that sell other beneficial insects. It is recommended that 225 pairs of beetles be released per hectare at a cost of 550 taka (~\$7.97 USD).

Grafting

Grafting is used to control bacterial wilt (BW) and root-knot nematode (RKN), two soil-borne diseases affecting eggplant and tomato crops. Eggplant grafting technology was first developed by the Asian Vegetable Research and Development Center (AVRDC) in Taiwan, but has been transferred throughout Asia (Karim et al., 2003). Grafting involves removing the roots of a high yielding eggplant or tomato seedling and securing a bacterial wilt resistant wild eggplant rootstock, *Solanum sisymbriifolium* or *Solanum torvum* (Rashid et al., 2007). The new rootstock is taped or clipped into place and the seedling is housed in a humid environment for 7-10 days before being transplanted in the field. The wild rootstock protects against the disease, reduces crop loss by 90%, and produces yields that are 2-3 times higher than non-grafted plants.

Figure 2.8: Grafted seedlings in nursery



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Resistant Varieties

Crop geneticists have developed plant lines that are resistant to a range of different pests including both disease and insect pests. Planting resistant rice varieties is one of the simplest and most effective methods to prevent crop loss due to problems such as rice blast, bacterial blight, sheath blight, tungro, and major insect pests.

Several eggplant and tomato lines have been tested for resistance to FSB, jassids, red spider mites, bacterial wilt, and RKN (Muniappan et al., 2010). In cucurbits, varieties have been selected for their resistance to viruses such as Watermelon Mosaic Virus, Cucumber Green Mottle Mosaic Virus, and Papaya Ring Spot Virus. The specific varieties used for each crop vary by location. The IPM CRSP Annual Report for 2010 provides detailed information about the resistant lines that were tested in Bangladesh and Nepal.

Perching

Natural predators can be very effective at controlling pests and are frequently incorporated into IPM systems. Perching is a strategy used in rice production in which branches are placed in and around rice paddies to encourage birds to inhabit the area and consume insects that may infest the rice crop. Results from field experiments have varied with some trials indicating that perching decreased crop damage twofold and others showing no effect (Wahiduzzaman et al., 1997). However, many farmers insist that the practice is effective and

with low input costs and management demands it is a simple practice for farmers to incorporate in production.

II.3.14 Information on Selected Crops Grown in Bangladesh

This study focuses on the impact of IPM technology dissemination with four crops: eggplant, cucurbits, tomatoes, and rice. Although there are many other crops that contribute to agricultural production, these four are critical to the diets of Bangladeshi people and have been a focus of recent IPM research. Appendix Table C.2 presents national-level market information for the four crops. This study could be expanded upon by incorporating cabbage, beans, and potatoes into the model.

Eggplant

Commonly called brinjal, eggplant is a staple vegetable crop for Bangladeshi people. The vegetable is grown in both the summer and winter planting seasons on nearly 47,000 hectares across the country (Karim, 2009). The national average production per hectare is seven tons but yields for intensive production are often considerably higher. In the winter growing season, eggplant is planted in September and harvested in February. In the summer, eggplant is sown in February or March and harvested in August or September, depending on the climate. Summer yields are generally lower than those in the winter averaging 6422 kg/ha and 7410 kg/ha, respectively (Karim, 2009). Approximately 335,500 metric tons of eggplants are produced annually with an average price of 12.5 taka per kilogram (Bangladesh, 2007, 2010).

The most detrimental pest problems for eggplant include fruit and shoot borer (EFSB), root knot nematode (RKN), and bacterial wilt (BW). Commonly, farmers use pesticides to control for disease by spraying the plants weekly throughout the 5-6 month growing season. One liter of chemical pesticide is used per application at a cost of about 500 taka (~\$7.25 USD).

IPM technologies can provide pest control without high applications of chemicals providing both monetary and health benefits to the farmer. The typical IPM package for eggplant includes using soil amendments, Tricho-compost, pheromone traps, biological controls, and grafting. After farmers are aware of the various techniques they can tailor the practices to suit their production system. In the future resistant varieties may also play a key role in pest control.

BARI continues to conduct research on resistant varieties of eggplant; however, they are not yet widely available to farmers.

Tomato

Tomatoes are grown on nearly 21,000 hectares across Bangladesh in both the winter and summer planting seasons. Winter tomatoes are planted in October and harvested in February or March and account for over 95% of total annual production (Karim, 2009). Summer tomatoes are planted in May and harvested in September or October. Often the summer crop is grown under plastic tunnels to protect it from the heavy rains. The average national yields are approximately 7,170 kg/hectare, but can be significantly higher for individual farmers who grow tomatoes intensively. Field test plots have reported winter yields of over 30,000 kg/ha (HRC, 2010). Approximately 140,000 metric tons of tomatoes are produced annually and are sold for an average price of 18 Taka per kilogram (Bangladesh, 2007, 2010).

Pest problems occur in both growing seasons, but are exacerbated in the summer with hot, humid temperatures. Hook and root rot, BW, and RKN are common problems. Chemical pesticides are often sought as a remedy for pest problems but are unable to effectively control pests, resulting in high chemical application rates with little success. IPM technologies including soil amendments, Tricho-compost, and grafting are often more effective at regulating pests and cheaper for the farmer. Currently, BARI is working to develop resistant tomato varieties and effective biological controls – these technologies may complement the current IPM package in the near future.

Cucurbits

Cucurbits include all of the plants in the Cucurbitaceae family which encompasses gourds and melons. The predominate cucurbits (local names are in parentheses) grown in Bangladesh are cucumbers (Sosha), bitter gourds (Karala), water gourds (Chalcumra), pointed gourds (Patal/Patol), ribbed gourd (Jhinga), snake gourd (Chichinga), pumpkin, white pumpkin, short cucumbers (Khirai), teasle gourd (Kakrol), and bottle gourds (Lao). The national aggregate production of these cucurbits is about 608,400 metric tons annually (Bangladesh, 2009). The different types of cucurbits vary in price from 8 to 15 taka per kilogram with an average price of 10 taka (Bangladesh, 2010).

Fruit flies are a major pest problem for cucurbits, infecting all 15 types of cucurbit vegetables (Nasiruddin et al., 2004). The female flies insert their eggs into the fruits which then hatch and the insects feed on the fruits, making them unsuitable for human consumption. Pesticides are often sprayed at a cost of 30,000-40,000 taka (~\$507.25 USD) per hectare per season and can account for nearly 25% of production costs. IPM technologies can reduce the cost of pest control. Soil amendments, Tricho-Compost, biological controls, and pheromone traps comprise the basic IPM package for cucurbits. Two resistant pumpkin varieties have been developed at BARI and will hopefully be available for widespread use in upcoming years.

Rice

Rice is the primary staple crop for Bangladeshis. Approximately 10.8 million hectares, accounting for 75% of all agricultural land, are cultivated for rice production (Shrestha and Neupane, 2002). There are three rice seasons, Boro, Aus, and Aman. About 58% of the total production (in metric tons) is Boro rice. Aman and Aus rice account for around 36% and 6% of annual production, respectively. Per hectare yields differ significantly across the three seasons. The national rice yield for Boro, Aman, and Aus rice is 3685, 1958, and 1655 kilograms per hectare, respectively (Karim, 2009). Approximately 28.1 million metric tons of rice are produced annually throughout Bangladesh at an average price of 16 taka per kilogram (Bangladesh, 2007, 2010).

Over 75 different rice pest problems have been identified and approximately 25 have been classified as important because of the danger to production. Of all of the pesticides used in Bangladesh, about 80% are applied to rice. Worldwide, 12% of all pesticides sold are applied to rice making rice farmers targets for agricultural marketing and promotions (Matteson, 2000).

Many different IPM practices have been tested with varying results. Light traps, perching, handpicking, roughing, biological controls, and resistant varieties have all been used and disseminated to farmers. Currently the primary IPM package being taught to farmers includes using resistant varieties, perching, and biological controls using natural pest predators. The other IPM methods may still be used depending on the individual farmer's knowledge and production practices.

II.4 Nepal

II.4.1 Introduction

Located north-west of Bangladesh, Nepal is situated between China and India as depicted in Figure 2.9. World renowned for the Himalayan Mountains, Nepal has become a tourist destination for outdoor enthusiasts from around the globe. However, in contrast to the beautiful landscapes, many Nepalese people face a much less glamorous life, wrought with poverty and political instability. Between 1970 and 2007 Nepal's Human Development Index (HDI), which measures overall well-being based on health, education, and income, increased by 2.4% annually (Human Development Index, 2009b). Currently Nepal is ranked 138th (out of 182 countries) in the HDI rankings.

Figure 2.9: Map of Nepal



Source: CIA World Fact Book, 2011

(a) Location of Nepal



Source: CIA World Fact Book, 2011

(b) Map of Nepal

II.4.2 Geography

Covering an area of 147,181 km², Nepal comparable in size to the state of Arkansas and contains three distinct geographic regions. Bordering India, the southern portion of the country is referred to as the Terai region and is characterized by flat river plains. Moving north, the central region is increasingly hilly and mountainous. The northern portion of the country attracts the most attention from tourists as it is home to the Himalayan Mountains. Eight of the world's ten highest peaks are located in Nepal, including the world's tallest peak, Mount Everest.

The climate varies across the three distinct regions. Cool summers and harsh winters characterize the northern region, while the southern areas encounter subtropical summers and mild winters (CIA, 2011b).

II.4.3 Demographics and Culture

The population of Nepal is nearing 29.4 million people with an annual growth rate of 1.4% (CIA, 2011b) despite net out migration. The average fertility rate is 2.5 children born per woman and the declining infant mortality rate is 45 deaths per 1000 births. Nineteen percent of the population lives in urban areas. The population density is 200 people per square kilometer, significantly lower than that of Bangladesh.

Over eighty percent of the population follows the Hindu faith, with Buddhist, Muslim, and Kirant minorities (CIA, 2011b). A powerful caste system also exists throughout the country. Four primary castes exist in the status hierarchy: Brahman, Kshatriya, Vaisya, and Sudra (Shrestha and Neupane, 2002). Sometimes the fourfold system is expanded to include a fifth caste known as the Dalits, commonly called the “Untouchables.” The caste system determines social, economic, religious, and political expectations. Furthermore, it sometimes limits access to land, credit, and other resources.

Nepali is the official language across the country, but many other languages are practiced depending on the region. Historically, access to education was a privilege that was reserved for people of higher castes and economic status (Shrestha and Neupane, 2002), but since the mid 1950’s Nepal has made a conscious effort to support national education. Literacy rates have improved drastically since a 5% literacy rate was estimated in 1950; however, a 2001 census estimated that over half of the adult population was still illiterate (CIA, 2011b).

II.4.4 Economy

In 2009, Nepal had a GDP of \$15.1 billion (CIA, 2011b). The services, agriculture, and industry sectors contributed 52%, 33%, and 15% to the total GDP, respectively. Prominent industries include tourism, carpets, and textiles. Each year Nepal imports products valued at \$5.26 billion; the majority of the imports are purchased from India and China. Although Nepal is

a net importer several commodities are produced for the export market including clothing, pulses, carpets, and textiles. Major importers of Nepalese goods include India, the U.S., Bangladesh, and Germany.

Unemployment is a major concern as over 46% of the population lack jobs (CIA, 2011b). Many Nepalese workers seek work abroad to boost their family's income. In recent years, remittances from overseas workers have helped to reduce the poverty level in Nepal; however, the rate of out-migration and the flow of workers to other countries has also raised concern about the workforce that will be available in the future (Colavito, 2010).

II.4.5 Agricultural Overview

The agricultural sector accounts for 33% of the GDP and employs over three-fourths of the population (Shrestha and Neupane, 2002). Primary agricultural products include pulses, rice, corn, wheat, sugarcane, jute, and root crops. There are approximately 5.75 million acres of land under cultivation of which 78% is devoted to only four crops: rice, maize, wheat, and millet.

The per capita availability of land has been declining and in recent years food deficits have become common especially in the hilly and secluded areas of the country (Shrestha and Neupane, 2002). Although to a lesser extent, land availability is even a problem in the Terai region, home to 60% of the country's cultivated land. Currently the average land holding is approximately 0.7 hectares with 50% of landowners having less than 0.5 hectare (Colavito, 2010). Poor road infrastructure and limited market access also constrain growth of the agricultural sector.

Most Nepalese farmers are considered smallholders and focus on subsistence-level farming. Typically smallholders maintain a level of productivity that is below regional levels due to a lack of appropriate technologies and quality inputs (Colavito, 2010). In addition to crop production, many farmers are involved in animal husbandry (Shrestha and Neupane, 2002). The benefits of raising livestock and poultry are threefold as they provide manure for crop production, can be sold to supplement household income, and provide additional protein for the household diet.

II.4.6 Communication

The communications sector in Nepal has improved dramatically since the 1980's. In 2009, over 7.6 million people had mobile phones and there were over 577,000 internet users (CIA, 2011b). The government operates two television stations and multiple national and regional radio stations. Additionally, there are over 60 independent radio stations and a growing number of independent television stations.

II.4.7 Poverty

Despite a recent decline in urban poverty, the widespread occurrence of rural poverty is a growing issue (IFAD, 2009). Over eighty percent of the population live in rural areas and primarily rely on subsistence farming. It is estimated that over 35% of rural households live below the poverty line (Colavito, 2010). Lacking access to markets many rural households consume only a few staple crops and subsequently suffer from inadequate nutrition. Furthermore, these households often have little access to social services such as health care and education, in addition to lacking proper sanitation services and access to clean drinking water.

The range of ethnic groups coupled with the presence of a strong caste system compound poverty issues and make it difficult for households to change their economic condition. People in the lowest caste (Dalits) along with the elderly, disabled, and sick are very likely to be among the poorest people in the country (IFAD, 2009). Additionally, inhabitants of steep, mountainous areas are often isolated in poverty because of the lack of accessible roads and weak communication infrastructure.

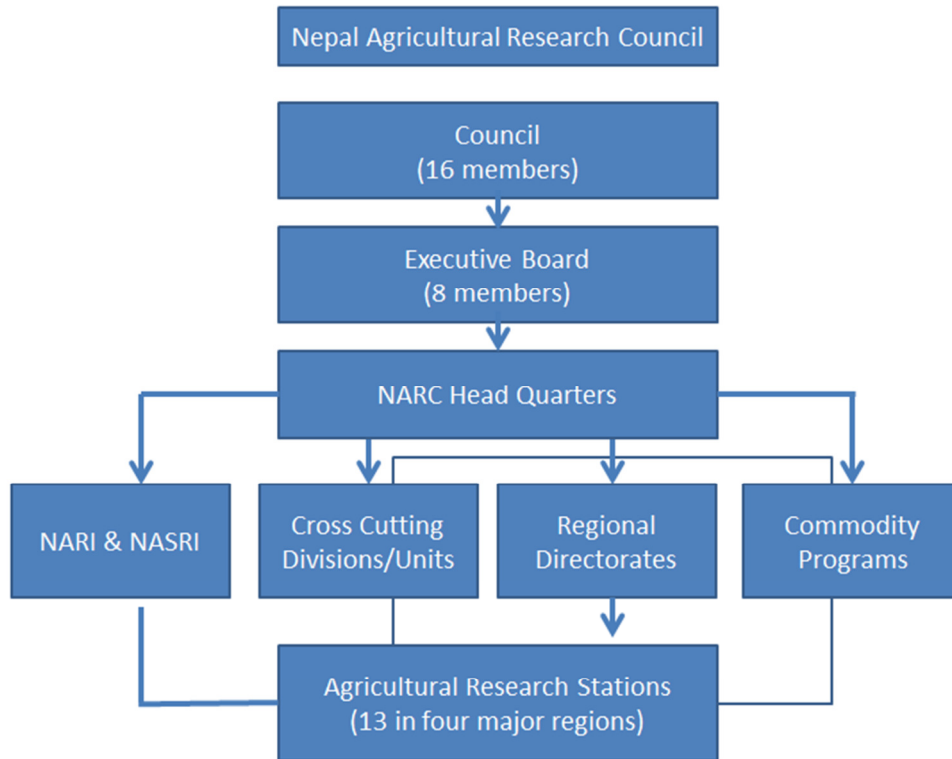
II.4.8 Agricultural Extension System and IPM

Nepal Agricultural Research Council

In 1991, the Nepal Agricultural Research Council (NARC) was established as an autonomous organization to conduct agricultural research across the country (NARC). NARC coordinates with private organizations to generate new and improves technologies, including IPM technologies.

Although NARC institutions strive to develop agricultural technologies for farmers, the group of technologies is relatively small when compared to the need for appropriate technologies across diverse agro-climatic zones throughout the country (Gauchan et al., 2003).

Figure 2.10: Organization of NARC



Source: Adapted from <http://www.narc.org.np>

Department of Agriculture

The Department of Agriculture functions as one of five departments under the Ministry of Agricultural and Cooperatives (MOAC). Nepal is divided into three agro-ecological zones and five development regions. Each region has its own Directorate of Agriculture, Seed Laboratory, Soil Testing Laboratory, Crop Protection Laboratory, Plant Quarantine Office and Agricultural Training Center. Additionally, there are 75 District Agriculture Development Offices (DADO) and 378 Agricultural Service Centers (ASC) located throughout the country.

The Directorate of Agricultural Training (DAT) leads the five regional training centers and annually hosts 12 training courses for DOA officers. However, only about 10% of households are in contact with government sponsored extension services (Colavito, 2010).

Agriculture Information and Communication Center

Previously known as the Agricultural Information Section and the Agricultural Communication Division, the Agricultural Information and Communication Center (AICC) was renamed in 2000 and recognized as one of the central units of the MOAC (AICC, 2010). The AICC is responsible for producing agricultural information for farmers, traders, and entrepreneurs and communicating the information through radio, television, print, and the internet. The organization is driven by the goal of using information and communication technology (ICT) to facilitate the timely transfer of information to agricultural stakeholders and producers.

The major functions of the AICC are the following:

1. Produce and broadcast farm radio programs and agricultural news.
2. Produce and broadcast video documentaries, agricultural programs, and news from Nepal Television.
3. Publish and distribute bimonthly agricultural magazine, calendar, booklet, and other printed material.
4. Collect, document, and maintain a digital library of agricultural information.
5. Maintain the AICC website.

The AICC is responsible for disseminating a wide range of agricultural information including information about IPM and pest management.

- Print media – The AICC has been publishing *Krishi*, a bimonthly newsletter printed in the local dialect, for over 40 years. Additionally, the AICC prints booklets, leaflets, and calendars that are then distributed to farmers free of charge.
- Farm Radio Program - Radio communication was established in Nepal in 1951 and the AICC has been broadcasting the farm radio program since 1966. It is estimated that there are approximately 2.5 million radio sets throughout the country. Seven 15-minute

programs air each week. Additionally, regional stations and private media companies have also been broadcasting agricultural programs.

- Agriculture Television Program – Nepal Television (NTV) was established in 1984 and currently reaches 65% of the Nepalese population. The station broadcasts daily 20-minute agricultural programs. Since 2004, an additional program airs each Friday entitled, *Agricultural News*.
- Internet media – Computers were introduced in Nepal in 1971 and have become increasingly popular, especially since the availability of the internet in 1994. The widespread use of computers has been relatively slow in rural areas; however an increasing number of people continue to gain access annually. The AICC has developed an online resource where it maintains electronic copies of paper resources such as the Krishi newsletter and other print media. Additionally, statistical reports and announcements are published on the website and available to the general public. Although some materials are printed in English, most booklets, newsletters, and reports are maintained in the local dialect.

International Development Enterprises

International Development Enterprises (IDE) is a multi-national NGO that is committed to fighting poverty and promoting development by empowering the rural poor. The organization aims to promote growth using a market-based development model in which income to the rural poor is increased by improving market access, increasing agricultural productivity, and creating sustainable local businesses (IDE, 2010).

IDE Nepal has been especially committed to disseminating IPM technologies in cooperation with the IPM CRSP and NARC. They concentrate on high-value crops including vegetables, coffee, and tea. Currently, they are committed to disseminating information about bio-fertilizers, bio-pesticides, mulching, and grafting.

Recently, IDE has focused efforts on developing Marketing Planning Committees (MPC) in order to strengthen the role of smallholders in the market. MPC's may play a vital role in the dissemination of agricultural information in the future. MPC's are discussed in more detail in Section II.4.10.

CEAPRED

The Center for Environmental and Agricultural Policy Research, Extension, and Development (CEAPRED) was established in 1991 with a mission to improve the livelihoods for poor and disadvantaged communities, enhance food security, and empower women across Nepal (Center for Environmental and Agricultural Policy Research, 2007). CEAPRED promotes IPM technologies through vegetable FFS and operates an IPM center which tailors training courses to farmer demands.

Caritas

Caritas Nepal is based in Lalitpur and serves 29 districts of Nepal with a goal to empower oppressed and marginalized people (Caritas-Nepal, 2007). In 2005, the NGO began phase one of a three-year IPM program for rice and vegetables. With 23 partner organizations Caritas Nepal conducted 223 FFS in 16 districts, training 6488 farmers. Currently, they are implementing the second phase of the plan which will run until 2012. FFS are still used as the primary instrument to reach farmers, but the program area in which FFS are conducted has expanded to 24 districts across Nepal. The most recent FFS are allocating more time to vegetable IPM because of its impact on household nutrition.

II.4.9 National IPM Program

After a brown plant hopper (BPH) outbreak in 1997, Nepal organized its first IPM program for rice with support from the Food and Agricultural Organization (FAO) (Pokhrel and Saha, 2008). Community IPM programs proliferated between 1998 and 2002. Recognizing the importance of IPM, the government established a Phase 1 of the National IPM Program which operated from 2004 until 2008. The program aimed to strengthen the IPM extension system and to empower farmers through trainings and FFS. The Ministry of Agriculture (MOA) oversaw the program and mobilized the Department of Agriculture, Plant Protection Directorate (PPD), Regional Agricultural Directorates, DADO offices, the National Agricultural Research Council (NARC), NGO's and farmer organizations on national, regional, and district levels. The total program budget for the four year program was USD \$12,965,675 and was funded from the Royal Norwegian Government and other donors. Currently the Nepalese government allocates local

budgets for FFS via the District Agricultural Development Offices and prioritizes the promotion of IPM at the national level. However, more funding is needed to increase farmer awareness about IPM and to decrease the threat of pests and of pesticide use across Nepal.

II.4.10 Role of Marketing and Planning Committees

USAID, IDE, and Winrock International have been working since 2003 to promote the commercialization of smallholder agriculture by helping to develop Marketing Planning Committees (MPC) through which farmers can gain collective power and benefit from a strategic marketing strategy. MPC's allow farmers to aggregate smallholder produce to meet market demand. Several farmer organizations join together and elect representatives to serve on the board of the MPC. With one voice, the MPC strives to develop linkages with government and NGOs working to further agricultural development, gain marketing information, develop community production plans to take advantage of off-season profit opportunities, link farmers with credit and input services, and facilitate farmer trainings regarding improved production technologies (Colavito and Nanes, 2009).

Figure 2.11: MPC Collection Center in Nepal



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Nearly 100 MPC's have been developed to date, representing about 50,000 poor smallholders and benefiting over 300,000 people. The MPC's have developed over 80 collection centers in 15 districts where a variety of produce is collected weekly. Two districts level MPC's

have been formed in Syangja and Palpa. These apex groups are directed by members elected from the local MPC's (Colavito and Nanes, 2009).

One of the fundamental benefits of MPC's is the ability to quickly reach thousands of farmers through social networks. Proponents of MPC's believe that they could be an integral part of the agricultural extension system through cooperation with government and private extension organizations.

CHAPTER III: METHODOLOGY/ EMPIRICAL STRATEGY

III.1 Introduction

Chapter Three presents the methodology used to evaluate the IPM extension activities in Bangladesh and Nepal. Section III.2 describes the empirical strategy that was used to examine IPM extension in Bangladesh. Section III.2.1 describes the framework used to conduct an economic surplus analysis and Section III.2.2 presents the adoption estimates that were used in the analysis. Section III.2.3 presents the calculations of the surplus per dissemination dollar that were used as the decision-making variables in the linear programming (LP) model. The basic structure of the model is described in Section III.2.2 and outlined in Figure 3.2. The framework for the linear programming models is presented in Section III.2.4. Finally, Section III.2.5 describes how the LP model was used to evaluate the economic impact of IPM dissemination.

Section III.3 describes the methodology that was used to evaluate farmer awareness and adoption of IPM technologies in Nepal. Section III.3.2 describes the framework for the binary response model. Section III.3.3 builds on this framework by presenting the probit model framework and is followed by the interpretation of the probit model in Section III.3.4. The issue of endogeneity is presented in Section III.3.5. Section III.3.6 then describes how the bivariate probit model can be used to control for endogeneity. Sections III.3.7 and III.3.8 describe how farmer knowledge and adoption were estimated, respectively.

III.2 Bangladesh

III.2.1 Economic Surplus Model

Increased productivity and input cost reductions drive the economic benefits provided by IPM technologies. Disseminating IPM information and teaching farmers about the technologies is the first step toward adoption. Thus it is assumed that the dissemination budget provides a certain level of economic benefit based on the rate of adoption for a specific practice. These benefits can be measured as changes in total economic surplus resulting from the adoption of IPM practices. The changes are maximized in the linear programming model used in this study. This section will describe the surplus analysis used to estimate the benefits from an IPM program

in Bangladesh based on the economic surplus model employed by Alston, Norton and Pardey (1998).

Assumptions of Model

Several assumptions can be made when constructing an economic surplus model. These assumptions allow the model to estimate the benefits of research based on a downward supply shift (Alston et al., 1998).

The following assumptions were made to construct the surplus model used in this study:

- i. The supply and demand curves are linear and shift in a parallel manner as a result of research-induced technical changes.
- ii. The model is static, dynamic issues are put aside.
- iii. Competitive market clearing is imposed.
- iv. If valid, Harberger's three postulates suggest that surplus measures can be used as welfare measures (Alston et al., 1998).
 - a. The competitive demand price for a given unit measures the value of that unit to the demander.
 - b. The competitive supply price for a given unit measures the value of that unit to the supplier.
 - c. When evaluating the net benefits of costs of research, the costs and benefits accruing to each member of the relevant group should be added without regard to the individual(s) to whom they accrue.
- v. The models in this study reflect four individual commodity markets: eggplant, cucurbits, tomatoes, and rice.
 - a. The cross-price supply and demand elasticities between markets are assumed to equal zero. This assumption suggests that a change in price of one commodity does not affect the supply or demand of another commodity.

- b. The models for the three vegetables are constructed to represent closed economies while the rice model is considered a small, open economy.

Basic Economic Surplus Model

The basic supply and demand model is the foundation for the economic surplus model. Figure 3.1 displays the basic model of technology benefits in a closed economy – the original supply and demand curves are denoted by S_0 and D , respectively. The original supply and demand curves are defined as,

$$\text{Supply (S}_0\text{): } Q_s = \alpha + \beta P$$

$$\text{Demand (D): } Q_d = \gamma - \delta P$$

Where,

P = price of commodity

By algebraically rearranging the equations the curves can be defined as,

$$P = (1/\beta) Q_s - (\alpha / \beta)$$

$$P = (-1/\delta) Q_d + (\gamma / \delta)$$

$(1/\beta)$ = slope of supply curve

$(-1/\delta)$ = slope of demand curve

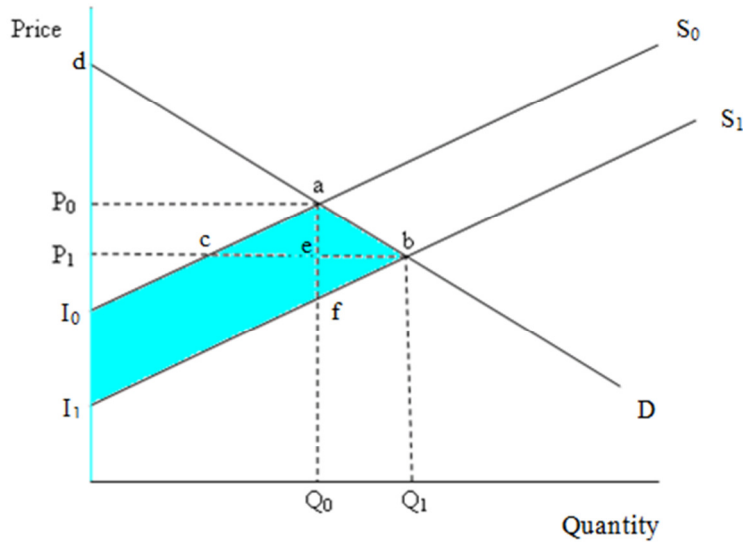
The intersection of the original (pre-research) supply and demand curves determine the equilibrium price (P_0) and quantity (Q_0) of the commodity. This intersection is denoted by point ‘a’ in Figure 3.1. Mathematically the price and quantity of the commodity can be determined by setting the supply and demand equations equal,

$$Q_s = \alpha + \beta P = \gamma - \delta P = Q_d$$

The consumer and producer surpluses can be calculated using Harberger’s three postulates. The original consumer surplus is represented by the triangle, d,a, P_0 , and the producer surplus is represented by P_0 , a, I_0 . The total surplus can be calculated by adding the consumer and producer surpluses and equals the total value of consumption (the area under the demand

curve) minus the total cost of production (the area under the supply curve) (Alston et al., 1998). Total surplus in Figure 3.1 is depicted by the triangular area, d, a, I₀.

Figure 3.1: Economic Surplus Model



Source: Adapted from Alston, Norton, and Pardey, 1998

IPM technologies usually result in a positive change in productivity by increasing crop yields and/or lowering the per unit input costs, thus shifting the supply curve downward from S_0 to S_1 . This proportional supply shift is called the unit cost reduction, K , and is a major determinant of the total benefits resulting from agricultural research (Alston et al., 1998). The size of K depends on the proportionate change in yield and cost resulting from the new IPM technology, as well as, the probability of success and the adoption rate. Figure 3.1 illustrates K as the proportionate downward shift from 'a' to 'f'. After a new technology is successfully adopted the supply curve is defined as,

$$\begin{aligned} \text{Supply } (S_1): Q_s^t &= \alpha + \beta (P + K) = (\alpha + \beta K) + \beta P \\ &= Q_s^t = \alpha^t + \beta P^t, \end{aligned}$$

Where $\alpha^t = \alpha + \beta K$ (Mills, 1998).

Assume the demand equation remains the same.

The price and quantity before research are denoted by P_0 and Q_0 . A new research-induced equilibrium (point 'b'), can again be calculated by setting the new supply equal to the demand and solving for price and quantity. The research-induced quantity and price are denoted by Q_1 and P_1 in Figure 3.1. The research also induces a welfare change which is represented by the change in economic surplus.

Change in consumer surplus:

$$\Delta CS = CS_1 - CS_0 = P_{1,b,I_1} - P_{0,a,I_0} = P_{0,a,b,P_1}$$

Change in producer surplus:

$$\Delta PS = PS_1 - PS_0 = P_{1,b,d} - P_{0,a,d} = I_{0,e,b,I_1}$$

Change in total surplus

$$\Delta TS = TS_1 - TS_0 = d_{b,I_1} - d_{a,I_0} = I_{0,a,b,I_1}$$

These equations can also be expressed algebraically as:

Change in consumer surplus:

$$\Delta CS = P_0 Q_0 Z(1 + 0.5 Z\eta)$$

Change in producer surplus:

$$\Delta PS = P_0 Q_0 (K-Z)(1 + 0.5 Z\eta)$$

Change in total surplus

$$\Delta TS = \Delta CS + \Delta PS = P_0 Q_0 K(1 + 0.5 Z\eta)$$

Where,

K = the vertical shift of the supply function as a proportion of the initial price.

η = the absolute value of the elasticity of demand

ϵ = the elasticity of supply

$Z = K\epsilon/(\epsilon+\eta)$, which equals the reduction in price, relative to its initial (pre-research) value, due to the supply shift

The closed economy model presented above was used to calculate the total economic surplus for the three vegetable crops in this study. The total surplus from rice IPM was calculated using a small-country open economy model, because although rice is widely traded, the production is not large enough to affect the world price. In the small open economy model the change in total surplus is calculated as $\Delta TS = P_0 Q_0 K(1 + 0.5K\epsilon)$.

Measuring Extension Benefits

This study calculates the annual change in total economic surplus resulting from an IPM extension strategy. The extension strategy is limited to the dissemination of information about six IPM technologies for four crops by five dissemination methods. In total there are 65 activities in the extension strategy. Each activity is a unique combination of a crop, IPM practice, and dissemination method. Therefore, to calculate the change in total economic surplus from the extension program, the change in surplus of each activity must first be calculated.

To begin the calculations, several pieces of information are necessary, including: the elasticity of supply, elasticity of demand, total annual production, and price for each commodity; the percent yield change and cost change per hectare resulting from each IPM practice applied to the associated crops; and the adoption rate of each technology depending on how it was disseminated.

The demand elasticities for rice and vegetables were obtained from the USDA Economic Research Service website and were -0.4 and -0.5, respectively (Economic Research Service, 2009). A supply elasticity of 0.5 was suggested by Islam and Norton in their 2007 analysis of Bt eggplant in Bangladesh and was utilized in this analysis for each of the vegetable markets. The supply elasticity for rice was obtained from a 1981 paper on agricultural policies in Bangladesh (Ahmed, 1981). Although this study was conducted 30 years ago, it suggested an elasticity of supply of 0.20 which is an intermediate estimate when compared to more recent studies that estimate supply elasticities between 0.13 and 0.40 (Islam and Norton, 2007; Brennan, 2003).

The data pertaining to crop production and prices were obtained from the Ministry of Agriculture's Handbook of Agricultural Statistics, the Bangladesh Bureau of Statistics, and the Department of Agricultural Marketing (Bangladesh, 2007, 2009, 2010). Data regarding the

changes in yield and cost resulting from IPM practices were collected from BARI field trials and reports. The projected adoption rates were provided by scientists and extension experts in Bangladesh; these estimates are described in Section III.2.2.

These data are used in the following algebraic equations that lead to the estimation of total economic surplus for each activity:

1. Gross proportionate cost change = (% Yield Change) / (Supply Elasticity)
2. Proportionate cost change per ton = (Proportionate cost change per hectare) / (1+ % Yield Change)
3. Net change = (Gross proportionate cost change) – (Proportional cost change per ton)
4. K factor = Net Change * Probability of Success * Adoption Rate
 - In this study the probability of success is assumed to equal one, because only technologies that were successfully developed will be disseminated to farmers.
5. Total Surplus (*Closed Economy*) = $K * Price * Quantity * (1 + 0.5 * [(supply\ elasticity * K) / (supply\ elasticity + demand\ elasticity)] * demand\ elasticity)$
6. Total Surplus (*Small Open Economy*) = $K * Price * Quantity * (1 + 0.5 * K * supply\ elasticity)$

Appendix Tables C.8 and C.9 provide examples of the economic surplus calculations for eggplant using soil amendments and rice using a package of IPM practices, respectively. Section III.2.3 describes how the total surplus is then used to calculate the surplus per dollar of the dissemination budget.

III.2.2 Estimating Adoption of IPM Technologies

Although the information obtained from the BARI IPM survey was useful to understand how IPM technologies were being used in specific areas of the country, it could not provide information about the potential for future adoption. In order to forecast the adoption that may result from various dissemination efforts the study relied on the expert opinion of professionals working at BARI and MCC.

Two questionnaires were designed to obtain the projected adoption rates of IPM technologies. The first questionnaire, presented in Appendix A.4, enquired about the adoption of five vegetable technologies and the second questionnaire, presented in Appendix A.5, enquired about the adoption of rice IPM. Three scientists at BARI and one extension expert at MCC provided projected adoption rates for six IPM practices based on the method used to disseminate each technology. The medium level of adoption was obtained by averaging the four estimates. The “low” and “high” levels of adoption were obtained using the minimum and maximum projection for each technology. The three levels of adoption are presented in Appendix Table C.7 and will be used to conduct a sensitivity analysis of the LP model.

III.2.3 Calculating Surplus Per Dollar of the Dissemination Budget

It was necessary to calculate the amount of surplus that was generated by one dollar of the dissemination budget to obtain the decision-making variable coefficients for the linear programming model used in this analysis. Table 3.1 presents an example of this calculation using eggplant grafting technologies. Column B represents the current cost of teaching farmers about this technology through the five dissemination methods. Column C presents the number of farmers that are reached using each dissemination method. Information regarding the cost of each dissemination method and the estimated number of farmers reached were obtained through interviews with DAE personnel. Based on past research it is assumed that FFS participants share the information that they learn with four additional farmers. The cost per farmer in column D was calculated by dividing the total cost by the number of farmers reached. The farmers adopting in column E was calculated by multiplying the amount of farmers reached by the projected adoption rates. This calculation was conducted three times for each activity in the model at the low, average, and high rates of adoption. Cost per farmer adopting was therefore calculated by dividing column B by column F. Total surplus was then calculated using the method described in Section III.2.1. The surplus per dollar invested (column H) was calculated by dividing total surplus (column G) by total cost (column B). The values from column H were used as coefficients in the LP model that will be described in Section III.2.5.

Table 3.1: Example of Calculating Surplus per Dollar of Dissemination for Eggplant Grafting Technology

A	B	C	D	E	F	G	H
Dissemination Method	Total Cost	Farmers Reached	Cost Per Farmer	Total Farmers Adopting	Cost Per Farmer Adopting	Total Surplus	Surplus Per Dollar Invested
Paper Media	\$4,815	16,690	\$0.29	292	\$16.49	\$3,611	\$0.75
Electronic Media	\$4,606	106,563	\$0.04	6,927	\$0.66	\$85,659	\$18.60
FD	\$7,194	25,242	\$0.28	6,626	\$1.09	\$81,942	\$11.39
Agent Visit	\$970,752	496,699	\$1.95	68,296	\$14.21	\$845,940	\$0.87
FFS	\$45,742	20,194	\$2.27	4,039	\$11.33	\$49,942	\$1.09

Source: Estimates calculated from data obtained from the Department of Agricultural Extension, Dhaka, Bangladesh.

III.2.4 Foundations of Linear Programming Modeling

Brief History of Linear Programming

Since the 1960's, simulation and optimization tools, such as mathematical programming models, have been used to study agricultural production decisions at both farm and regional levels (Getz, 1982). These models allow researchers to study a wide range of factors that influence production.

Mathematical models are appealing to researchers because they are flexible and can be manipulated to accurately reflect the reality of the current situation. Additionally, numerous data sources can be combined to construct an LP model, making it an attractive tool when data are scarce (Berger, 2001). Data collected from experiments, observations, expert opinion, and surveys can all be incorporated in a mathematical model. Estimates from past research can also be utilized. These types of models are especially useful in developing countries where aggregate data may be lacking. By combining many data sources, these models are often considered more robust than many types of econometric analysis.

The true benefit of mathematical programming models lies in the ability of the model to select decision-making options in order to maximize a specified objective. The model provides quantitative solutions which can assist farmers and policy-makers. In a 2001 study on farm-level decision-making, a cohesive set of models was developed to provide policy-makers with insights so that they could understand the implications of the diffusion of various innovations at the

household level (Berger, 2001). These models allow strategies to be developed to overcome a wide range of production obstacles and policy challenges.

Assumptions of Linear Programming

The construction of a linear programming model is based on four major assumptions: 1.) proportionality, 2.) additivity, 3.) divisibility, and 4.) certainty (Hillier and Lieberman, 2010). As LP models are used to evaluate a range of different types of problems, it is important to recognize these assumptions and relate them to each problem to determine the soundness of the model structure.

The proportionality assumption states that the contribution of each activity, x_j , to the value of the objective function, Z , is proportional to the level of the given activity (Hillier and Lieberman, 2010). This assumption also applies to the constraints, in that the contribution of each x_j to the left-hand side of each functional constraint must be proportional to the level of that activity. Therefore, in order to fulfill the proportionality assumption it is not feasible to have quadratic terms in the objective function or the constraints.

According to the additivity assumption, every function in the model, including both the objective function and functional constraints, must be the sum of the individual contributions of the respective activities, x_j (Hillier and Lieberman, 2010). This assumption rules out the possibility of terms resulting from the product of multiple variables. Therefore, the model is not able to account for value that may result from the interaction between two activities.

The assumption of divisibility states that the decision-making variables are allowed to take on any value, including non-integer values, which satisfy the constraints (Hillier and Lieberman, 2010). The divisibility assumption will not hold if the decision-making variables are restricted to integer values. In such a case, a special optimization model known as an integer programming model could be used to account for this issue.

The certainty assumption states that all parameters in the model, including the objective function coefficients c_j , the left-hand side constraint coefficients a_{ij} , and the right-hand side constraints b_j , are assumed to be known constants (Hillier and Lieberman, 2010). This assumption is rarely satisfied completely because of a level of uncertainty that accompanies many situations, especially when models are used to predict future activities. In order to address

the concern of uncertainty most researchers conduct sensitivity analyses after finding the optimal solution calculated by the original model. To perform the analysis, parameters are varied and tested at different levels to determine how sensitive the model is to changes. Particular parameters may be identified as “sensitive” if the optimal solution changes when the value of the parameter is altered. Parameters may be considered “robust” if they vary little when the model is adjusted.

Linear programming models are a simplified representation of “real world” problems and therefore must be designed and interpreted with care (Hillier and Lieberman, 2010). It is important to address each assumption and determine if discrepancies exist in order to understand the possible limitations of the model. Linear programming models have proven useful to examine a variety of issues, especially when data is limited or when combining different types of data to answer the question at hand.

III.2.5 Modeling IPM Extension

The linear programming model used in this study is structured to maximize the economic benefits of the DAE’s Integrated Pest Management extension program subject to a set of defined constraints. As stated in the previous section it is important to determine any discrepancies that may exist between the stated problem and the four assumptions of LP models. As each part of the LP model is described, the assumptions will be discussed.

The simplified structure of the linear programming model is displayed in Figure 3.2. Each activity, or decision-making variable (DMV), is represented by c_{ijkl} , where ‘i’ is the crop, ‘j’ is the IPM practice, ‘k’ is the dissemination method, and ‘l’ is the level of funding. The coefficient for each DMV is the amount of economic surplus that is gained by a \$1 investment in that activity and is represented by a_{ijkl} . Each constraint is represented by ‘R’. Constraint coefficients are represented by positive or negative ‘A’.

Figure 3.2: Simplified Linear Programming Model

Equation Description	Objective	Dissemination Activity								RHS
		Activity 1		Activity 2		...	Activity 65			
		Current	High	Current	High		Current	High		
(a) Objective Function	1	c_{ijk1}	c_{ijk2}	c_{ijk1}	c_{ijk2}	...	c_{ijk1}	c_{ijk2}		
(b) Surplus Contributions to Objectives	-1	a_{ijk1}	a_{ijk2}	a_{ijk1}	a_{ijk2}	...	a_{ijk1}	a_{ijk2}	= 0	
Subject To:										
1. Total DAE IPM Dissemination Budget (1)		1	1	1	1	...	1	1	<= R	
2. Upper Limit for AEC and AIS IPM Dissemination Budgets (2)		A	A	A	A	...	A	A	<= R	
3. Lower Limit for AEC and AIS IPM Dissemination Budgets (2)		A	A	A	A	...	A	A	>= R	
4. Proportion to Each Crop (4)		$\pm A$	$\pm A$	$\pm A$	$\pm A$	...	$\pm A$	$\pm A$	<= 0
5. Proportion to Each Practice (5)		$\pm A$	$\pm A$	$\pm A$	$\pm A$	...	$\pm A$	$\pm A$	<= 0
6. Upper Limit for Each Dissemination Method (5)		A	A	A	A	...	A	A	<= R	
7. Lower Limit for Each Dissemination Method (5)		A	A	A	A	...	A	A	>= R	
Funding Limit for Each Activity										
8. Current Budget (65)		1							<= $R_{1,1}$	
9. High Budget (65)		1	1						<= $R_{1,2}$	
				1					<= $R_{2,1}$	
				1	1				<= $R_{2,2}$	
						
							1		<= $R_{65,1}$	
							1	1	<= $R_{65,2}$	
10. Proportion of Dissemination Method Funding to Each Crop (20)		$\pm A$	$\pm A$	$\pm A$	$\pm A$	...	$\pm A$	$\pm A$	<= 0
11. Proportion of IPM Practice Funding to Each Veg. Crop (12)		$\pm A$	$\pm A$	$\pm A$	$\pm A$	...	$\pm A$	$\pm A$	<= 0
12. Proportion of Dissemination Method Funding to Each Vegetable Practice (25)		$\pm A$	$\pm A$	$\pm A$	$\pm A$	...	$\pm A$	$\pm A$	<= 0

Key:

i = crop

j = IPM practice

k = dissemination method

l = level of budget

** Note ** Number of constraints is in parentheses

Decision Making Variables and Their Coefficients

The decision-making variables (DMV), located across row a, indicate the amount of the total budget (in dollars) that will be invested in each activity. Each activity is a combination of crop, IPM practice, and extension method. The decision-making variable coefficients located on row b are calculated from the economic surplus analysis in Section III.2.3 and indicate the return from a \$1 USD investment in a particular dissemination activity.

Diminishing marginal returns to extension activities may exist because of constraints within the extension program such as limited personnel as well as constraints limiting the number of farmers that can be reached, such as poor infrastructure. It is important to account for possible diminishing returns; however, adding non-linear terms in the model would violate the proportionality assumption. In order to reflect the diminishing returns without violating this assumption, two levels of dissemination are created for each activity. The first level indicates the current level of the dissemination budget and provides the full amount of surplus calculated in the economic surplus analysis. The second level, called “high dissemination”, allows additional money to be allocated to that activity at a lower level of surplus. For this analysis the high budget activity provides an economic return that was 75% of the return from the original budget. The 75% return reflects the fact that an increased budget may not be able to reach a proportionally higher number of farmers due to overhead costs and other constraints, such as personnel availability or country infrastructure. The money allocated to each DMV can be selected at the level currently allocated by the DAE to that crop and practice, or the budget can be increased to reach additional farmers.

For example, if \$1,500 is allocated to eggplant-grafting-field days it indicates that the DAE should spend \$1,500 to disseminate eggplant grafting technologies via field days. However, because the current budget for this activity is \$1,439, only this amount can be invested in “eggplant – grafting – field day – current.” The remaining \$61 is allocated to “eggplant – grafting – field day – high,” indicating that the current budget has been exceeded by \$61. The coefficient on the “current” decision making variable is 11.39, indicating that \$11.39 of surplus will be generated by a \$1 investment in this

activity. Therefore, the \$1,439 investment provides a \$16,390.21 return. The additional \$61, allocated to the “high” activity, provides a 25% lower return per dollar. Therefore, the total return for this activity is $\$1,439 \times (11.39) + \$61 \times (11.39 \times 0.75)$, which equals \$16,911.30.

There are 130 DMV in total representing the current and high budget allocations for 65 different IPM extension activities. The complete list is provided in Table D.1 in Appendix D. Although the described model satisfies the proportionality and additivity assumptions by being linear in nature, the additivity assumption in the underlying problem could be questioned due to the complementary nature of both IPM practices and dissemination tactics. This issue will be addressed in the limitations section in chapter five. The divisibility assumption is satisfied because the dissemination budget allocated to each activity can take on non-integer values representing parts of a dollar. Like many studies, a sensitivity analysis is conducted to address the certainty assumption of the model. The results from the sensitivity analysis are presented after the baseline model results in Chapter Four.

Constraints

In an effort to achieve a realistic outcome, two baseline models are constructed with several types of constraints. The constraints can be divided into four categories: budgetary constraints, crop constraints, IPM practice constraints, and extension method constraints. Figure 3.2 presents a simplified version of the linear programming model used in this study. The AEC and AIS budgets are aggregated in row one, defining an overall budget constraint for the DAE. Currently, their IPM extension budget is nearly USD \$10 million. The AEC and AIS budgets are also individually constrained with upper and lower limits as depicted in rows two and three, respectively. The current AEC budget for IPM extension is about USD \$9.9 million. The constraints in rows two and three ensure that the budget does not increase or decrease by more than 50%. The AIS budget is handled in a similar way. With a current budget of USD \$61,271, row three constrains the budget from decreasing more than 50%. The upper limit of the AIS budget, in row two, allows the budget to increase until the total budget constraint is met. In other words,

the AIS budget can equal a value up to the difference of the total budget and the AEC budget.

In an effort to reflect the current goals of the DAE dissemination program, row four represents four constraints that force the model to allocate a certain proportion of the budget to each vegetable crop and rice. No more than 80% of the funding can be allocated to rice, ensuring that at least 20% of the total budget is dedicated to disseminating technologies associated with the three vegetable crops. At least 10% of the total vegetable budget is allocated to each of the three crops: eggplant, tomatoes, and cucurbits. Additionally, the proportionality constraints depicted on row five guarantee a minimum investment in each IPM technology by committing at least 10% of the total vegetable budget to each of the five IPM technologies.

The constraints depicted on row seven ensure that each extension method is utilized to reach at least half of the number of farmers that currently received information from that information channel. These constraints limit drastic changes in the dissemination program in an effort to model a realistic strategy that could be feasibly implemented by the DAE. Assuming that 100 farmers attend each field day, there are currently 462,500 farmers that receive IPM information via field days. The constraint ensures that at least 231,250 farmers will continue to be reached by this method by committing at least \$47,959 to field day extension. The budget for extension agents must be at least USD \$5,824,512 allowing 60% of the current farmers reached by agents to continue to be reached through this method. A minimum budget of USD \$329,674 must be allocated to FFS in an effort to reach at least 50,000 farmers with this method.

Each activity is constrained so that funding cannot be allocated in excess of the amount that would be required to reach all of the farmers by that particular method. These constraints are presented on rows eight and nine. For example, the budget for “eggplant – grafting – field day – current” could not be greater than \$1,439 – the approximate budget currently committed to this extension activity. The upper-bound for each dissemination method was calculated by multiplying the cost of reaching one farmer by the total number of farmers. For example, the budget for “eggplant – grafting – field day – high” could not be greater than \$142,146 – the amount of the budget that would be

necessary to reach all of the vegetable farmers with information about eggplant grafting at field days.

Finally, the constraints represented by row 10 ensure that each dissemination method is used to extend information about IPM practices for each of the four crops. Currently, about 69% of the total dissemination budget is dedicated to rice IPM and just over 10% is dedicated to each of the vegetable crops. The first baseline model does not constrain the budget to the current funding structure; however, it ensures that no more than 80% of the total budget for each dissemination method can be allocated to rice IPM. Additionally, at least 20% of the vegetable budget for each dissemination method must be extended to each of the three vegetable crops.

The second baseline model is constructed with the same constraints as the first baseline model with the addition of constraints on rows 11 and 12 (see Figure 3.2). These constraints only affect the dissemination of vegetable crops by requiring a minimum proportion of the budget to be allocated to each IPM practice and dissemination method for the three crops. These additional constraints ensure that information about IPM technologies is disseminated for each vegetable crop by the five dissemination methods. The constraints represented by row 11 require that if an IPM technology is used for more than one crop then at least 10% of the total budget allocated to that technology must be allocated to each of the crops. For example, soil amendments are used when growing eggplants, tomatoes, and cucurbits; therefore, this constraint ensures that at least 10% of the total soil amendment budget is dedicated to each of the three crops. Row 12 represents a set of constraints that require that at least 15% of the funding for each dissemination method is allocated to each of the five vegetable IPM practices, thus ensuring that a mix of methods is used to disseminate information about each technology.

III.3 Nepal

III.3.1 Introduction

In 2006 Nepal became an IPM CRSP project location, collaborating with the International Development Enterprises (IDE) Nepal Program and the National Agricultural Research Council (NARC) of Nepal. Over the past five years, progress has been made in developing and extending IPM technologies to Nepalese farmers. However, household level survey data measuring the effectiveness of these dissemination efforts and the adoption of IPM technologies have not yet been collected. Survey data collected in Phase IV of the IPM CRSP should provide researchers with the information needed to evaluate the success of the program and design appropriate projects moving forward.

Although a large data set was not available for analysis, program coordinators sought feedback about the effectiveness of dissemination efforts thus far. A small household-level survey conducted in 2010 by researchers at IDE to assess women's participation in the IPM CRSP was used for a preliminary study regarding dissemination and adoption. The survey was conducted in three districts of Nepal where IDE is currently active and included 80 participants. Although a larger, more representative survey is preferred, the data provide some insight into the current status of IPM in the IDE project areas. The survey results are presented in Section IV.3.2.

The purpose of this study is to identify factors that influence farmer awareness of IPM and the adoption of IPM technologies. A bivariate probit model was used to estimate farmer awareness regarding IPM while controlling for the endogeneity of network linkages. Adoption was estimated using a two-step endogenous participation model. Sections III.3.2, III.3.3, III.3.4, and III.3.5 provide an overview of binary response models as described in Wooldridge (2009). The models presented in these four sections form the foundation for the bivariate probit model presented in Section III.3.6. Section III.3.7 describes the specific model used in this study. Finally, Section III.3.8 describes the two-step model used to estimate adoption of IPM technologies.

III.3.2 Binary Response Models

A binary dependent variable is an example of a limited dependent variable because its value is restricted to one of two values – zero or one (Wooldridge, 2009). The dependent variable may represent a discrete choice such as to adopt or not to adopt a new technology. In this study, the dependent variable indicates whether a farmer has knowledge about IPM with knowledge being considered a positive outcome. If a farmer is aware of IPM then the dependent variable equals one, otherwise it equals zero.

Binary models must be estimated and interpreted in a unique manner. Consider the multiple regression model (3.3.1) with a binary dependent variable y , where x_i 's are the explanatory variables, β_j 's are the estimation parameters and μ is the error term. Assuming that the zero conditional mean holds, the regression can be rewritten as equation (3.3.2). Then, considering that the dependent variable is binary, the equation can be rewritten to show that $E(y|x) = P(y=1|x)$, indicating that the probability that $y = 1$ is equal to the expected value of y . $P(y=1|x)$ is known as the response probability or the probability of success.

$$(3.3.1) \quad y = \beta_0 + \beta_1 x_1 + \dots + \beta_j x_j + \mu$$

$$(3.3.2) \quad E(y|x) = \beta_0 + \beta_1 x_1 + \dots + \beta_j x_j$$

$$(3.3.3) \quad P(y=1|x) = \beta_0 + \beta_1 x_1 + \dots + \beta_j x_j$$

The multiple regression model depicted in equation (3.3.3) indicates that the response probability is a linear function and is therefore called a linear probability model (LPM). Using the ordinary least squares (OLS) estimation procedure, β_j measures the change in probability of success as x_j changes, *ceteris paribus*:

$$(3.3.4) \quad \Delta P(y=1|x) = \beta_j \Delta x_j.$$

However, there are several problems with using the LPM framework. First of all, for some values of x_j , predicted probabilities of a positive outcome can be greater than one or less than zero, leading to interpretation issues. Secondly, the LPM indicates that

the partial effects of explanatory variables are constant; however, probability is not linearly related to independent variables across all values. Due to these issues, the accuracy of prediction using this model is questionable.

Furthermore, the LPM violates the fifth Gauss-Markov assumption of no heteroskedasticity (Wooldridge, 2009). Heteroskedasticity occurs when the variance of the error term changes depending on the value of the explanatory variables. The variance of a linear probability model, conditional on x , is represented in equation (3.3.5) and indicates that there is heteroskedasticity present in the model unless the probability is independent of every x_j . Although heteroskedasticity does not bias the model, it does make the t and F statistics inaccurate – even in large samples.

$$(3.3.5) \quad \text{Var}(y|x) = P(y=1|x) [1 - P(y=1|x)]$$

III.3.3 Logit and Probit Models

More sophisticated binary response models, such as the logit and probit models, have been developed to address the problems occurring with the linear probability model. These models ensure that the probabilities remain within zero and one and provide nonlinear functional forms. The logit model has a logistic form using the cumulative distribution function for a standard logistic variable. The probit model uses the standard normal cumulative distribution function (cdf). Both models ensure that the response probability is strictly between zero and one across all values of the parameters and x_j 's. The response probability can be referred to as the function $G(z)$ in equation (3.3.6), where $0 \leq G(z) \leq 1$. The different specifications for logit and probit models are shown in equations (3.3.7) and (3.3.8), respectively.

$$(3.3.6) \quad P(y = 1|x) = G(\beta_0 + x\beta)$$

$$(3.3.7) \quad \text{Logit : } G(z) = \frac{\exp(z)}{1 + \exp(z)}, \quad \text{where } z = \beta_0 + x\beta$$

$$(3.3.8) \quad \text{Probit: } G(z) = \Phi(z) \equiv \int_{-\infty}^z \phi(x) dx \quad \text{where, } \phi(x) = \frac{1}{\sqrt{2\pi}} e^{-(x^2/2)}$$

Both the logit and probit models are derived from an underlying latent variable model, where y^* is the unobserved variable and is determined by equation (3.3.9). It is assumed that μ is independent of x and that μ has either a standard logistic (logit) or standard normal (probit) distribution. The response probability is indicated in equation (3.3.11).

$$(3.3.9) \quad y^* = \beta_0 + x\beta + \mu, \text{ where } x\beta = \beta_1 x_1 + \dots + \beta_k x_k$$

$$(3.3.10) \quad y_i^* = \begin{cases} 0 & \text{if } y_i^* \geq 0 \text{ if } (\mu \geq -\beta_0 + x\beta) \\ 1 & \text{if } y_i^* < 0 \text{ if } (\mu < -\beta_0 + x\beta) \end{cases}$$

$$(3.3.11) \quad P(y=1|x) = P(y^* > 0|x) = P[\mu > -(\beta_0 + x\beta)|x]$$

Economists tend to favor the normality assumption for the error term, making the probit model more widely used in econometric analysis. Probit models are commonly used in studies modeling the adoption of agricultural technologies (Doss and Morris, 2000; Negatu and Parikh, 1999; Mbata 2001; Ricker-Gilbert et al., 2008). Additionally, probit models have been used to measure knowledge of agricultural practices. The equations presented in the remainder of this chapter will be defined according to the probit specification where $G(z) = \Phi(z) \equiv \int_{-\infty}^z \phi(x) dx$, Φ is the cdf of a continuous variable and $\phi(x)$ is the standard normal density.

Both the logit and probit models are estimated using maximum likelihood estimation (MLE). A major benefit of using MLE instead of OLS is that the heteroskedasticity in $\text{Var}(y|x)$ is automatically accounted for. To obtain a maximum likelihood estimator, it is necessary to know the density of y , given x_j . This can be written as,

$$(3.3.12) \quad f(y|x_j; \beta) = [\Phi(x_j \beta)]^y [1 - \Phi(x_j \beta)]^{1-y}, \quad y = 0, 1$$

Taking the log of (3.3.12) results in the log-likelihood function:

$$(3.3.13) \quad l_i(\beta) = y_i \ln[\Phi(x_j\beta)] + (1 - y_i) \ln[1 - \Phi(x_j\beta)]$$

The log-likelihood for a sample size n is obtained from summing (3.3.13) across all of the observations to form (3.3.14).

$$(3.3.14) \quad \ell(\beta) = \sum_{i=1}^n \ell_i(\beta)$$

$\hat{\beta}$ is the maximum likelihood estimator of β and maximizes the log-likelihood. Maximum likelihood estimation is consistent, asymptotically normal and efficient.

III.3.4 Interpreting the Logit and Probit Models

The interpretation of binary response models is slightly different than linear regression models. The magnitudes of each β_j cannot be directly interpreted, however they accurately indicate the direction of each effect of x_j on y^* . The marginal effect obtained from the partial derivative must be calculated in order to find the effect of each x_j on the dependent variable:

$$(3.3.15) \quad P(y=1|x) / \partial x_j = \Phi(\beta_0 + x\beta) \beta_j$$

Before interpreting the marginal effects of the explanatory variables on the dependent variable it is important to determine how well the model estimates the data. Two methods are commonly used to determine a model's goodness-of-fit. The first method is to calculate the percent of correct predictions and the second method relies on the pseudo R-squared value.

Computing the percent correctly predicted by the logit or probit models is one measure of goodness-of-fit. There are several ways to compute this measurement. To

begin, the binary prediction threshold can be set at 0.5 so that success is indicated by any predictions of 0.5 or greater and zero is predicted otherwise.

$$(3.3.16) \quad \text{if } G(\hat{\beta}_0 + x_i \hat{\beta}) \geq 0.5, \text{ then } \hat{y} = 1 \quad \text{and} \quad \text{if } G(\hat{\beta}_0 + x_i \hat{\beta}) \leq 0.5, \text{ then } \hat{y} = 0$$

The predicted outcomes are then compared to the actual outcomes in a two-way table. By dividing the number of correct predictions by the number of observations it is easy to obtain the percent correctly predicted ratio.

Table 3.2: Comparison of Actual and Predicted Outcomes

		Predicted	
		Y = 0	Y = 1
Actual	Y = 0	4	1
	Y = 1	1	4

$$\text{Accuracy of Prediction} = (4+4)/(4+4+1+1) = 0.8 = 80\%$$

An alternative to setting a 0.5 threshold is to adjust the threshold until the number of predicted successes equals the number of successful observations. This threshold level is obtained through a process of trial and error by adjusting the probability level which will be considered a success up or down until $\sum y = \sum \hat{y}$. The ratio of correct predictions over total observations again measures the goodness-of-fit. This method is used to evaluate the models in this study. The outcomes are presented in Section IV.3.

Pseudo R-squared values can also be calculated. One pseudo R-squared calculation is obtained by the equation, $\mathcal{L}_{ur}/\mathcal{L}_0$, where \mathcal{L}_{ur} is the log-likelihood function for the estimated model, and \mathcal{L}_0 is the log-likelihood function in the model with only an intercept (Wooldridge, 2009, p. 581).

If the ratio of correct predictions and/or the pseudo R-squared indicate that the model is a good fit for the data then the model may provide some insight about the effect of each explanatory variable on the response probability of the dependent variable. If x_j is a continuous variable, then

$$(3.3.17) \quad \Delta \hat{P}(y = 1|x) \approx [\phi(\hat{\beta}_0 + x \hat{\beta}) \hat{\beta}_j] \Delta x_j, \quad \text{for small changes in } x.$$

The magnitudes of the partial effects can be calculated by replacing each explanatory value with its respective sample mean.

$$(3.3.18) \quad \Delta \hat{P}(y=1|x) \approx [\phi(\hat{\beta}_0 + \bar{x}\hat{\beta}) * \hat{\beta} x_j]$$

III.3.5 Endogeneity

Endogeneity occurs when there are unobserved factors that affect one or more of the explanatory variables in the model (Wooldridge, 2009). Because these factors cannot be explicitly measured they remain in the error term causing correlation between the error term and the independent variable(s). The assumption of a zero conditional mean is thus violated and the model becomes biased and inconsistent.

Incorporating an instrumental variable and conducting a two-stage regression model are two common methods used to correct for endogeneity in a model. An instrumental variable (IV) is one that is correlated with the endogenous independent variable. An IV must be exogenous in the original regression equation and be uncorrelated with the omitted variables. For example, in the equation $y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \mu$ with an endogenous variable x_2 , an appropriate instrument must be correlated with x_2 , but uncorrelated with y and μ .

The IV estimator in the single equation regression model can also be incorporated into a multiple regression model. For clarity, imagine a two equation model that can be estimated using ordinary least squares. The first equation (3.3.19) is known as the structural equation with y_2 being an endogenous explanatory variable and z_1 being exogenous. An instrumental variable, z_2 , is identified that is correlated to y_2 but not directly correlated with y_1 or μ . Correlation between y_1 and z_2 can only occur indirectly through the effect on y_2 . A second equation (3.3.20) can be specified to determine the outcome of y_2 . This equation is called a reduced form equation, meaning that the endogenous variable is written as a function of the exogenous independent variables, including the IV.

The model can be estimated in two steps. First, equation (3.3.20) is estimated and the predicted values for y_2 are obtained, shown as \hat{y}_2 . Then \hat{y}_2 is substituted for y_2 in equation (3.3.19) to form equation (3.3.21).

$$(3.3.19) \quad y_1 = \beta_0 + \beta_1 y_2 + \beta_2 z_1 + \mu$$

$$(3.3.20) \quad y_2 = \alpha_0 + \alpha_1 z_1 + \alpha_2 z_2 + v$$

$$(3.3.21) \quad y_1 = \beta_0 + \beta_1 \hat{y}_2 + \beta_2 z_1 + \mu$$

This basic procedure can be adjusted and applied to more sophisticated models such as the bivariate probit model described in Section III.3.6. Mauceri used an instrumental variable and two-stage regression model to account for the endogeneity of farmer field school participation (Mauceri et al., 2007). The following section will describe a two-stage extension of a probit model.

III.3.6 Bivariate Probit Model

Bivariate probit models are extensions of the basic probit model using multiple equations (Greene, 2003). The errors in the equations are assumed to be correlated and therefore, it is important to consider the joint probability of the two outcomes. In this study, network linkage (NET_LINK) is an endogenous regressor and therefore, must be jointly estimated with farmer knowledge (KNW_IPM_O). Using Greene's model, the basic specification for the two-equation model is:

$$(3.3.22) \quad y_1^* = \beta' x_1 + \gamma y_2 + \varepsilon_1, \quad y_1 = 1 \quad \text{if } y_1^* > 0, \quad 0 \text{ otherwise,}$$

$$(3.3.23) \quad y_2^* = \alpha' x_2 + \varepsilon_2, \quad y_2 = 1 \quad \text{if } y_2^* > 0, \quad 0 \text{ otherwise,}$$

$$(3.3.24) \quad E[\varepsilon_1 | x_1, x_2] = E[\varepsilon_2 | x_1, x_2] = 0,$$

$$(3.3.25) \quad \text{Var}[\varepsilon_1 | x_1, x_2] = \text{Var}[\varepsilon_2 | x_1, x_2] = 1,$$

$$(3.3.26) \quad \text{Cov}[\varepsilon_1, \varepsilon_2 | x_1, x_2] = \rho.$$

In the model, β' represents all of the coefficient estimates for the regressors in the first equation and α' represents all of the coefficients for the regressors in the second equation. The second equation includes the regressors from equation one with the addition of an instrumental variable, IRR_H20. The coefficient for the endogenous regressor, NET_LINK, is represented by γ .

Like the univariate probit model the bivariate probit model is solved using maximum likelihood estimation where the cumulative density function is,

$$(3.3.27) \quad \Phi_2(x_1, x_2, \rho) = \text{Prob}(X_1 < x_1, X_2 < x_2) = \int_{-\infty}^{x_2} \int_{-\infty}^{x_1} \phi_2(\varepsilon_1, \varepsilon_2, \rho) d\varepsilon_1 d\varepsilon_2,$$

Where, Φ_2 is the bivariate normal cdf, $\phi_2(\varepsilon_1, \varepsilon_2, \rho)$ is the bivariate standard normal density and ρ is a correlation parameter indicating the extent to which the error terms in each equation covary as shown in equation (3.3.26).

Therefore, the probabilities that enter the likelihood function are,

$$(3.3.28) \quad \text{Prob}(Y_1 = y_{i1}, Y_2 = y_i \mid x_1, x_2) = \Phi_2(x_1, x_2, \rho)$$

The log-likelihood function is thus,

$$(3.3.29) \quad \log L = \sum_{i=1}^n \ln \Phi_2(x_1, x_2, \rho)$$

The maximum likelihood estimates are then obtained by taking the derivatives of the log-likelihood with respect to β_j and ρ and then setting the derivatives equal to zero.

Using the method proposed by Greene (1998), the marginal effect of the endogenous binary variable, y_2 , is calculated with the following equation:

$$(3.3.30) \quad \Phi(\beta'x_1 + \gamma) - \Phi(\beta'x_1) \text{ where } \Phi \text{ is the univariate cdf.}$$

Using a bivariate model is helpful because the endogenous variable in the equation of interest can be estimated in the second equation using instrumental variables.

Section III.3.7 will explain how a bivariate probit model was used to control for endogeneity when estimating the factors that affect farmer knowledge about IPM.

III.3.7 Estimating Farmer Knowledge about IPM

This study examines the factors influencing farmer knowledge of IPM using two probit specifications – a univariate probit and a bivariate probit. A description of the independent variables used in each model is presented in Table 3.3.

Table 3.3: Explanatory Variables Influencing IPM Knowledge and Adoption

Variable	Description
RES_GENDER	Binary: 1= female
RES_AGE	Continuous: measured in years
RES_AGE2	Continuous: measured in years squared
RES_NOED	Binary: 1 = no education
RES_PRIM	Binary: 1 = primary education
RES_MHC_ED	Binary: 1 = education beyond primary
HHSIZE	Continuous: # of members in the household
LALITPUR	Binary: 1 = lived in Lalitpur
KASKI	Binary: 1 = lived in Kaski
RUPANDEHI	Binary: 1 = lived in Rupandehi
NET_LINK	Binary: 1 = had network linkages to obtain ag. information and inputs
TRAIN_IPM	Binary: 1 = had received IPM training
CRDT_ACC	Binary: 1 = had access to credit
HHINC	Continuous: total annual HH income measured in Nepalese rupees
VEG_PCT	Continuous: income from vegetables / total income
IRR_H20	Binary: 1 = access to irrigation

Initially, a univariate probit specification was used to measure the factors affecting farmer knowledge about IPM practices. Equation (3.3.31) shows the first model used to estimate farmer awareness. The base group in the model was a male farmer living

in the Kaski district with no formal education, no network linkages, and no access to credit.

$$(3.3.31) \quad \text{knw_ipm_o} = \beta_0 + \beta_1 \text{net_link} + \beta_2 \text{res_gend} + \beta_3 \text{res_age} + \beta_4 \text{res_age2} + \beta_5 \text{res_prim} + \beta_6 \text{res_mhc_edu} + \beta_7 \text{lalitpur} + \beta_8 \text{rupandehi} + \beta_9 \text{hhsiz} + \beta_{10} \text{crdt_acc} + \beta_{11} \text{hhinc} + \beta_{12} \text{veg_pct} + \mu$$

It was suspected that endogeneity was present in the model due to unobservable farmer characteristics that influenced the ability of farmers to acquire network linkages. Because NET_LINK was thought to be influenced by unobserved farmer characteristics contained in the error term, correlation was suspected between NET_LINK and the error term, thus resulting in a biased model. A bivariate probit model corrected for the endogeneity by incorporating a two-step approach using an instrumental variable to determine if farmers would have network linkages. Access to irrigation (IRR_H20) was used in the reduced form equation as an instrumental variable. Research has indicated that IPM and irrigation are complementary technologies so it was considered a viable IV for this analysis (Fernandez-Cornejo et al., 1994). IRR_H20 was also considered to be a suitable IV because it was correlated with network linkages, but had no direct partial effects on IPM knowledge.

The reduced form equation (3.3.32a) was solved first so that the results could feed into the structural equation (3.3.32b). Both equations were estimated through maximum likelihood estimation with the assumption of normality.

$$(3.3.32a) \quad \text{net_link} = \beta_0 + \beta_1 \text{irr_h20} + \beta_2 \text{res_gend} + \beta_3 \text{res_age} + \beta_4 \text{res_age2} + \beta_5 \text{res_prim} + \beta_6 \text{res_mhc_edu} + \beta_7 \text{lalitpur} + \beta_8 \text{rupandehi} + \beta_9 \text{hhsiz} + \beta_{10} \text{crdt_acc} + \beta_{11} \text{hhinc} + \beta_{12} \text{veg_pct} + \nu$$

$$(3.3.32b) \quad \text{knw_ipm_o} = \beta_0 + \beta_1 \text{net_link} + \beta_2 \text{res_gend} + \beta_3 \text{res_age} + \beta_4 \text{res_age2} + \beta_5 \text{res_prim} + \beta_6 \text{res_mhc_edu} + \beta_7 \text{lalitpur} + \beta_8 \text{rupandehi} + \beta_9 \text{hhsiz} + \beta_{10} \text{crdt_acc} + \beta_{11} \text{hhinc} + \beta_{12} \text{veg_pct} + \mu$$

III.3.8 Estimating the Adoption of IPM Practices

IPM adoption was estimated using a two-step estimation procedure which, like the bivariate probit, uses nested models to control for endogenous variables. This model is estimated using the “*treatreg*” command in Stata (StataCorp, 2007). The reduced form equation estimates NET_LINK using a probit model with the assumption of normality. However, this model differs from the bivariate probit because the structural equation is estimated using a linear regression under the assumption of that the error terms of each equation are jointly normally distributed. The benefit of using this model is that the standard errors are corrected, thus allowing for an easier interpretation of the parameter coefficients and significance level for each explanatory variable.

Instead of estimating the occurrence of IPM adoption, this study estimates the intensity, measured by the percentage of IPM practices that are adopted by each farmer. This adoption measurement allows the ordinal variable for number of practices adopted to be transformed into a continuous variable between 0 and 1. The reduced form equation (3.3.33a) is estimated using a probit model while the structural equation (3.3.33b) is estimated by OLS. The base group in the model was a male farmer living in the Kaski district with no formal education, no network linkages, no access to credit, and no IPM training.

$$(3.3.33a) \quad \text{net_link} = \beta_0 + \beta_1 \text{irr_h20} + \beta_2 \text{res_gend} + \beta_3 \text{res_age} + \beta_4 \text{res_age2} + \beta_5 \text{res_prim} + \beta_6 \text{res_mhc_edu} + \beta_7 \text{lalitpur} + \beta_8 \text{rupandehi} + \beta_9 \text{hhsz} + \beta_{10} \text{crdt_acc} + \beta_{11} \text{hhinc} + \beta_{12} \text{veg_pct} + \beta_{13} \text{train_ipm} + v$$

$$(3.3.33b) \quad \text{ipm_pct} = \beta_0 + \beta_1 \text{net_link} + \beta_2 \text{res_gend} + \beta_3 \text{res_age} + \beta_4 \text{res_age2} + \beta_5 \text{res_prim} + \beta_6 \text{res_mhc_edu} + \beta_7 \text{lalitpur} + \beta_8 \text{rupandehi} + \beta_9 \text{hhsz} + \beta_{10} \text{crdt_acc} + \beta_{11} \text{hhinc} + \beta_{12} \text{veg_pct} + \beta_{13} \text{train_ipm} + \mu$$

CHAPTER IV: RESULTS

IV.1 Introduction

Chapter Four provides an overview of the results for both the Bangladesh and Nepal studies. Section IV.2 presents an assessment of the IPM dissemination strategy employed by the Bangladesh Department of Agricultural Extension and offers alternative strategies that may increase the economic benefits of the extension program. Section IV.3 presents the results of the econometric analysis used to estimate the factors influencing awareness and adoption of IPM technologies in Nepal.

IV.2 Bangladesh Study Results

IV.2.1 Introduction

An economic surplus analysis is conducted to estimate the economic benefits resulting from the current extension strategy being implemented by the DAE to disseminate IPM information to Bangladeshi farmers. An LP model is then used as a tool to evaluate alternative dissemination strategies that may provide greater economic benefits by maximizing total economic surplus.

Both qualitative and quantitative data from various sources are incorporated into the model. During a research trip to Bangladesh, national-level crop production and yield data were obtained from the Bangladesh Bureau of Statistics and farm-level production budgets were collected from field studies conducted by BARI. Questionnaires were used to guide interviews with extension personnel at the DAE and local NGO's, scientists at BARI and BRRI, and private companies that currently market IPM technologies throughout Bangladesh. These interviews provide information about extension budgets, current IPM dissemination strategies, crop production levels, and constraints faced by scientists, extension staff, and the private industry. Questionnaires completed by scientists and extension personnel are used to obtain projected adoption rates of six IPM practices. Additionally, a household-level survey provides some baseline information about the types of crops being grown and the IPM practices that are most commonly

adopted by farmers. All of these data are used to construct a linear programming model that can be adjusted to reflect a variety of changes – changes both within the DAE program or concerning the benefits and adoption of the IPM practices themselves.

Sections IV.2.2, IV.2.3, and IV.2.4 describe the data that were collected on the adoption of IPM practices and the costs associated with IPM dissemination. This information provides some of the important assumptions that underlie the framework of the LP model. Section IV.2.5 describes the LP models that are constructed as baselines from which sensitivity analyses are conducted. The sensitivity analyses are presented in Section IV.2.6. Finally, Section IV.2.7 describes the implications of shadow prices.

IV.2.2 Summary from Survey

In 2010, a baseline survey was conducted by BARI scientists to examine the current use of IPM technologies on vegetable crops in Bangladesh (see Appendix A.1). The survey was administered in three districts in which vegetables are intensively grown: Bogra, Narsingdi, and Jessore. Within each district, two upazilas (sub-districts) were selected, from which two blocks (jurisdictions within upazilas) were chosen for the study. Twenty-five farmers were then randomly selected from each block to participate in the survey that was conducted by enumerators who were trained by BARI staff.

Of the 300 respondents, 21 (9.7%) were female and the participants ranged in age from 17 to 75 with an average age of 42 years. Years of agricultural experience ranged from two to 52 years. Thirty-eight percent of the farmers had received education through the secondary level. The participants were grouped into two categories: “IPM farmers” and “non-IPM farmers.” The IPM farmers were those who adopted IPM technologies, whereas the non-IPM farmers relied on traditional and cultural production practices. Ninety-nine (33%) of the farmers used IPM practices. Table 4.1 presents a summary of selected socio-economic characteristics that describe the survey participants.

Table 4.1: Summary of Socio-economic Characteristics of Survey Respondents

Variable	Description	Obs.	Avg.	Std. Dev.	Min	Max
MALE	1= male	300	0.90	0.30	0	1
AGE	in years	300	42.45	12.32	17	75
AGE_SQ	years squared	300	1953.57	1085.90	289	5625
NOEDUC	1 = no education	300	0.27	0.45	0	1
PRIMEDUC	1 = primary education	300	0.27	0.44	0	1
POSTPRIM_EDU	1 = education beyond primary	300	0.46	0.50	0	1
EXPER	number of years farming	300	17.87	10.34	2	52
HHSIZE	# of members in the household	300	5.97	1.49	3	9
LAND_HA	ha. of land in production	300	0.99	0.62	0.14	3.99
D_MARKET	distance from the nearest market (km)	299	1.31	0.88	0.11	6.00
ADOPT_IPM	1 = if the farmer adopted an IPM practice	300	0.33	0.47	0	1
JESSORE	1 = lived in Jessore	300	0.33	0.47	0	1
BOGRA	1 = lived in Bogra	300	0.33	0.47	0	1
NARSINGDI	1 = lived in Narsingdi	300	0.33	0.47	0	1

Data Source: IPM CRSP Baseline Survey, BARI, Gazipur, Bangladesh.

The average farm size was less than one hectare, but a variety of crops were cultivated, including both rice and vegetables. Table 4.2 presents a summary of the respondents' crop production. All of the farmers produced rice and all but one produced vegetables. The most common vegetables in production were cucurbit crops which were grown by 82% of the respondents and consisted of cucumbers, bottle gourds, sweet gourds, bitter gourds, teale gourds, ridge gourds, and pointed gourds. Forty-four percent of the farmers grew eggplant and twelve percent produced tomatoes. The average land size for vegetable production was 0.28 ha.

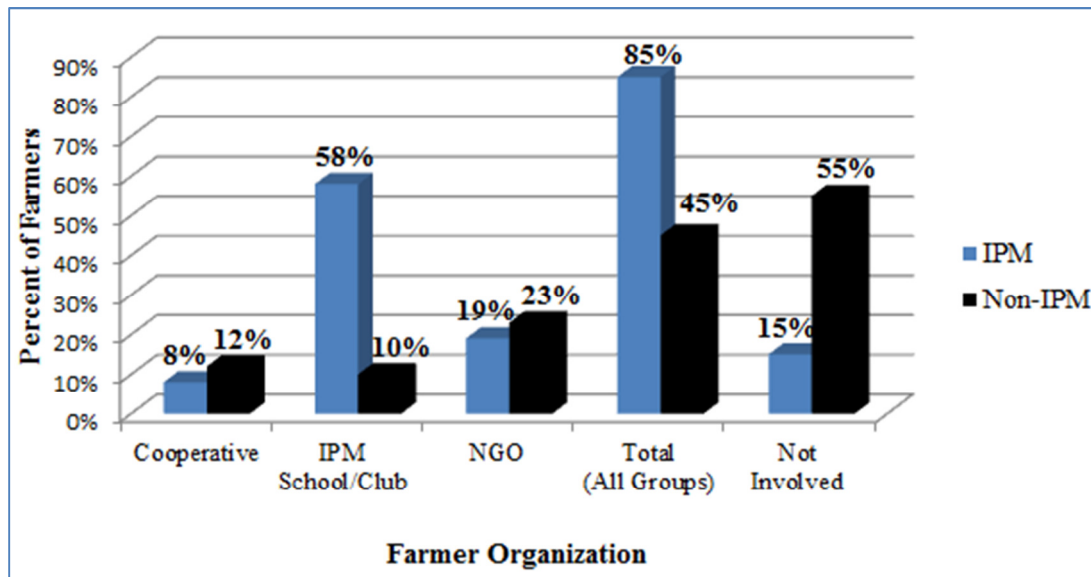
Table 4.2: Summary of Crop Production of Survey Respondents

	Crop	% of Respondents	Hectares in Production			
			Average	Std. Dev.	Min.	Max.
1	Eggplant	44.0%	0.08	0.05	0.02	0.39
2	Tomato	12.0%	0.10	0.09	0.02	0.40
3	Cucurbits	82.0%	0.17	0.16	0.01	1.20
4	Rice	100.0%	0.65	0.51	0.06	3.74
	Vegetables (1-3)	99.7%	0.28	0.24	0.00	1.93
	All Crops (1-4)	100.0%	0.99	0.62	0.14	3.99

Data Source: IPM CRSP Baseline Survey, BARI, Gazipur, Bangladesh.

Figure 4.1 illustrates the participation in three types of farmer organizations: cooperatives, IPM clubs, and NGOs. Eighty-five percent of IPM adopters were involved in some type farmer organizations, whereas only 47% of non-IPM farmers were members of a group. This result suggests that farmers associated with groups may be more likely to adopt IPM technologies. Previous studies have presented similar results, concluding that farmers with connections to groups are more likely to participate in IPM training and adopt IPM technologies than non-member farmers (Ricker-Gilbert et al., 2008; Caviglia-Harris, 2003).

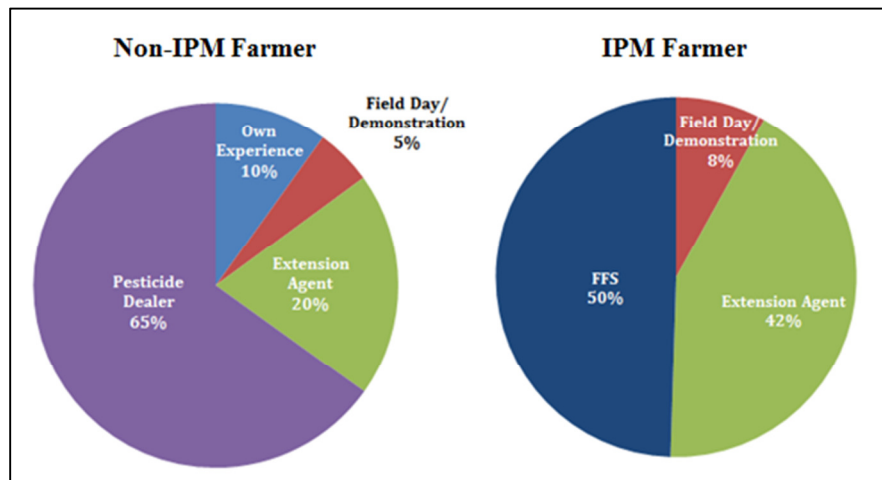
Figure 4.1: Participation in Farmer Organizations



Data Source: IPM CRSP Baseline Survey, BARI, Gazipur, Bangladesh.

Most of the farmers indicated that they had received information about pest management from one of four main sources; however, some participants said that they had learned how to handle pests through their own experience. Figure 4.2 depicts where the farmers gained knowledge about pest management. In this sample, non-IPM and IPM farmers did not gain knowledge about pest management from the same sources. IPM farmers reported obtaining information from field days/demonstrations, extension agent visits, and FFS, whereas the majority of non-IPM farmers received their information from pesticide dealers. A small portion of the respondents from both groups credited field days as their source of IPM information. More so than traditional farmers, IPM adopters commonly received pest information from extension agents. Half of the IPM farmers indicated that they had attended a FFS.

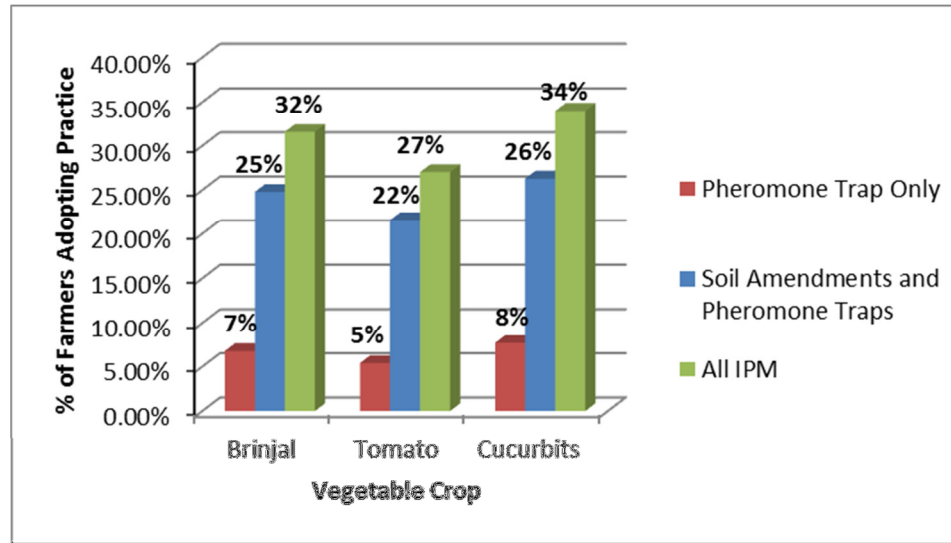
Figure 4.2: Sources of Pest Management Information



Data Source: IPM CRSP Baseline Survey, BARI, Gazipur, Bangladesh.

Figure 4.3 illustrates the percentage of producers who adopted soil amendments and pheromone traps. None of the farmers used soil amendments alone – it was always coupled with the use of pheromones. A small percentage of farmers adopted pheromone traps exclusively. Close to one-third of producers adopted at least one IPM practice. Overall, cucurbit producers had the highest adoption rate, followed by eggplant producers.

Figure 4.3: Adoption of IPM Technologies for Vegetables



Data Source: IPM CRSP Baseline Survey, BARI, Gazipur, Bangladesh.

Several interesting observations can be made from examining the survey data. First of all, 247 (82%) of the participants grew cucurbits and 87 (35%) of those farmers used at least one IPM practice during production. Of the IPM farmers growing cucurbits 97% used sex pheromone traps, which may be indicative of the current popularity of the practice. Furthermore, 75% of these farmers used soil amendments. Sex pheromones were also extremely popular in tomato and eggplant production.

No farmers indicated that they had adopted biological controls or grafting. Although this result may seem surprising at first it is difficult to predict the reasons for the absence of adoption. It is possible that grafted seedlings and beneficial insects were not available in the areas that were surveyed or that pest severity was not high enough to warrant the use of these technologies. The survey did not ask farmers if they adopted Tricho-compost specifically, but instead asked about the adoption of soil amendments in general. Further research is necessary to identify the current availability and adoption of Tricho-compost.

IV.2.3 Estimating Adoption of IPM Technologies

Although the information obtained from the survey is useful to understand how IPM technologies are being used in specific areas of the country, it cannot provide information about the potential for future adoption. In order to estimate the adoption that may result from various dissemination efforts, the study relies on the expert opinion of professionals working at BARI and at MCC.

Three scientists at BARI and one extension expert at MCC provided adoption estimates for six IPM practices. A medium level of adoption is calculated by averaging the four estimates. Low and high adoption projections are obtained using the minimum and maximum estimate for each technology. The three levels of adoption are presented in Appendix Table C.7. It would have been preferable to obtain adoption estimates from other extension workers; however, due to time constraints, additional questionnaires could not be completed. The three scientist projections are similar to those of the extension worker suggesting that their estimates are based on their knowledge of IPM extension programs in addition to their scientific expertise.

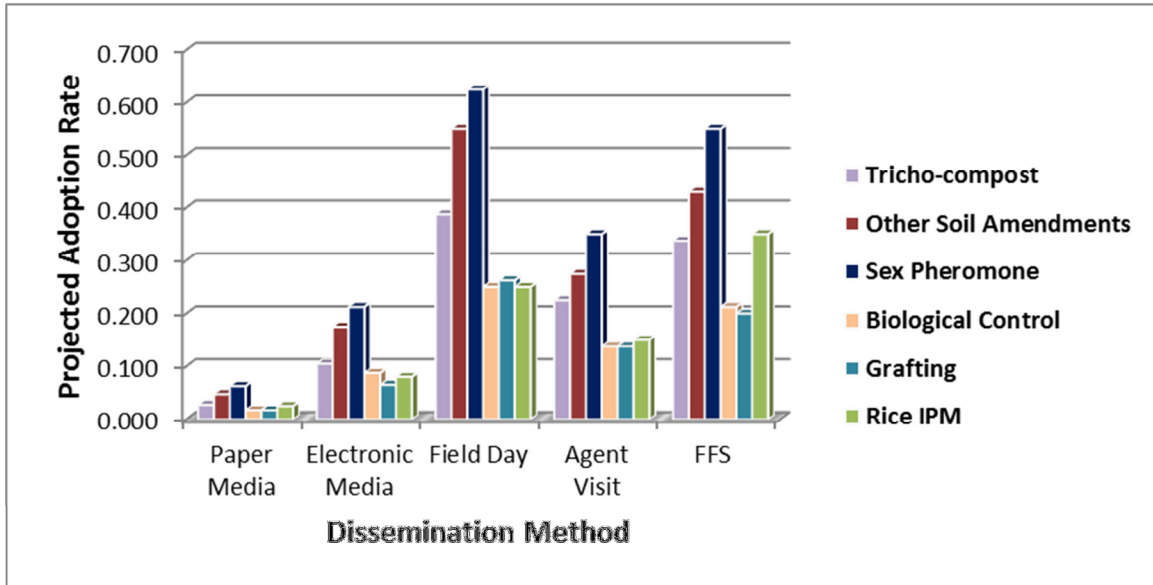
The questionnaire designed to obtain projected adoption rates for the six vegetable technologies did not differentiate between the three vegetable crops. It is assumed that the farmers growing eggplant, tomatoes, and cucurbits are fairly homogenous and have a similar likelihood of adopting the technologies. Socio-economic data from the 2010 IPM Baseline Survey support this assumption. Appendix Table C.10 presents a comparison of the socio-economic characteristics of farmers growing the three vegetable crops. When comparing the participants across the three groups, the average age, household size, farm size, and distance to the closest market differ very little. Additionally, the percentages of participants that are male, are a member of a farmer organization, and adopt IPM are also similar. Variation between the three groups is found when comparing education, experience, and the district location. The tomato farmers have a high average level of education and more years of farming experience. Additionally, the majority of the tomato and eggplant farmers live in Bogra, whereas, the farmers growing cucurbits are more evenly distributed across the three districts. Overall,

farmers growing the three vegetable crops are similar and therefore, the projected adoption rates of the five technologies are used for the applicable vegetable crops.

It is important to note the differences in projected adoption rates between various dissemination methods and across the six different IPM practices. Figure 4.4 illustrates these differences by charting the adoption rate of each practice by the type of dissemination method that would be used to transfer the knowledge to farmers. Among the different extension tactics, it is estimated that farmers receiving IPM information at field days are the most likely to adopt IPM technologies. Paper media has the lowest projected adoption rate, followed by electronic media. Among the three interpersonal dissemination methods, extension agent visits are estimated to have the lowest adoption rate. It is suggested that the differences in projected adoption rates among the dissemination methods is due, in part, to the degree to which the extension mechanism allows farmers to visualize the IPM technology in practice and observe the results. FFS and field days provide farmers with an opportunity to see the technology, whereas, extension agent visits and paper media are rarely able to provide sufficient visual confirmation. To an extent, TV programs also allow farmers to observe an IPM practice, and may be able to change farmers' perceptions more effectively than other media sources.

Between the different IPM practices, it is projected that sex pheromones and soil amendments have the highest average rates of adoption. Biological controls, grafting, and rice IPM practices have considerably lower average rates of adoption. Many of the experts again cite the "visibility" of pest reduction as a reason for the varying adoption rates, noting that farmers are more likely to adopt practices in which the results are visible before harvest. For example, farmers remove dead insects from sex pheromone traps on a daily or weekly basis which gives them confidence in the technology as opposed to using beneficial insects and not being certain if they are reducing the number of pests. Furthermore, practices for which results are clearly visible are more frequently noticed by neighboring farmers who then decide to try the IPM technology with their own crops.

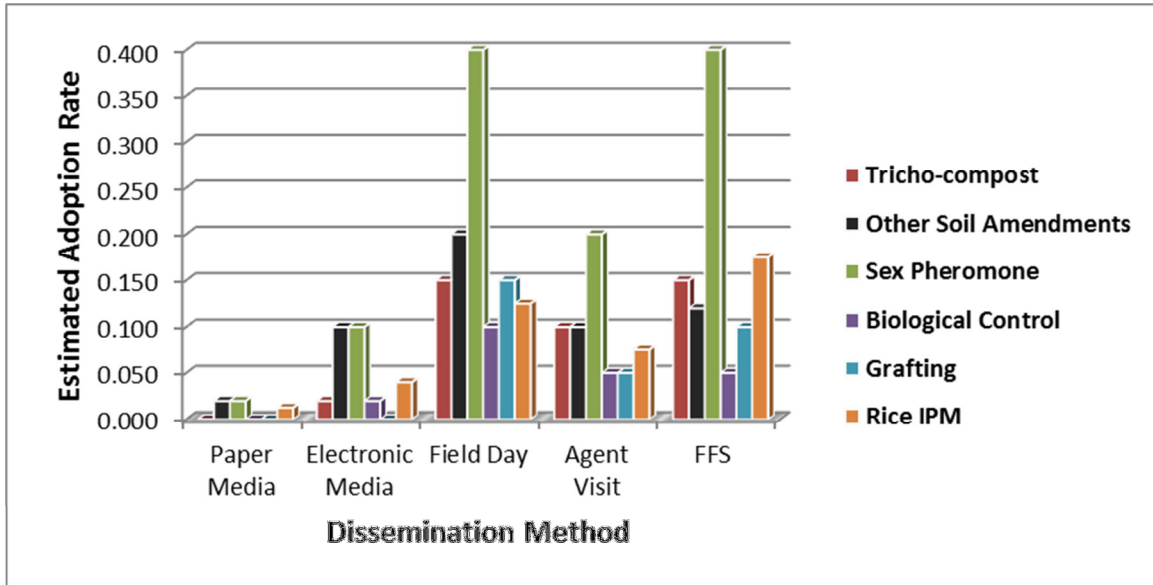
Figure 4.4: Average Projected Adoption Rates for Six IPM Practices Based on Dissemination Method



Data Source: BARI Scientists, Gazipur, Bangladesh.

The variation between the adoption projections is higher in the “low” adoption estimates as depicted in Figure 4.5. Zero adoption is the lower bound for disseminating information about Tricho-compost, biological controls, and grafting through media. The low projections may be the result of several factors, most importantly the concern about insufficient availability of the technologies. Tricho-compost, beneficial insects, and grafted seedlings are not yet accessible across all of Bangladesh; therefore, even if a farmer gains knowledge about the practices, he or she may not be able to purchase the inputs necessary to incorporate the technology in production.

Figure 4.5: Low Adoption Rate Projections for Six IPM Practices Based on Dissemination Method



Data Source: BARI Scientists, Gazipur, Bangladesh.

IV.2.4 Dissemination Costs

The cost of disseminating IPM information varies greatly depending on the extension method. In general, the cost of transferring information to a farmer is lowest using media and increases as the method of dissemination becomes more personal – FFS and agent visits are usually considered the most individualized forms of agricultural extension. To determine the cost of disseminating IPM information to farmers, the total DAE budget and budgets for each extension method were obtained during interviews with DAE administrators. Table 4.3 provides a summary of the extension costs for each method of information transfer. Row four represents the total variable cost of extending agricultural information to farm households using five different dissemination methods. The DAE extends information about many agricultural technologies; however, only the portion of the budget dedicated to IPM is used in this analysis. To determine the portion of the funding that is dedicated to IPM, the overall budgets are multiplied by the percentage of information pertaining to IPM that is transferred by each method. The estimate for the percent of IPM information transferred by each method is based on information provided by the DAE and differs depending on the dissemination method.

The IPM budget for each method is then divided by the total number of farm households reached by that dissemination tactic to calculate the cost of transferring IPM to one household (row 8).

When compared to other studies, such as the 2008 study conducted by Ricker-Gilbert, the per household costs calculated in row 8 of Table 4.3 are considerably lower. This is likely because previous studies typically calculated per household costs based on the total cost to reach a farmer using a particular extension mechanism, but they did not always account for the fact that numerous types of agricultural information unrelated to pest management are also communicated through these channels. For example, in a typical DAE farmer field school only about 27% of the information is related to pest management. The other 73% of the FFS is dedicated to other production and marketing topics such as seed management, harvesting techniques, and record keeping.

Table 4.3: Summary of DAE Dissemination Costs by Extension Method

	Paper Media	Electronic Media	Field Day	Extension Agent	FFS
1. Total Budget for Agricultural Extension	\$114,819	\$110,217	\$355,254	\$32,358,400	\$2,258,877
2. Total Farm HH Reached (All Agricultural Extension)	322,500	2,021,250	462,500	11,376,000	92,500
3. % of total farming HH	2.19%	13.75%	3.15%	77.39%	0.63%
4. Cost to Extend Agricultural Information (\$ per HH)	\$0.36	\$0.05	\$0.77	\$2.84	\$24.42
5. Total Budget for IPM Only	\$32,101	\$30,704	\$95,918	\$9,707,520	\$609,897
6. Total Farm HH Reached (Extension of IPM Only)	322,500	2,021,250	462,500	9,100,800	92,500
7. % of total farming HH	2.19%	13.75%	3.15%	61.91%	0.63%
8. Cost to Extend IPM Information Only (\$ per HH)	\$0.10	\$0.02	\$0.21	\$1.07	\$6.59

Data Source: Department of Agricultural Extension. Dhaka, Bangladesh.

IV.2.5 Baseline Model

In order to make comparisons to the current dissemination strategy it is necessary to construct a baseline model. The baseline model provides a starting point from which to conduct sensitivity analyses to determine the impact of changes in the coefficients and constraints. The setup of the baseline model is described in Chapter Three and a simplified structure is presented in Figure 3.2. The constraints are constructed so that the model parallels the DAE’s current IPM dissemination strategy; however, the constraints are relaxed enough to provide flexibility within the model so that funds can be reallocated to the most economically beneficial practices and dissemination strategies among the four crops.

The detailed results from the baseline model are provided in Appendix Table E.1. Using the average adoption rate, the economic surplus resulting from the optimal dissemination strategy is nearly \$790 million. Table 4.4 presents the differences between how the current dissemination strategy allocates funds among the four crops and the optimal strategy proposed in the first baseline model. With the relaxed constraints, the model moves a portion of the original budget away from eggplant and tomatoes and into cucurbits and rice.

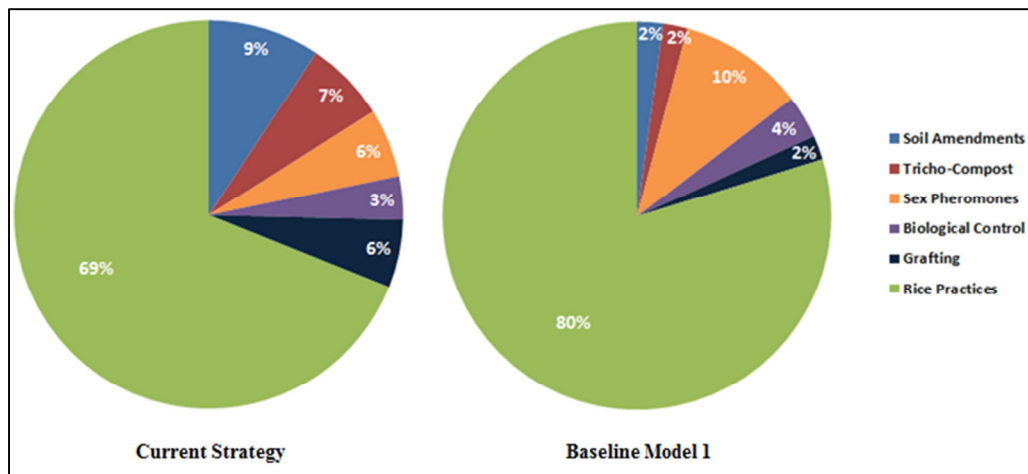
Table 4.4: Comparison of the Dissemination Budget for Baseline Model #1 and the Current Budget – Budget Allocation Among Crops

Crop	Current Budget	% of Current Budget	Baseline Model #1	% of Baseline Budget	Difference between Current and Baseline	% Change from Current Budget
Eggplant	\$1,033,109	10.4%	\$430,737	4.3%	-\$602,372	-58.3%
Tomato	\$1,033,109	10.4%	\$409,272	4.1%	-\$623,837	-60.4%
Cucurbit	\$1,033,109	10.4%	\$1,178,345	11.8%	\$145,236	14.1%
Rice	\$6,872,257	68.9%	\$7,953,230	79.8%	\$1,080,972	15.7%
Total	\$9,971,584	100.00%	\$9,971,584	100.00%		

In order to maximize economic surplus, the model increases the budget for rice and cucurbits by \$1,080,972 and \$145,236, respectively. The total budget for rice is approximately \$7.9 million, which is the maximum amount of the budget that can be allocated to rice because of a binding funding constraint. This lowers the overall budgets for eggplant and tomatoes by nearly \$1.2 million.

Figure 4.6 illustrates the budget allocation among the six different IPM practices. The model selects the maximum allowance for the rice IPM packages, sex pheromones, and biological controls thus decreasing the budgets for soil amendments, Tricho-compost, and grafting.

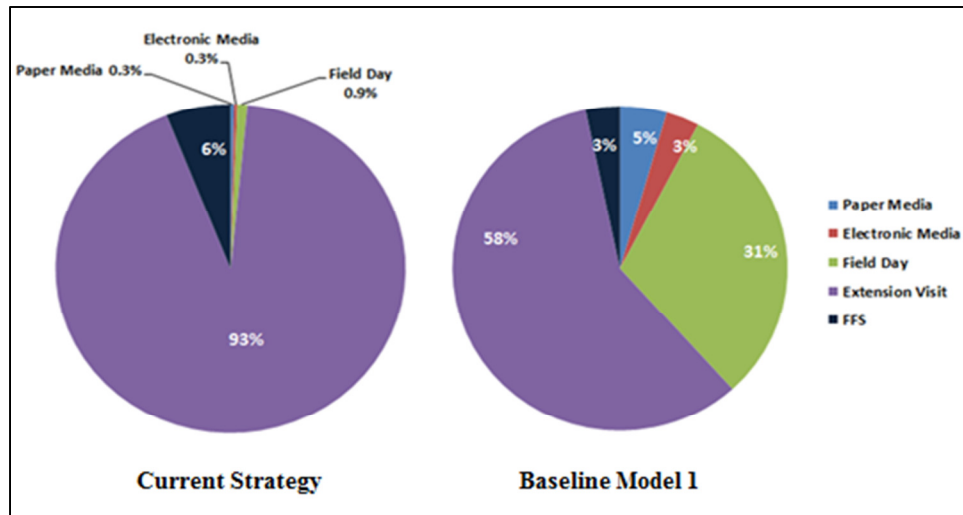
Figure 4.6: Proportion of Budget Allocated to Each IPM Practice



Perhaps more significant is that budget reallocation that occurs among the dissemination methods. The current strategy relies heavily on interpersonal dissemination methods. Currently, over \$9.2 million - almost 93% of the total IPM budget - is allocated to extension agent visits and \$595,000 is apportioned to FFS. Although these budgets are several magnitudes greater than the funds committed to media and field days, the methods struggle to reach a significant portion of the Bangladeshi farmers due to high costs and limited reach. Additionally, the estimated adoption rates for most practices when conveyed to a farmer by an extension agent are lower than the adoption rates expected from field days. Due to the high costs and low adoption impact of extension visits the

baseline model moves away from the interpersonal tactics while significantly increasing the media and field day budgets. Figure 4.7 illustrates the budget reallocation among dissemination methods.

Figure 4.7: Proportion of Budget Allocated to Each Dissemination Strategy



The flexibility provided in the first baseline model offers some insight into the most profitable crops, practices, and dissemination methods; however, the generous constraints allow large portions of the budget to be allocated to a few activities instead of spreading the budget more evenly across each crop and practice. In reality, IPM is usually disseminated in packages for each crop and farmers are encouraged to adopt several complementary technologies. To simulate the dissemination of IPM packages, a second baseline model is created with the addition of two types of constraints. As depicted in Figure 3.2, the first baseline model consists of the constraints on lines 1 – 10. The second baseline model is identical to the first model with the addition of the constraints on rows 11-12. The additional constraints ensure that a minimum level of funding is provided to each crop for a particular practice and that each practice is disseminated by multiple methods. For example, soil amendments can be used for all three vegetable crops, but the dissemination of soil amendments provides the greatest surplus when applied to cucurbits and disseminated through electronic media. In other words, without the additional constraints on rows 10-12 the majority of the budget for soil amendments would be

allocated to cucurbits and electronic media, but in reality the extension program teaches farmers about using soil amendments on all three crops using a variety of extension mechanisms. These additional constraints are constructed to reflect how IPM is currently extended in Bangladesh based on the goals of the DAE extension program.

Table 4.5 presents the budget allocation for the second baseline model. Although the model still allocates the highest possible budget to rice and cucurbits, it is constrained so that the budget is more evenly distributed among the vegetable crops and no more than 69% of the total IPM budget can be allocated to rice practices.

Table 4.5: Comparison of the Dissemination Budget for Baseline Model #2 and the Current Budget – Budget Allocation Among Crops

Crop	Current Budget	% of Current Budget	Baseline Model #2	% of Baseline Budget	Difference between Current and Baseline	% Change from Current Budget
Eggplant	\$1,033,109	10.4%	\$927,357	9.3%	-\$105,752	-10.2%
Tomato	\$1,033,109	10.4%	\$927,357	9.3%	-\$105,752	-10.2%
Cucurbit	\$1,033,109	10.4%	\$1,236,476	12.4%	\$203,367	19.7%
Rice	\$6,872,257	68.9%	\$6,880,393	69.0%	\$8,136	0.1%
Total	\$9,971,584	100.00%	\$9,971,584	100.00%		

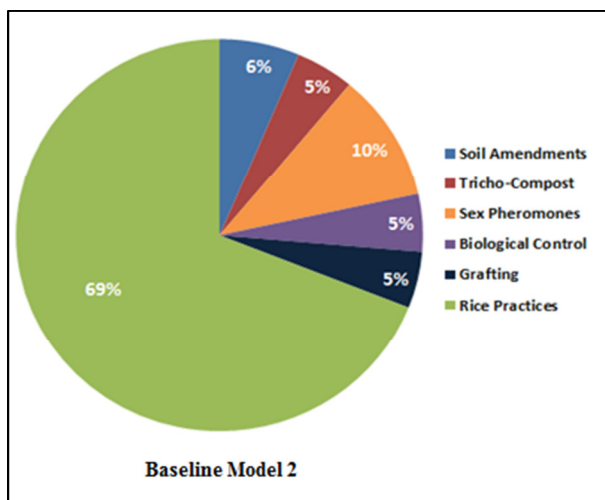
Adding the additional constraints decreases the maximum economic surplus by \$118 million. The differences in total economic surplus between the current strategy and the two baseline models are presented in Table 4.6. By allocating funds to media resources, the surpluses obtained by the baseline models are significantly greater than those in the current strategy. In both baseline models, the surplus obtained from disseminating IPM practices for cucurbit crops are more than 400% higher than the current cucurbit surplus.

Table 4.6: Total Economic Surplus Resulting from Current Dissemination Strategy Compared to Baseline Models

Crop	Current Surplus	% of Total Surplus	Baseline Model #1 Surplus	% of Total Surplus	Baseline Model #2 Surplus	% of Total Surplus
Eggplant	\$5,790,850	2.5%	\$13,102,418	1.7%	\$23,140,100	3.4%
Tomato	\$3,253,628	1.4%	\$6,127,667	0.8%	\$7,354,794	1.1%
Cucurbit	\$10,355,968	4.4%	\$47,580,821	6.0%	\$50,813,083	7.6%
Rice	\$214,579,693	91.7%	\$721,509,323	91.5%	\$589,477,001	87.9%
Total	\$233,980,139	100.0%	\$788,320,229	100.0%	\$670,784,978	100.0%

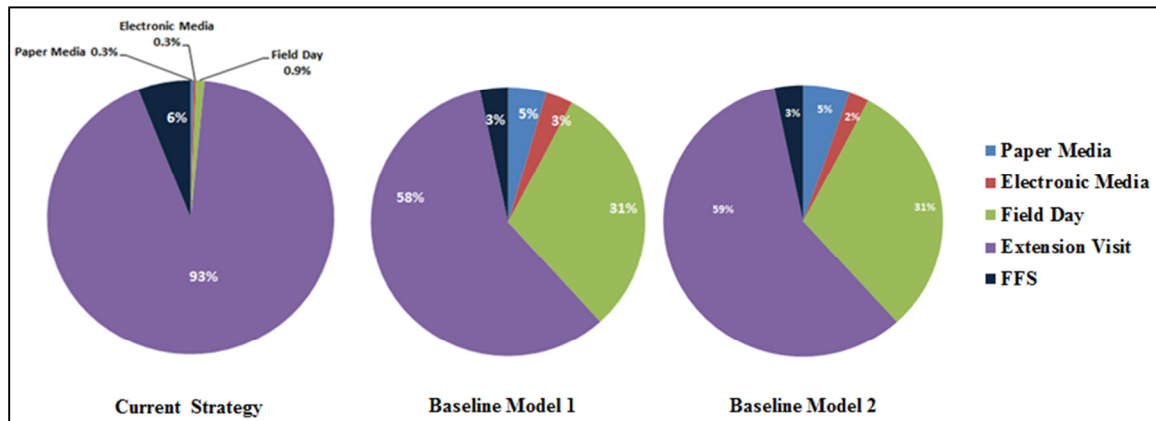
The constraints on the second baseline model ensure that a mix of IPM practices is disseminated for each crop. Figure 4.8 illustrates how the budget is allocated among the six IPM practices in this model. When compared to the first baseline model, more of the budget is allocated to vegetable IPM and the range of funding among the practices is reduced.

Figure 4.8: Budget Allocation Among IPM Practices in Baseline Model 2



Although the additional constraints affect the mix of IPM practices and the budget allocation among the crops, the proportion of the budget allocated to each dissemination method changes very little relative to the first baseline model. Figure 4.9 illustrates how funding is allocated for each dissemination method in the current and baseline models. There is only a 1% change between the first and second baseline models.

Figure 4.9: Budget Allocation Between Dissemination Methods in Three Models



IV.2.6 Sensitivity Analysis

As explained in Chapter Three, parameter certainty is one of the assumptions of a linear programming model that is commonly questioned. Researchers aim to construct models in a way which reflects reality, but it is difficult to know how accurate the model truly is. If some of the data are slightly askew, the outcome of the model may differ drastically or may not change at all. It is important to understand how sensitive the model is to changes in order to fully recognize the robustness or limitations of the results.

Model with Relaxed Constraints

Although it is important to set the constraints of the model in a way that reflects a realistic extension program, one model is designed with only budget constraints allowing the budget to be reallocated in the most cost-effective manner within the overall funding limitations. Without constraints to ensure that each practice and crop be represented in the strategy, the results of the model suggest committing 99% of the budget to rice and

only 1% to vegetables. Among the vegetables, the model uses 0.43%, 0.32%, and 0.22% of the budget to disseminate practices for cucurbits, tomato, and eggplant, respectively. Electronic media is the only dissemination tactic used to transfer information about vegetable technologies to farmers. The other four dissemination methods are utilized to disseminate rice technologies, exclusively. The budgets for electronic media, paper media, and field days are set at the maximum amount allowed by the model with the remainder of the budget divided between extension agents and FFS. The detailed budget allocation is presented in Table E.6 in the appendix.

Adjusting Adoption Level

The rate of farmer adoption of IPM technologies is affected by numerous factors and is difficult to project. Therefore, the model is run with three different levels of adoption to determine how sensitive the outcome is to varying adoption rates. The upper and lower bounds of the adoption estimates provided by the experts at BARI and MCC are used to obtain the “low” and “high” adoption levels for the sensitivity analysis (see Table C.7 in Appendix C).

The detailed results of the sensitivity analysis for the first and second baseline models are presented in Table E.1 and E.2 in appendix E. In the first baseline model, the proportion of the dissemination budget allocated to each crop differs less than 2% among the three different adoption levels and it does not differ at all in the second baseline model. Additionally, the proportion of the budget that is allocated to each dissemination strategy does not change. At the low and average levels of adoption, the mix of IPM practices to which the budget is allocated is very similar. Only at the high adoption level does the model begin to reallocate the budget among the practices. In the first baseline model, the high adoption rate causes nearly 4% of the budget to be reallocated from sex pheromone traps to soil amendments and biological controls. At the average level of adoption the model selects the lowest budget possible for both Tricho-compost and biological controls; therefore, moving to the low level of adoption does not affect the funding allocated to these two practices although they have the smallest adoption rates at the low level. If a minimum level of funding is not required for Tricho-compost and biological controls these practices are not selected in the model.

The results of this analysis suggest that the baseline model is robust to changes in the adoption rates. Although total economic surplus changes dramatically at the three different adoption levels, the proportion that each crop contributes to the total surplus differs by less than 1% and 2% in the first and second baseline models, respectively.

Relaxing the Budget Constraint for Extension Agents

In the first baseline model, the budget for extension agent visits is constrained by requiring a minimum budget of \$5.8 million - enough money to reach 60% of the current farmers contacted by extension agents. However, due to the high costs and the low estimated adoption of IPM resulting from extension visits, the model always selects the minimum budget for this dissemination tactic. To determine if the mix of activities changes when this constraint is relaxed, the model is run with a minimum extension agent budget of \$3.9 million – enough funding to reach 40% of the current farmers contacted by agents in the DAE. As presented in Table 4.7, the mix of dissemination methods changes when the constraint is relaxed, by first allocating the maximum budget allowed for paper media, electronic media, and field days. The farmer field school budget increases by \$242,000 and the remaining budget is allocated to extension visits.

Table 4.7: Budget Allocation Among Dissemination Methods

Dissemination Method	Baseline Model #1	% of Baseline Budget	Model with Relaxed Ext. Agent Cons.	% of Budget
Paper Media	\$449,740	4.5%	\$775,511	7.8%
Electronic Media	\$319,006	3.2%	\$328,172	3.3%
Field Day	\$3,048,652	30.6%	\$3,048,652	30.6%
Extension Visit	\$5,824,512	58.4%	\$5,247,470	52.6%
FFS	\$329,674	3.3%	\$571,778	5.7%
Total	\$9,971,584	100.0%	\$9,971,584	100.0%

Adjusting Rice Productivity

Rice production far surpasses vegetable crops in both tons of production and total value. The aggregate annual crop value for rice is over 35 times higher than eggplant, tomatoes, and cucurbit crops combined and the annual production (in metric tons) of the

crop is over 25 times higher than the three vegetable crops. Since rice is such an integral part of agricultural production and household expenditures, changes in price, productivity and profitability greatly affect Bangladeshi farmers and consumers. To determine how sensitive the mix of selected activities is to changes in rice yield and production cost, the model is run at five different levels of IPM benefits (including Scenario 3, which represents the level of benefits used in the baseline models):

Scenario 1.) 1% cost reduction and 1% yield increase

Scenario 2.) 1% cost reduction and 3% yield increase

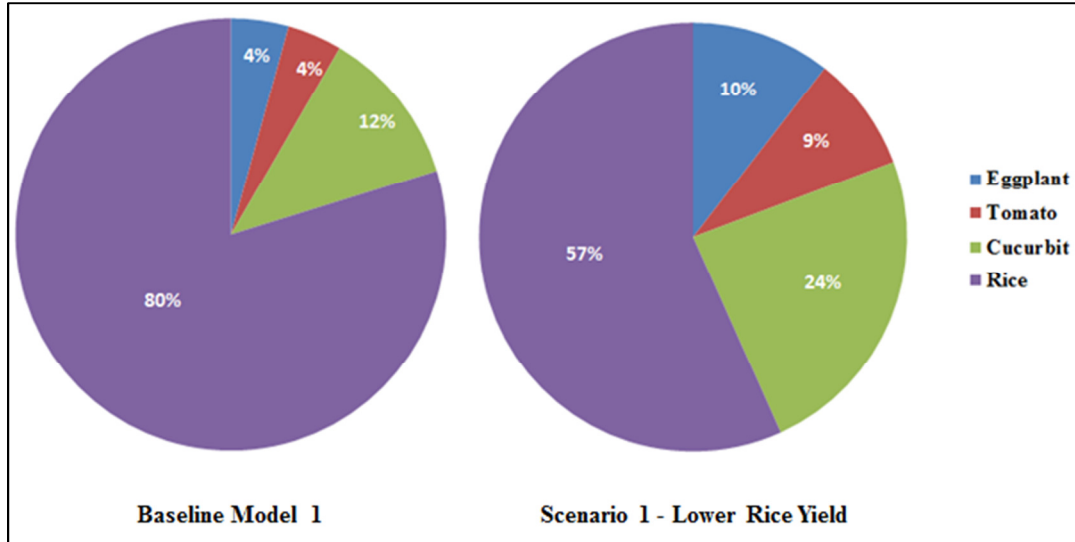
Scenario 3.) 1% cost reduction and 5% yield increase (Baseline Models)

Scenario 4.) 1% cost reduction and 9% yield increase

Scenario 5.) 10% cost increase and 5% yield increase

The detailed results of each of these scenarios are presented in Table E.3 in appendix E. In scenarios 2, 3, 4, and 5 there are only minute changes in the budget allocation among crops, IPM practices, and extension methods. As depicted in Figure 4.10, scenario one is the only model that differs due to a significant decrease in crop yield relative to the first baseline model. When the increase in rice yields using IPM is low (~1% yield increase) the economic surplus gained from this activity decreases to a point at which it becomes more beneficial to reallocate some of the rice IPM dissemination budget to the three vegetable crops. In this scenario, the proportion of funding allocated to rice decreases by 22% of the total budget. With a decline in the rice IPM budget, more money is allocated to disseminate the vegetable technologies. Although more funding is allocated to each of the five vegetable practices, the largest budget increase occurs in the dissemination of soil amendments and biological controls. The proportion of the budget allocated to each dissemination method does not differ among the five scenarios.

Figure 4.10: Budget Allocation Among Crops When Rice Yield Changes



Adjusting Vegetable Yields

Although the production of rice greatly outweighs vegetable production both in quantity and value, it is unclear whether larger benefits from vegetable IPM practices might warrant the reallocation of some of the rice budget among the three vegetable crops. To test the sensitivity to yield increases from vegetable IPM practices the yield of each practice is increased by 10% relative to the first baseline model. Although these yields create much higher gains to vegetable producers, the benefits are not great enough to change the mix of dissemination activities that are selected.

To determine if the budget allocation changes if the productivity of a single vegetable crop increases, two additional specifications are tested. First, the eggplant yields using IPM practices are increased by 10%. The second model is specified with a 10% increase in tomato yields as a result of IPM. Table E.4 in appendix E provides a summary of the results from these models. A 10% increase in eggplant yield shifts almost \$300,000 of the vegetable IPM budget from cucurbit crops to eggplant. The increased eggplant yield also causes funding to be reallocated from sex pheromones to soil amendments. A 10% increase in tomato yield, however, has no effect on the budget allocation among the crops. The same trend found in the first baseline model is also observed when the vegetable yields are increased in the second baseline model.

Adjusting for Diminishing Returns

To account for the diminishing returns associated with increasing a dissemination budget, the surplus benefits from a dollar in the “high” budget categories are set at 75% of the surplus gained from a dollar of the “current” budget. This rate of diminishing returns is the same for both vegetables and rice in the baseline models. It is suspected, however, that the returns from an increased rice budget may diminish at a higher rate than would be the case in vegetables. This suspicion is due to the fact that rice IPM has been emphasized to a greater extent by extension personnel in Bangladesh and therefore, increasing the budget by a certain percentage may not increase the yield by the same amount. Due to limitations in the available data, it is not possible to know if this is the case; however, it is important to understand if this factor would have an effect on the mix of activities selected by the model.

To test the sensitivity of the model to diminishing returns, a new model is specified in which a dollar in the “high” rice budgets provides 60% of the surplus gained by a dollar in the “current” budget. In the new model the return on a dollar in the “high” budgets for the vegetables is maintained at 75% of the surplus gained from a dollar in the current budget. When compared to the first baseline model, the allocation of funding between crops and IPM practices does not vary by more than 1%, but funding is reallocated among dissemination methods. Table 4.8 presents a comparison between the baseline model and the newly specified model. The budgets for electronic media, field days, extension agent visits remain relatively unchanged, but funding for paper media is cut by more than half and is reallocated to FFS. This result occurs because with a lower return on rice, the dissemination of vegetable technologies provides a greater surplus per dollar of the dissemination budget. Funding used for FFS provides a particularly high return; therefore, causing the model to reallocate some of the paper media budget for rice to vegetable FFS.

Table 4.8: Budget Allocation Among Dissemination Methods

Dissemination Method	Baseline Model #1		Model with Change in Diminishing Returns	
	\$ of Budget	%	\$ of Budget	%
Paper Media	\$449,740	4.5%	\$ 198,470	2.0%
Electronic Media	\$319,006	3.2%	\$ 328,172	3.3%
Field Day	\$3,048,652	30.6%	\$ 3,048,652	30.6%
Extension Visit	\$5,824,512	58.4%	\$ 5,824,512	58.4%
FFS	\$329,674	3.3%	\$ 571,778	5.7%
Total	\$9,971,584	100.0%	\$ 9,971,584	100.0%

A model is also run to determine the optimal solution without diminishing returns. If diminishing returns do not exist, the total surplus increases to \$992.7 million and \$840.9 million for Baseline 1 and Baseline 2, respectively. However, the proportions of the budget allocated among the crops, practices, and dissemination methods do not change when compared to the original baseline models.

IV.2.7 Lessons Learned from Shadow Prices

Shadow prices measure the marginal value of an activity (Hillier and Lieberman, 2010). The value of the shadow price for each activity in this model indicates how much the objective function (maximizing economic surplus) will increase if an additional dollar is allocated to the budget of that activity. Likewise, the shadow prices for aggregate budget constraints indicate the amount of additional surplus that would be gained if another dollar was allocated to the budget. Shadow prices equal zero when the constraint is not binding. If the shadow price is nonzero then the constraint is equal to its bound. Shadow prices provide useful information to program coordinators by indicating activities that, given additional funding, would result in the greatest marginal return relative to other activities.

In the first baseline model, the high shadow prices on field days and electronic media indicate the value of these activities. The upper-bound field day budget constraint is binding with a shadow price of \$94.81. This shadow price indicates that \$94.81 of additional economic surplus could be gained by relaxing the constraint by one dollar. The budget constraints for the dissemination of sex pheromone traps and biological controls for cucurbits using field days are also binding. The shadow prices are \$42.03 for each activity.

Although the overall budget constraint for electronic media is not binding, several individual budget constraints on activities being disseminated by electronic media are binding. The “Tricho-compost – electronic media” budget constraints are binding for all of the vegetable crops. The shadow prices indicate that relaxing this constraint by one dollar for eggplants, tomatoes, and cucurbits, could result in an increased surplus of \$48.36, \$11.34, and \$50.84, respectively. Additionally, the budget constraints for the electronic media dissemination of “other soil amendments” are also binding. Relaxing these constraints by one dollar for eggplants, tomatoes, and cucurbits could increase the total surplus by \$73.62, \$39.73, and \$89.94, respectively. The shadow price for the electronic media dissemination of sex pheromone traps and biological controls for cucurbit crops is \$192.68 – the largest shadow price for any vegetable activity.

These shadow prices suggest that additional funding for cucurbits could have the greatest impact if allocated to electronic media dissemination of sex pheromones and biological controls. Whereas, funding for eggplants and tomatoes could have more impact if allocated to the dissemination of Tricho-compost and other soil amendments using electronic media.

IV.2.8 Conclusion

Overall, the results from this study provide some insight about which IPM practices are currently being adopted and the potential for the expanded use of IPM technologies in Bangladesh. The responses from the household survey indicate that soil amendments and sex pheromone traps are commonly used by vegetable farmers in Bangladesh and that they are frequently used together. Many of the farmers in areas of

intensive vegetable production receive IPM information from FFS and extension agent visits, whereas non-IPM farmers most commonly receive pest management information from pesticide dealers.

Adoption estimates obtained from scientists and extension experts indicate that although extension agents are the most widespread source of IPM information it may be possible to increase the adoption of IPM by increasing the number of field days that are conducted around the country and by utilizing more electronic media. The estimates also indicate that the adoption rate may be higher for technologies that offer more visible results throughout production rather than having to wait until harvest to measure the gains. Additionally, experts raise concern about the availability of Tricho-compost, biological controls, and grafted seedlings across the country.

The results from the sensitivity analysis allow several conclusions to be drawn regarding the linear programming model. First of all, several results of the model, such as the budget allocated to field days and FFS, are quite robust. The allocation of funding changes very little between these methods when comparing the models run in the sensitivity analysis. The maximum amount of funding permitted by the budget constraints is committed to field days, whereas, the models allocate a minimum funding level to FFS.

Due to the fact that rice is such a large contributor to agricultural production it must be carefully constrained in the model. The sensitivity analysis that is conducted by changing the rice yields and costs using IPM suggests that if the yield gain from using rice IPM is 1% or lower (when compared to traditional pest management) then additional funding will have a greater economic impact if it is invested in the dissemination of vegetable IPM. However, when the yield increase is greater than 1% the model suggests committing additional funding to disseminating information about rice IPM. It is difficult to determine exactly where the threshold lies; however, determining the current yields resulting from rice IPM is critical as it is a major driver of economic surplus in the model.

The results also suggest that increasing the proportion of the overall budget that is dedicated to mass media may provide additional economic benefits that are not currently

being realized. By reapportioning the dissemination budget, the total economic surplus gained from IPM adoption may increase by more than two-fold.

IV.3 Nepal Study Results

IV.3.1 Introduction

This section presents the results of the econometric analysis of IPM knowledge and adoption in three districts of Nepal. Section IV.3.2 describes the descriptive statistics of the survey participants. The remaining sections describe the results of three models. The first two models assess the factors affecting farmer knowledge of IPM – endogeneity is controlled for in the bivariate probit model. The third model – a two-step endogenous participation model – examines the factors influencing IPM adoption.

The survey used as an instrument for this study was described in Chapter Three and is presented in Appendix A.2. In the 2010 survey, participants were asked a set of demographic questions followed by questions about their membership in various farmer groups, their knowledge and use of IPM, their economic activities, and their access to resources. Participants were also questioned about household decision-making and family health. The primary purpose of the questionnaire is to provide project coordinators at IDE with baseline information about households in three key program areas. The data collected based on this questionnaire are used to examine some of the factors affecting IPM knowledge and practice.

Caution should be exercised when interpreting these results as the small sample may not accurately represent the entire population of Nepalese farmers. Although the sample size limits the conclusions that can be drawn from this study, the analysis can at least spark some interesting questions about the factors affecting IPM awareness and adoption. Furthermore, the results of this study may provide impetus for future research.

IV.3.2 Descriptive Statistics

This survey was completed by 80 respondents in three districts: Lalitpur, Kaski, and Rupandehi. Lalitpur is located in the Central Region near Kathmandu – the capital of

Nepal. Kaski and Rupandehi are located in the Western Region. Each survey site is highlighted in the Nepal district map in Figure B.2 in Appendix B.

Of the survey participants 59 (74%) were women and 21 (26%) were men. Forty (50%) of the participants were from the Lalitpur district, 27 (34%) were from Kaski, and 13 (16%) lived in Rupandehi. Age varied from 19 years to 73 years, with an average participant age of 36. Household size also varied and ranged from one to sixteen members with an average size of six people.

Due to the small sample size and lack of variation within the education variable, education was reclassified into three categories: no formal education, primary education, and education beyond primary school. Twenty-three (33%) of the participants had received no formal education, 19 (27%) had completed primary education, and 28 (40%) had received education after primary school. Post-primary education included middle and high school, college, and further vocational training. Table 4.9 presents a summary of the descriptive statistics for the socio-economic variables used in the model.

Table 4.9: Descriptive Statistics of Socio-Economic Characteristics

Variable	Description	Obs.	Average	Std. Dev.	Min.	Max.
RES_GENDER	1= female	80	0.74	0.44	0	1
RES_AGE	in years	73	36.14	10.27	19	73
RES_AGE2	years squared	73	1,410	860	361	5,329
RES_NOED	1 = no education	70	0.33	0.47	0	1
RES_PRIM	1 = primary education	70	0.27	0.45	0	1
RES_MHC_ED	1 = education beyond primary	70	0.40	0.49	0	1
HHSIZE	# of members in the household	80	5.98	2.67	1	16
<i>District:</i>						
LALITPUR	1 = lived in Lalitpur	80	0.50	0.50	0	1
KASKI	1 = lived in Kaski	80	0.34	0.48	0	1
RUPANDEHI	1 = lived in Rupandehi	80	0.16	0.37	0	1

Data Source: Survey for Women's Participation in IPM CRSP, IDE Nepal, Lalitpur, Nepal

The majority of the survey participants (61.3%) were considered Brahmin and Chhetri – two of the highest castes in Nepalese society. Only 5% of the respondents represented the Dalit class – Nepal's lowest ranked caste. Fourteen of the respondents

were from the Madhesi ethnicity which represents the native people living in the Terai region. The remaining 13 participants were of the Janajati ethnicity, representing the indigenous people of Nepal. Table 4.10 shows the number of respondents from each caste.

Table 4.10: Caste/Ethnicity of Survey Respondents

Caste/Ethnicity	# of Respondents	% of Respondents
Brahmin and Chhetri	49	61.3%
Janajati	13	16.3%
Madhesi	14	17.5%
Dalit	4	5.0%

Data Source: Survey for Women's Participation in IPM CRSP, IDE Nepal, Lalitpur, Nepal

Although there was not enough variation in the data to propose the effects that a person's caste or ethnicity may have on their IPM knowledge and use, a few interesting trends were observed. 75% of the respondents from the Dalit caste did not adopt any IPM practices and 43% of the Madhesi class did not adopt. This observation suggests that, when compared to the Janajati, Brahmin and Chhetri groups, farmers in lower castes adopted fewer IPM practices. Table 4.11 presents the rate of adoption and the average number of practices adopted for each of the four groups. The Janajati and Brahmin/Chhetri groups adopted more practices than the lower classes. This result will be discussed in Chapter Five as it may have several implications for future research.

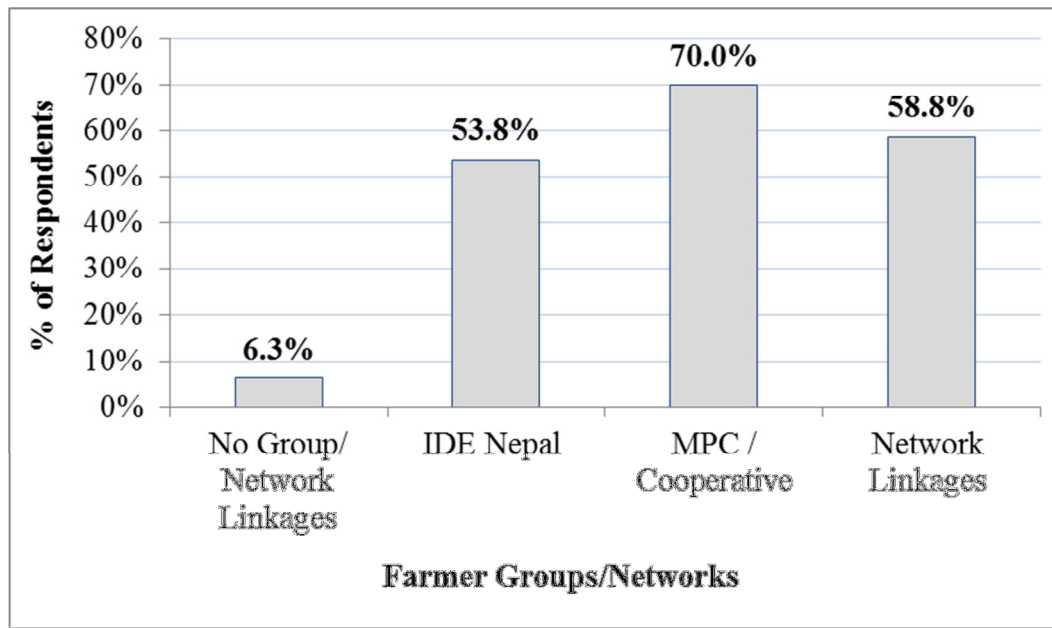
Table 4.11: IPM Adoption of Respondents by Caste/Ethnicity

Caste/Ethnicity	# of IPM Practices Adopted				Avg. # of IPM Practices Adopted
	0	1 or 2	3 or 4	5+	
Dalit	75.0%	0.0%	25.0%	0.0%	1.0
Madhesi	42.9%	14.3%	28.6%	14.3%	2.0
Janajati	7.7%	23.1%	46.2%	23.1%	3.5
Brahmin and Chhetri	18.4%	20.4%	30.6%	30.6%	3.1

Data Source: Survey for Women's Participation in IPM CRSP, IDE Nepal, Lalitpur, Nepal

Group membership or affiliation may influence farmer knowledge and adoption of IPM. Survey participants indicated two main types of group affiliation: IDE Nepal and MPC/Cooperatives. Forty-three (54%) of the participants had worked with the IDE/ IPM CRSP project and 56 (70%) respondents were members of MPC's or cooperatives. Although 70% of the participants reported membership in at least one group, only 47 (59%) participants indicated that they had access to agricultural information and inputs through networks and other linkages. It is difficult to deduce why some member-farmers did not report having network linkages. Farmers may be members of organizations that do not provide agricultural inputs/information or they may choose not to utilize the resources that the group provides. Figure 4.11 depicts the affiliation of respondents with these three categories.

Figure 4.11: Respondents' Affiliation with Agricultural Groups/Networks

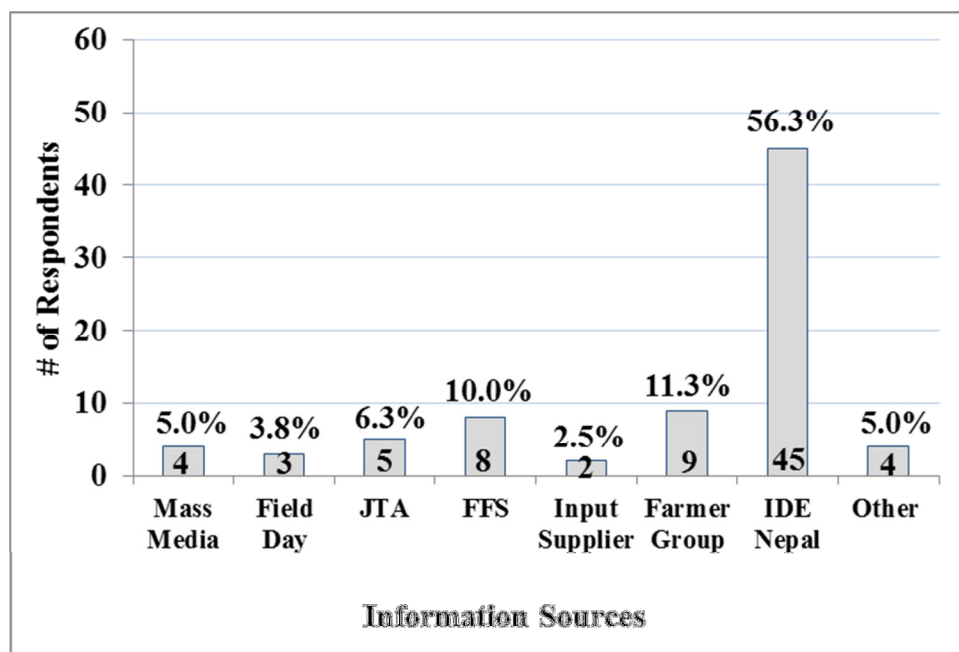


Data Source: Survey for Women's Participation in IPM CRSP, IDE Nepal, Lalitpur,

Survey respondents received their initial exposure to IPM from a variety of sources as depicted in Figure 4.12. The vast majority learned about IPM from working with IDE Nepal. Nine respondents credited farmer groups for being their initial information source and eight participants cited farmer field schools. Less than 10% of the participants cited mass media, field days, extension agents (JTA), or input suppliers as

providing initial IPM information. It is surprising that more farmers did not credit these four information channels as primary information sources because they tend to be the channels that reach broad audiences. The high percentages of farmers citing the three more interpersonal channels (IDE, farmer groups, FFS) may be the result of a sample selection issue, an inadequate survey instrument, or may truly reflect the population. These possibilities and the implications for future studies will be discussed in Chapter Five.

Figure 4.12: Reported Sources of Initial IPM Information

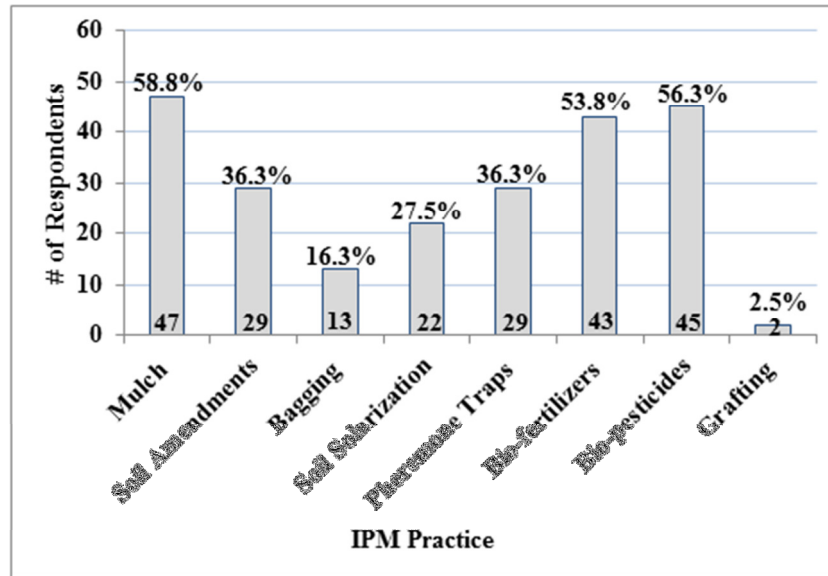


Data Source: Survey for Women's Participation in IPM CRSP, IDE Nepal, Lalitpur, Nepal

Twenty-three (29%) respondents indicated that they had received some type of IPM training; however, the source of this training was not explicitly identified. Fifty of the respondents cited IDE Nepal as a supplier of IPM information, making it reasonable to predict that the majority of respondents might have received their training from IDE Nepal rather than from government extension programs. Just over 75% of the respondents indicated that they incorporated at least one IPM practice in their production of vegetables. Mulching, bio-fertilizers, and bio-pesticides were the most popular IPM practices, followed by the adoption of soil amendments and pheromone traps. Grafting

technology was adopted the least, possibly due to the higher level of training and inputs required for successful adoption. Figure 4.13 depicts the number of respondents (and percentage of total respondents) adopting each of the eight different IPM practices.

Figure 4.13: IPM Practices Used by Survey Participants



Data Source: Survey for Women's Participation in IPM-CRSP, IDE Nepal, Lalitpur, Nepal

The other explanatory variables used in the model were access to credit (CRDT_ACC), total annual household income (HHINC), the percentage of total income from vegetables (VEG_PCT), and access to irrigation (IRR_H20). Two-thirds of the respondents said that they had access to credit. The range of annual household income was quite large. The highest income was 1,300,000 NR (~ \$18,056 USD) and the lowest was 8000 NR (~ \$111 USD). Income resulting from vegetables ranged from 0 percent to 100 percent of the total income reported. Two-thirds of the respondents indicated that they had access to irrigation. Table 4.12 provides the descriptive statistics for the dependent and explanatory variables.

Table 4.12: Descriptive Statistics for Variables Used in the Model

Variable	Description	Obs.	Average	Std. Dev.	Min.	Max.
NET_LINK	1 = had network linkages to obtain ag information and inputs	62	0.60	0.49	0	1
TRAIN_IPM	1 = had received IPM training	62	0.27	0.45	0	1
RES_GEND	1 = female	62	0.74	0.45	0	1
RES_AGE	respondent age in years	62	36.03	10.69	19	73
RES_AGE2	age (in years) squared	62	1,410.71	904.06	361	5,329
RES_NOED	1 = no education	62	0.32	0.47	0	1
RES_PRIM	1 = attended primary education	62	0.27	0.45	0	1
RES_MHC_ED	1 = attended post-primary education	62	0.40	0.49	0	1
HHSIZE	# of members in the household	62	6.16	2.71	1	16
CRDT_ACC	1 = had access to credit	62	0.71	0.46	0	1
HHINC	total annual HH income (1,000 Nepalese rupees)	62	166.33	198.50	8	1,300
VEG_PCT	vegetable income / total income	62	34.68	30.20	0	100
IRR_H20	1 = access to irrigation	62	0.68	0.47	0	1
LALITPUR	1 = lives in Lalitpur district	62	0.53	0.50	0	1
RUPANDEHI	1 = lives in Rupandehi district	62	0.18	0.39	0	1
KASKI	1 = lives in Kaski district	62	0.29	0.46	0	1

Data Source: Survey for Women's Participation in IPM CRSP, IDE Nepal, Lalitpur, Nepal

IV.3.3 Measuring IPM Awareness Using a Univariate Probit Model

The first step toward getting farmers to adopt IPM practices is to raise awareness about the existence of IPM and the efficacy of IPM practices. Farmers can gain knowledge about IPM through many sources including friends, extension personal, mass media, etc. After a farmer gains knowledge about IPM, he or she may attempt to gain more information about the technologies by seeking advice from extension personnel, friends, or input suppliers.

This section will concentrate on the factors affecting basic knowledge of IPM, that is, if a farmer knows about IPM or does not. It should also be noted that some farmers may not be familiar with the term “IPM” but may be familiar (or even adopting) integrated pest management practices. The issue of survey terminology will be addressed in Chapter Five.

A probit model is used to estimate the impact of network linkages and other factors on farmers’ knowledge of IPM. Question #6 in the household survey asked farmers if they had knowledge about IPM practices before the IPM CRSP program was introduced by IDE. The response to this question is either ‘yes’ or ‘no’ and is used as the binary dependent variable in a probit regression with a vector of socio-economic variables and other factors as independent variables. The results are presented in Table F.1. The coefficients resulting from the preliminary regression cannot be easily interpreted; however, they indicate if the explanatory variable positively or negatively affects the probability that farmers are aware of IPM. The marginal effects are calculated to determine the level of impact resulting from each variable. The marginal effect for continuous variables is calculated using the mean value of each variable; therefore, the coefficients should be interpreted as increases or decreases from the mean. The marginal effects for dummy variables are calculated for a change from zero to one. The marginal effects are presented in Table F.2.

The results indicate that network linkages have a statistically significant positive effect on IPM knowledge at the 5% level. The dy/dx coefficient (the marginal effect) of 0.372 indicates that a farmer with network linkages is 37.2% more likely to have IPM

knowledge than a farmer without network linkages, holding all other factors constant. The respondent's age is statistically significant at the 5% level and negatively affects knowledge of IPM. This result is consistent with current literature that suggests that increased age may also be associated with a farmer's resistance to new technologies because older farmer are more hesitant to assume risk from new practices and less willing to make investments in the farm (Mauceri et al., 2007). Education level is also statistically significant. Respondents with a primary education are 55% more likely to know about IPM than those with no formal education. Respondents with post-primary education are 67% more likely to know about IPM compared to the base group with no formal education. Household income is significant at the 10% level but the marginal effect is quite small. Scaled by 10,000 Nepalese rupees, the coefficient indicates that an increase in annual HH income of 10,000 NR (~\$139 USD) results in a 0.1% greater probability of having awareness of IPM. The percent of income resulting from vegetable production is significant at the 5% level. The model indicates that a one percent increase will result in a 1.1% greater likelihood that the farmer has knowledge of IPM.

Using the 'predict' command in Stata, the model predicts the probability that each observation would have some level of IPM knowledge (StataCorp, 2007). Probabilities greater than or equal to 0.51 are coded as '1' indicating that the respondent would be aware of IPM while probabilities of less than 0.51 are coded as '0'. The two-way table presented in Table 4.13 shows the number of correct and incorrect predictions. An accuracy ratio is calculated by dividing the number of correct predictions by the total number of predications. This probit model correctly predicts the outcome 87% of the time, indicating that the model is fairly accurate.

Table 4.13: Accuracy of Predictions Using a Probit Model Measuring Knowledge

		Predicted	
		0	1
Actual	0	37	4
	1	4	17

Accuracy of Prediction =	87.1%
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IV.3.4 Measuring IPM Awareness Using a Bivariate Probit Model

Section IV.3.3 described the results for the model using a univariate probit model. Analysis using a bivariate probit model is conducted to control for endogeneity within the NET_LINK variable. This specification is more sophisticated because a second equation is incorporated to control for factors affecting a farmer's ability to maintain network linkages. The first equation (the structural equation) in the bivariate model is identical to the probit specification described in Section IV.3.3. Equation two uses NET_LINK as the dependent variable and introduces IRR_H20 as an instrumental variable. The results of this model are displayed in Table F.3 in the appendix. The marginal effects are incorporated in the results table in the dy/dx column. They are calculated to determine when knowledge in the structural equation equals one. The marginal effects are calculated at the mean for continuous independent variables and for a discrete change from zero to one for binary independent variables.

After correcting for endogeneity in the model, education has a significant positive effect on farmer knowledge at the 5% level. Age is significant at the 5% level indicating that older farmers are less likely to know about IPM. Credit access, HH size, and vegetable contribution to total income were significant at the 10% level.

The significance of network linkages increases from the 5% level in the univariate probit to the 1% level in the bivariate probit. The marginal effect for NET_LINK is calculated using two methods. Calculating the partial effect at the average (PEA) results in a marginal effect of 0.65. On the other hand, calculating the average partial effect (APE) provides a more modest marginal effect of 0.47, indicating that a farmer with network linkages is 47% more likely to have knowledge of IPM compared to a farmer without network linkages. The APE is considered to be the more appropriate calculation for the marginal effect of binary variables (Wooldridge, 2009).

Interestingly, the results from the second equation, estimating participation in NET_LINK, indicate that access to irrigation, location, annual HH income, and vegetable income significantly affect the probability of a farmer having network linkages for agricultural inputs and information. IRR_H20 is significant at the 1% level indicating that

a farmer with access to irrigation is more likely to have network linkages. Farmers in Lalitpur and Rupandehi are more likely to have network linkages than those in Kaski (which was the base group). Annual HH income and vegetable income are significant at the 1% and 5% levels, respectively.

In Stata, the post-estimation command “suest” combines the estimation results and associated covariance matrices of multiple models (StataCorp, 2007). Table F.4 displays the combined results from the univariate and bivariate probit models. The models are tested using the “testnl” command which tests if the non-linear models are statistically different. The null hypothesis is that the equations are equal. The result of this test, shown in Table F.5, provides evidence to reject the null hypothesis in favor of the alternative that the models are statistically different. The result provides support for the suspicion of endogeneity in the first model and justifies the decision to use a bivariate model for the estimation.

To test the predictive ability of the bivariate probit model, the predicted values of the dependent variable are compared to the actual values. Table 4.14 presents the two-way table constructed for the comparison. Knowledge scores of greater than or equal to 0.59 are reclassified as 1 and lower scores are zeros. The bivariate model predicts success correctly for 81% of the respondents.

Table 4.14: Accuracy of Predictions Using a Bivariate Probit Model to Measure Knowledge of IPM

	Predicted		
Actual		0	1
	0	35	6
	1	6	15

Accuracy of Prediction	=	80.6%
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IV.3.5 Measuring the Impact of Network Linkages on IPM Adoption

The ultimate goal of technology dissemination is to encourage adoption among farmers. Farmers adopt practices that provide them with greater utility than their current production methods (Mauceri et al., 2007). IPM packages are often introduced to combat several pest issues for a particular crop; however, farmers are more likely to test simple,

less risky technologies first before adopting the entire package. The trial period provides them with an opportunity to evaluate the new practice before investing more time and money into further adoption. This section analyzes the factors that affect the adoption of IPM.

The questionnaire used in this study asked farmers if they adopted any of the following eight IPM practices: mulching, bagging, bio-pesticides, bio-fertilizers, soil amendments, pheromone traps, soil solarization, and grafting. This study uses a two-step endogenous participation model to determine the factors that affect a farmer's level of IPM adoption. Instead of using an ordinal dependent variable ranging from zero to eight, a continuous variable is created by calculating the percent of IPM practices adopted by each farmer.

A two-stage model is used to account for the endogeneity in the NET_LINK explanatory variable. The reduced equation presented in Chapter Three is estimated using a probit model. The structural equation is then estimated using OLS (Nawata, 1994). The results from this model are presented in Appendix Table F.6. The significance of each variable is denoted with asterisks. One, two or three asterisks correspond to significance levels of 10%, 5%, or 1%, respectively.

Network linkages have a significant effect on adoption at the 1% level. The result suggests that farmers with network linkages are likely to adopt 32% more IPM practices than farmers without network linkages. Two specific types of network linkages are: (1) being a member of a MPC and (2) working with IDE. Table 4.15 presents a two-way table that compares IPM adoption between MPC-member farmers and farmers who are not affiliated with an MPC. The table shows that 30% of MPC-member farmers adopt five or more IPM practices compared to only 12.5% of non-member farmers. Table 4.16 provides a similar table comparing adoption rates between IDE affiliated farmers and farmers with no connection to IDE. Again, affiliated farmers are more likely to adopt IPM practices. None of the non-IDE farmers adopt five or more practices, whereas, 46.5% of IDE farmers do adopt. The majority of non-affiliated farmers do not adopt any IPM practices. Of the IDE farmers, only 2% do not adopt any of the technologies.

Table 4.15: IPM Adoption of MPC-member Farmers

	# of IPM Practices Adopted			
	0	1 or 2	3 or 4	5+
Non-Member	25.0%	20.8%	41.7%	12.5%
MPC - Member	23.2%	17.9%	28.6%	30.4%

Data Source: Survey for Women's Participation in IPM CRSP, IDE Nepal, Lalitpur, Nepal

Table 4.16: IPM Adoption of Farmers Working with IDE

	# of IPM Practices Adopted			
	0	1 or 2	3 or 4	5+
No IDE Affiliation	48.6%	37.8%	13.5%	0.0%
IDE	2.3%	2.3%	48.8%	46.5%

Data Source: Survey for Women's Participation in IPM CRSP, IDE Nepal, Lalitpur, Nepal

Location also has a significant effect on IPM adoption. Farmers in Lalitpur and Rupandehi adopt 28% and 45% fewer IPM practices than farmers in the Kaski, the base group district. There are several possible explanations for this result. Greater pest pressure in Kaski may result in greater demand for IPM practices. On the other hand, more IPM programs may focus on the Kaski district creating greater farmer awareness and providing more training about IPM. These possibilities will be discussed further in Chapters Five

Credit access significantly influences adoption as well. Farmers with access to credit adopt 14% more IPM practices than farmers with no access. Credit is often necessary for the initial investment needed to change production tactics and adopt new technologies. If credit is not available to farmers then they may not be able to take the first step towards adoption.

CHAPTER V: SUMMARY AND CONCLUSIONS

V.1 Introduction

Chapter Five summarizes the outcome of the research and highlights the most pertinent findings. Limitations of the project are noted and suggestions for future research are provided. Finally, Section V.4 presents the conclusions and implications resulting from this study.

V.2 Summary

The overall objective of this study is to examine how IPM information is currently being diffused in two South Asian countries, Bangladesh and Nepal, and to use economic models to suggest improved dissemination strategies. In Bangladesh, a linear programming model is used to identify how IPM extension budgets can be more effectively allocated among different crops, IPM practices, and dissemination mechanisms. In Nepal, an econometric analysis is used to determine the factors that influence a farmer's awareness and adoption of IPM. The goal of this study is to identify communication channels that are utilized by farmers that may be able facilitate more efficient transfer of IPM information.

Data for the Bangladesh study were collected from several sources including, BARI scientists and reports, extension personnel from the DAE and local NGO's, field-level enterprise budgets, and statistical databases managed by the Bangladesh Bureau of Statistics and the Bangladesh Ministry of Agriculture. Additionally, a household survey conducted by BARI is used to evaluate the current adoption of IPM practices in three districts of Bangladesh. For the econometric analysis examining IPM in Nepal, data were obtained from a household survey conducted by IDE in three districts. Information about current IPM dissemination strategies was obtained through interviews with government and NGO personnel during a research trip to Bangladesh and Nepal in June/ July of 2010.

An economic surplus analysis is used to estimate the economic impact of the current IPM dissemination strategy in Bangladesh. A linear programming model is then utilized as a tool to suggest alternative dissemination strategies that may provide greater

economic benefits. The model represents the dissemination strategy employed by the Bangladesh Department of Agricultural Extension to diffuse IPM information for four crops: eggplant, tomatoes, cucurbits, and rice. Five vegetable technologies were included in the model: Tricho-compost, other soil amendments, sex pheromones, biological controls, grafting. Rice IPM is incorporated as a package that includes handpicking, perching, and biological controls. As a starting point for sensitivity analyses, two baseline models are developed. Due to the uncertainty of some of the parameters, several sensitivity analyses are conducted to evaluate the robustness of the model.

The results from the baseline models and sensitivity analyses suggest that, relative to other dissemination methods, field days are the most cost-effective method of information transfer due to the moderate costs, widespread reach, and high adoption rate. A greater economic surplus could also be obtained by reallocating funding from extension agent visits and FFS to field days and electronic/paper media. The shadow prices suggest that increasing the budget to vegetables (specifically cucurbits and eggplant) could provide an economic advantage. Furthermore, the high shadow prices for sex pheromone traps and biological controls indicate that a greater surplus could be achieved with additional investment in these activities. Overall, the model is fairly robust to changes in the parameters. However, it is important to note that due to the magnitude of rice production, the model is sensitive to changes in the level of benefits (i.e. yield increases and cost reductions) resulting from rice IPM. Program coordinators must carefully evaluate how they want to emphasize rice IPM relative to vegetable IPM based on the program budget and the needs of farmers in a project area.

A bivariate probit model is used to evaluate the factors affecting farmer awareness of IPM in Nepal. This model is preferred to the univariate probit model because it controls for the endogeneity of farmer participation in network linkages. The model suggests that farmers with network linkages, such as being a member of a MPC or farmer organization, are 47% more likely to have knowledge about IPM practices. Age and education also significantly influence farmer awareness of IPM. Older farmers are less likely to have knowledge about IPM technologies. The results also suggest that farmers with some level of formal education are more likely to have awareness of IPM than

farmers with no formal education. Farmer knowledge also differs by location indicating that IPM may be disseminated more aggressively in certain areas of the country.

A two-step model controlling for endogenous participation in network linkages is used to estimate adoption of IPM technologies, using the percentage of IPM technologies adopted as the dependent variable. Network linkages have a significant effect on the adoption of IPM at the 1% level. Farmers with network linkages will likely adopt 32% more IPM practices than farmers without network linkages. Thirty percent of MPC-member farmers adopt five or more IPM practices compared to only 12.5% of non-member farmers.

V.3 Limitations and Suggestions for Future Research

In the linear programming model utilized in this study, it is assumed that the benefits of IPM practices and dissemination methods are independent of one another and that their benefits are linearly additive. In reality, farmers may learn about IPM practices from a number of different dissemination methods and each exposure to IPM information may build on the farmers' perceptions and promote the sequential or simultaneous adoption of multiple technologies. In such a case, the complementarity of these technologies causes the yield and cost benefits to be determined by the interactive nature of the practices instead of the value being independent and additive. More research is needed regarding the interaction between extension methods and the farmers' perceived benefits of each method. For example, it may be the case that mass media acts as a "primer" that encourages farmers to seek out more information about IPM from field days and more interpersonal methods. It is difficult for interpersonal extension programs to reach all farmers; therefore, dissemination methods that motivate farmers to seek out the information on their own may be an integral part of effective program design. To employ an effective extension strategy, it is important to consider how communication channels can be used to influence farmer perceptions of agricultural practices and ultimately encourage the adoption of new technologies.

The sensitivity analysis presented in Chapter Four indicates that benefits from rice IPM have the potential to greatly change the mix of extension activities selected. The

benefits of rice IPM and the level of technology adoption are estimated in this analysis using expert opinions of scientists and data from previous studies. This model could be improved by determining the exact benefits and adoption rates of IPM for rice, as this information would provide better support to justify the reallocation of funding within the extension budget. Considering this study limitation, the results of the LP should be interpreted with care.

The occurrence and severity of pest pressures affect the farmers' desire and need to adopt IPM technologies. It is important to understand the type and severity of pest problems across a program area to most effectively target dissemination efforts. Future studies could greatly contribute to the current literature by conducting an assessment of pest pressures in different regions of South Asia. Incorporating GIS mapping technologies could play an integral role in this assessment by providing spatially explicit information about areas used intensively for agriculture. These data could help extension programs target their dissemination efforts more efficiently. Additionally, determining how much IPM information farmers currently receive and estimating the level of IPM technology adoption across both countries is vital to understanding the success of extension programs.

Care must be exercised when wording household-level surveys, especially in circumstances when the questions will be translated into a local language. It is important for social scientists, physical scientists, and enumerators to work together to ensure that the correct questions are being asked. Field-testing the survey tool is also critical to understand how participants will interpret the questions. In this study, we suspect that phrases such as "mass media," "electronic media," and "paper media" may not have translated well and therefore, the responses that enumerators received may not reflect the actual use of these dissemination techniques. Providing descriptions of various dissemination methods may be more effective than using general terms that are commonly used in technical literature.

The small dataset for the Nepal study limits the conclusions that can be drawn about the importance of networks and linkages to agricultural information. Little is known about the potential for IPM information to be communicated to farmers through

MPC's. Research focusing on the effectiveness and sustainability of MPC's would be valuable to determine if these groups should be targeted with information about IPM and other technologies.

Neither study concentrates on the differences in knowledge or adoption of IPM between male and female farmers. Gender issues, however, are an important consideration when designing an extension program. As societies evolve, women's roles can change in significant ways. In South Asia, women have become more involved with the production of vegetables and could benefit from information about IPM. The DAE has been proactive in addressing the needs of both genders by incorporating men and women in their FFS program. Other dissemination methods may be more effective if gender is considered. For example, broadcasting television shows at times that are convenient for women may provide additional benefits that are not currently realized. Current research about women's involvement with agricultural production and household decision-making would be essential to develop extension programs that can effectively target both male and female farmers.

The changing government regulations for biopesticides and pheromones will likely influence how the technologies are marketed in Bangladesh and Nepal. In July of 2010, the government of Bangladesh approved the import and sale of pheromones – a policy that is quickly changing the industry and creating opportunities for private companies to thrive. The role of private companies has been largely overlooked in the literature, but is becoming an important component of IPM extension. More research on private stakeholders and the potential interaction between public and private organizations is needed.

Finally, little is known about the changing role of mass media resources in South Asia and the potential for media to change farmers' perceptions by promoting effective agricultural technologies. With the increasing availability of televisions, cell phones, and even computers, it may be possible to better utilize these methods of communication in extension programs. Research on the opportunities for growth and current constraints (such as low literacy rates) is greatly needed to determine the potential use of these communication channels.

V.4 Conclusions and Implications

Several conclusions can be made about the dissemination and adoption of IPM technologies in South Asia based on the results of this analysis and from the information collected during interviews and through private communication with professionals in Bangladesh and Nepal. Overall, this study contributes to the current dissemination and adoption literature by identifying cost-effective extension strategies that maximize the benefits from technology diffusion. The results suggest that particular attributes of both IPM technologies and dissemination methods may greatly affect the likelihood that farmers will gain awareness about IPM and ultimately adopt a new agricultural innovation. Furthermore, the information that was collected from key stakeholders suggests the need for sustainable diffusion strategies that can operate without relying on constant external funding.

Observability, a technology attribute defined by Rogers, plays a major role in the adoption rate of IPM practices. Farmers want to be able to see the effects of a new technology and are more likely to adopt technologies that provide visible results. This observation may play an important role both in the development of technologies and in the creation of effective dissemination strategies to encourage adoption. Field days, FFS, and, to a certain extent, electronic media provide farmers with the opportunity to observe IPM practices in use and to visualize the results. On the other hand, extension agent visits, although they are individualized and provide the farmer with information about IPM practices, rarely offer the opportunity for farmers to see the technology in practice. Without an opportunity to try the technology, farmers may be hesitant to assume the risk associated with the adoption of a new practice. By incorporating field demonstration plots in the fields of leading farmers or conducting farmer field schools, many extension agents have been able to overcome this obstacle; however, the budget allocation between dissemination methods may need to be adjusted to withstand the additional costs required to employ these tactics.

The availability of IPM technologies is a concern that has been raised particularly in Bangladesh, but may be an issue throughout other South Asian countries. Although research has proven the effectiveness of technologies such as Tricho-compost, beneficial

insects, and grafted seedlings, farmers may not be able to adopt the practices due to the fact that the inputs are not accessible. In the past year, the government of Bangladesh has approved the import of pheromones and legalized the marketing of these products. This new policy will likely further the diffusion of pheromone traps by mobilizing the private industry. In the last two years, private markets have also emerged for Tricho-compost and biological controls creating new opportunities for expansion and use of these technologies.

Pressure on extension budgets and the need to produce results with shrinking funds encourages extension program coordinators to seek self-sustaining methods of technology diffusion. IPM clubs are a present example of a method that attempts to organize farmers and encourages them to discuss pest issues and build solutions to these problems in a group setting. Initiatives such as the MPC program in Nepal may build upon farmer organizations by offering clear incentives for participation such as greater market access and larger profit margins. Disseminating IPM information through these types of organizations may be more sustainable due to the fact that farmers have clear incentives to participate. Furthermore, information about IPM can be funneled through these groups and reach 25 – 100+ farmers at a time. Perhaps through collaboration with extension agents or NGO programs, MPC-type organizations can be targeted for the establishment of demonstration plots so that more farmers can be exposed to the technologies in the field.

A major issue prohibiting the sustainability and growth of IPM in South Asia may be the nature of the funding structure for many of the research and extension programs. In recent years, most of the funding for IPM programs has been project-based. Although, the amount of funding has been sufficient to develop IPM technologies and disseminate them to farmers during the duration of a project cycle, the programs have lacked continuity and connectivity. The lack of continuity limits the effective targeting of farmers in South Asia and may constrain the maximum level of IPM adoption that can be obtained. Furthermore, as technologies become out-dated, additional extension efforts must be directed to provide farmers with information about new IPM technologies.

Based on the findings of this study, the following recommendations can be made to policy-makers and program coordinators to improve the dissemination of IPM and other agricultural information:

- Farmers are more likely to adopt practices when they can quickly observe positive results within their own trials or on a neighboring farm. Focusing dissemination efforts on “visible” technologies, like pheromone traps, will likely result in more widespread adoption and greater economic benefits.
- Likewise, the most effective dissemination methods are those that allow farmers to observe a technology in use and view the results. By seeing the technology in practice, farmers are able to assess the benefits and risk associated with its adoption. Field days, FFS, and electronic media are examples of dissemination methods that can capitalize on the visibility of technologies.
- Multifaceted extension strategies are important because, depending on the characteristics and complexity of an innovation, certain dissemination methods are better suited than others to disseminate particular types of technologies. Additionally, the extension methods differ based on cost, number of farmers reach, and effectiveness.
 - **Media** – Mass media, especially electronic media, has the potential to reach large audiences at a low cost; however, the benefits that can be gained from media resources are not fully realized at the current funding level. Additional funding would provide more farmers with awareness and basic knowledge about IPM and may encourage farmers to seek out information from neighboring farmers or from other extension methods such as field days.
 - **Field days/demonstrations** – Field days and demonstrations provide a cost-effective method of widespread dissemination. Expanding field day programs would provide farmers with information and training at a significantly lower cost than extension agent visits and FFS.
 - **Extension Agent Visits** – During household visits extension agents are able to work with farmers on an individualized level and propose solutions to specific production problems; however, agents are limited by the

number of household they can visit and they are rarely able to provide the farmers with demonstrations and hands-on training. Extension agents may be able to make a greater impact by focusing less on individual household visits and concentrating more on field days and demonstrations.

- **FFS** – Farmer field schools provide farmers with in-depth information and training about IPM. Unfortunately, the high cost of FFS limits the number of farmers that can be reached with this method. Scarce funds may be best utilized by strategically selecting locations for FFS and providing IPM information to the other farmers in the area using media and field days. Informal diffusion between FFS participants and neighboring farmers may expand by increasing the general knowledge and awareness of IPM.
- Finally, IPM adoption may become more widespread if information is disseminated through marketing planning committees and other farmer organizations. Many of these organizations already provide farmers with participation incentives; therefore, by targeting these groups, information has the potential to reach large numbers of farmers at relatively low marginal costs.

There is an urgent need for cost-effective and sustainable extension programs for agricultural technologies in South Asian countries. By coupling widespread dissemination mechanisms with demonstrations and hands-on training, organizations can reach more farmers and encourage technology adoption without exhausting their financial resources. Furthermore, by investing in cost-effective diffusion methods, extension programs may become more sustainable and function independently of external funding, thus allowing organizations to focus on reaching their own long-term goals.

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LIST OF ACRONYMS

AEC – Agricultural Extension Component

AICC – Agricultural Information Communication Center

AIS – Agricultural Information Service

APE – Average partial effect

ASC – Agriculture Service Center

AVRDC – Asian Vegetable Research and Development Center

BARC – Bangladesh Agricultural Research Council

BARI – Bangladesh Agricultural Research Institute

BPH – Brown plant hopper

BRRI – Bangladesh Rice Research Institute

BW – Bacterial wilt

CEAPRED – The Center for Environmental and Agricultural Policy Research, Extension,
and Development

CRSP – Collaborative Research Support Program

DADO – District Agriculture Development Office

DAE – Department of Agricultural Extension

DAT – Directorate of Agricultural Training

DMV – Decision-making variable

DOA – Department of Agriculture

FFS – Farmer Field School

EFSB – Eggplant Fruit and Shoot Borer

FAO – Food and Agriculture Organization

GDP – Gross Domestic Product

GKSS - Grameen Krishak Shahauk Shangtha

HDI – Human Development Index

HH - Household

IDE – International Development Enterprises

ICM – Integrated Crop Management

ICT – Information and Communication Technology

IPM – Integrated Pest Management
IRRI – International Rice Research Institute
IV – Instrumental Variable
LDC – Less developed country
LP – Linear programming
LPM – Linear Probability Model
MCC – Mennonite Central Committee
MLE – Maximum Likelihood Estimator
MOA – Ministry of Agriculture
MOAC – Ministry of Agriculture and Cooperatives
MOC – Mustard oil cake
MPC – Marketing and Planning Committee
MSG – Mashed sweet gourd
NARC – National Agricultural Research Council
NARS – National Agricultural Research System
NGO – Non-governmental organization
NTV – Nepal Television
OLS – Ordinary Least Squares
PEA – Partial effect at the average
PPD – Plant Protection Directorate
PR – Poultry refuse
REAP – Research and Extension Activity Partners Project
RKN – Root Knot Nematode
SAAO – Sub Assistant Agricultural Officers
SABL – Safe Agriculture Bangladesh Ltd.
Tk – Taka
USAID – United States Agency for International Development
USD – United States Dollar
USDA – United States Department of Agriculture

APPENDIX A: SURVEYS

A.1 Bangladesh IPM Survey Conducted by BARI

Agricultural Economics Division
Bangladesh Agricultural Research Institute
Joydebpur, Gazipur

Baseline survey on adoption and impact of IPM technologies

Sample No.-----

Gender: Male / Female

General information

1) Farmer's information:

1.1) Name:-----1.2) Village:-----

1.3) Post: ----- 1.4) Upazila:-----

1.5) District: -----

2) Family information:

Sl. No.	Relationship	Age	Education	Occupation	Working member		Experience in farming
					Male	Female	
1	Self						
2							
3							
4							
5							
6							
7							
8							

3) Land ownership pattern:

Sl. No.	Land type	Quantity (decimal)
1	Homestead	
2	Own cultivable land	
3	Rented in	
4	Rented out	
5	Mortgage in	
6	Mortgage out	
7	Leased in	
8	Leased out	
9	Pond	
10	Garden	
11	Fallow land	
12	Others	

4) Other information:

4.1 How far is your major field from the nearest market (km)?-----

4.2 How far is your village from the highway (km)?-----

4.3 How far is your house from the upazila agricultural office (km)?-----

4.4 How far is your village from the district town (km)?-----

4.5 How far is your house from the nearest school (km)?-----

4.6 Membership of different organization:

Sl. No.	Organization name	Yes (if yes then how long)	No
1	Rural co-operatives		
2	Co-operative society		

3	IPM school/ club		
4	NGO		
5	Union parishad		
6	Others (specify)		
7			

A) Crop production and Marketing related information

1) List of the crops you grew last year

Sl. No.	Crops	Season (summer/ winter)	Land area (decimal)	Production (mound)	Sale price (Tk./mound)	Total cost* (Tk)
1	Rice					
	Aus					
	Aman					
	Boro					
2	Jute					
3	Maize					
4	Wheat					
5	Brinjal					
6	Tomato					
7	Beans					
8	Okra					

9	Cucumber					
10	Bottle gourd					
11	Sweet gourd					
12	Ridge gourd					
13	Pointed gourd					
14	Teasle gourd					
15	Bitter gourd					
16	Cauliflower/ cabbage					
17	Others (specify)					
18						
19						
20						

*Total cost includes land preparation, labor, fertilizer, seed cost etc.

2) What are the sources of vegetable seed? (Tick mark)

Vegetable	Own	Neighbor	BARI	Dealer/ BADC	Private company	Local market	Others
Brinjal							
Tomato							
Beans							
Okra							
Cucumber							
Bottle gourd							
Sweet gourd							
Ridge gourd							
Pointed gourd							
Teasle gourd							
Bitter gourd							
Cauliflower/ cabbage							
Others (specify)							

3) What are the sources of irrigation for major vegetable? (Tick mark)

- a) STW ----- b) DTW----- c) LLP-----
 d) Rain water----- e) Others -----

4) To whom and where did you sell your vegetables?

Buyer	Market type	
	Village market	Town market
Commission agent		
Whole seller		
Retailer		
Consumer		
Others		

5) Disposal pattern of vegetable (%)

Own consumption	Sale	Relatives	Others

6) What portion of your cereal crops (rice, wheat, maize) did you sell?-----

7) What are the sources of your annual income and expenditure?

Income		Expenditure	
Sources	Amount (Tk)	Sources	Amount (Tk.)
Crop sale		Food expenses	
Livestock		Clothing	
Fisheries		Repairing of house	

Nursery		Medicine	
Service		Education	
Business		Festival	
Others		Others	

C) Pest and pest management related information

1) What are the primary pests of brinjal and measure to control them?

Insect/ diseases name	Severity level*	Controlling measures											
		Pesticide spray (No.)	Name of pesticide	Resistant variety	Soil amendment	Parasitic wasp	Grafting	Pheromone	Hand picking	Rogging	Remove infested plant	Others	
a) Insects													
b) Diseases													

(* Severity level: No= 0, 1= low, 2= medium and 3= high)

2) What are the primary pests of tomato and measure to control them?

Insect/ diseases name	Severity level*	Controlling measures											
		Pesticide spray (No.)	Name of pesticide	Resistant variety	Soil amendment	Parasitic wasp	Grafting	Pheromone	Hand picking	Rogging	Remove infested plant	Others	
a) Insects													
b) Diseases													

(* Severity level: No= 0, 1= low, 2= medium and 3= high)

3) What are the primary pests of beans and measure to control them?

Insect/ diseases name	Severity level*	Controlling measures											
		Pesticide spray (No.)	Name of pesticide	Resistant variety	Soil amendment	Parasitic wasp	Grafting	Pheromone	Hand picking	Rogging	Remove infested plant	Others	
a) Insects													
b) Diseases													

(* Severity level: No= 0, 1= low, 2= medium and 3= high)

4) What are the primary pests of okra and measure to control them?

Insect/ diseases name	Severity level*	Controlling measures												
		Pesticide spray (No.)	Name of pesticide	Resistant variety	Soil amendment	Parasitic wasp	Grafting	Pheromone	Hand picking	Rogging	Remove infested plant	Others		
a) Insects														
b) Diseases														

(* Severity level: No= 0, 1= low, 2= medium and 3= high)

5) What are the primary pests of cucumber and measure to control them?

Insect/ diseases name	Severity level*	Controlling measures												
		Pesticide spray (No.)	Name of pesticide	Resistant variety	Soil amendment	Parasitic wasp	Grafting	Pheromone	Hand picking	Rogging	Remove infested plant	Others		
a) Insects														
b) Diseases														

(* Severity level: No= 0, 1= low, 2= medium and 3= high)

6) What are the primary pests of bottle gourd and measure to control them?

Insect/ diseases name	Severity level*	Controlling measures										
		Pesticide spray (No.)	Name of pesticide	Resistant variety	Soil amendment	Parasitic wasp	Grafting	Pheromone	Hand picking	Rogging	Remove infested plant	Others
a) Insects												
b) Diseases												

(* Severity level: No= 0, 1= low, 2= medium and 3= high)

7) What are the primary pests of sweet gourd and measure to control them?

Insect/ diseases name	Severity level*	Controlling measures										
		Pesticide spray (No.)	Name of pesticide	Resistant variety	Soil amendment	Parasitic wasp	Grafting	Pheromone	Hand picking	Rogging	Remove infested plant	Others
a) Insects												
b) Diseases												

(* Severity level: No= 0, 1= low, 2= medium and 3= high)

8) What are the primary pests of ridge gourd and measure to control them?

Insect/ diseases name	Severity level*	Controlling measures											
		Pesticide spray (No.)	Name of pesticide	Resistant variety	Soil amendment	Parasitic wasp	Grafting	Pheromone	Hand picking	Rogging	Remove infested plant	Others	
a) Insects													
b) Diseases													

(* Severity level: No= 0, 1= low, 2= medium and 3= high)

9) What are the primary pests of pointed gourd and measure to control them?

Insect/ diseases name	Severity level*	Controlling measures											
		Pesticide spray (No.)	Name of pesticide	Resistant variety	Soil amendment	Parasitic wasp	Grafting	Pheromone	Hand picking	Rogging	Remove infested plant	Others	
a) Insects													
b) Diseases													

(* Severity level: No= 0, 1= low, 2= medium and 3= high)

10) What are the primary pests of teal gourd and measure to control them?

Insect/ diseases name	Severity level*	Controlling measures											
		Pesticide spray (No.)	Name of pesticide	Resistant variety	Soil amendment	Parasitic wasp	Grafting	Pheromone	Hand picking	Rogging	Remove infested plant	Others	
a) Insects													
b) Diseases													

(* Severity level: No= 0, 1= low, 2= medium and 3= high)

11) What are the primary pests of bitter gourd and measure to control them?

Insect/ diseases name	Severity level*	Controlling measures											
		Pesticide spray (No.)	Name of pesticide	Resistant variety	Soil amendment	Parasitic wasp	Grafting	Pheromone	Hand picking	Rogging	Remove infested plant	Others	
a) Insects													
b) Diseases													

(* Severity level: No= 0, 1= low, 2= medium and 3= high)

12) What are the primary pests of cauliflower/ cabbage and measure to control them?

Insect/ diseases name	Severity level*	Controlling measures											
		Pesticide spray (No.)	Name of pesticide	Resistant variety	Soil amendment	Parasitic wasp	Grafting	Pheromone	Hand picking	Rogging	Remove infested plant	Others	
a) Insects													
b) Diseases													

(* Severity level: No= 0, 1=low, 2= medium and 3= high)

13) What are the primary pest of ----- and measure to control them?

Insect/ diseases name	Severity level*	Controlling measures											
		Pesticide spray (No.)	Name of pesticide	Resistant variety	Soil amendment	Parasitic wasp	Grafting	Pheromone	Hand picking	Rogging	Remove infested plant	Others	
a) Insects													
b) Diseases													

(* Severity level: No= 0, 1=low, 2= medium and 3= high)

14) From where you got the information on pesticide management and application dose?

Sources	Pest management	Doses of pesticide
Family members		
Neighbor		
Relatives		
Pesticide dealer		
Sub assistant agril. officer (SAAO)		
Others		

D) IPM related information

1) Do you use IPM practices in your field? a) Yes ----- b) No -----

If yes, from where you got the information on IPM practices? (Tick mark)

a) News paper		b) Relatives	
c) Radio/TV		d) neighbor / friends	
e) Demonstration		f) Field day	
g) IPM school		h) SAAO	

2) Do you receive any training on IPM practices? a) Yes----- b) No-----

If yes, from where and how many training you received?

a) Agri. office (DAE)		b) BARI	
c) IPM club		d) NGO	
e) Others			

E) Willingness to adopt IPM practices in future

1) Do you want to use IPM practices in near future? a) Yes----- b) No-----

If yes, why you want to use IPM in future?

Reasons	Level of importance		
	High	Low	None
Reduce cost of pesticides			
High yield and income			
Low pesticide residues			
Do not have enough money to buy pesticide			
Less harmful to health			
Environment friendly			
Others			

If no, why you do not want to use IPM in future?

Reasons	Level of importance		
	High	Low	None
Lack of technical knowledge			
Slow to work			
Not effective for all insect			
Others			

F) Women's involvement

1) Who take decision on the use of pesticide/IPM?

	Respondent	Spouse	Both	Others
Who buy pesticide / IPM				
Who decide how much to spend on pesticide/IPM				
Who handle the situation when pest problem occurred				

2) Involvement of women in different activities (Tick mark)

Activities	Respondent	Spouse	Both	Others
Labor employment				
Child education				
Rural meeting				
Son/daughter's marriage				
Sale of land				
Livestock rearing				

3) Involvement of women in vegetable production

Activity type	Participation level			Per day working duration (hours)
	Always	Rarely	No	
Vegetable planting				
Fertilizer application				
Irrigation				
Pulling of infested plant				
Soil amendment				
Grafting				
Roughing				
Pesticide application				
Harvesting of vegetable				
Sale of vegetable				
Others				

A.2 Nepal IPM Survey Conducted by IDE

Survey on Gender Responsive Integrated Pest Management for Women's Participation in Integrated Pest Management Collaborative Research Support program (IPM CRSP) IDE, Nepal

Form fill up date:

Household No: _____ IPM CRSP Member Yes () No ()
()

Respondent Name: _____ Male () Female ()

Cast/Ethnicity: _____ Married () Unmarried ()

Third category gender ()

Address: _____ District: _____ VDC: _____ Tole: _____

1. Are you a member of a Marketing Planning Committee or cooperative? Yes () No ()

1.1 If yes, please provide the name of the group(s)/MPC/Cooperative and the number
of years you have been a member

1.2 Is your group/MPC/Cooperative registered? Yes () No ()

2. Do you sell your agriculture products/vegetables to a collection center? Yes () No ()

2.1 If yes, please provide the name of the collection center(s)

2.2 How often do you sell products at the collection centers?

2.2.1 Daily

2.2.2 Two times in a week

2.2.3 Three times in a week

2.2.4 Four times in a week

2.2.5 Weekly

3. How do you fix the price of products?

3.1 Individually 3.2 With advice of spouse 3.3 As per market

4 Do you have agriculture service provider(s)/input supplier(s) in your community or village? Yes () No ()

4.1 If yes, please provide the name of service provider/ supplier (Who are: male or female?)

5 Please, could you give your Household Profile

SN	Description (list family members)	Sex		Age	Education					Position in Group		
		M	F		P	M	H	C	NF ed	M	F	
1	HH head:											
2												
3												
4												
5												
6												
7												
8												
9												
10												

Note: P=P Primary School, M = Middle School, H=High School, C = College, NF Ed=Non formal education

6. Do you know about IPM Yes () No () (ask the question about the respondent's knowledge before implementation of grafting/IPM by IDE Nepal)

6.1 If yes, what do you know? _____

7. Where did you **first** hear about IPM?

- Farmer Field day
- Extension agent (JTA)
- Farmer Field School
- Input supplier; specify_____
- Farmer group (i.e. MPC or Coop.); specify_____
- IDE Nepal/IPM CRSP
- News papers
- Other; specify_____

8. Are you receiving agriculture/ IPM input/support/advices (please tick one agriculture or IPM) after you became aware of IPM? From following agencies

- Farmer Field day
- Extension agent (JTA)
- Farmer Field School
- Input supplier; specify_____
- Farmer group (i.e. MPC or Coop.); specify_____
- IDE Nepal (IPM CRSP)
- Other; specify_____

9. Do you have network/linkages to access the inputs or agriculture information?

Yes No (please tick one – input or agriculture information)

If yes: a. Individual b. Group

10. Have you ever heard information about IPM on the radio, television, or internet?

Yes No

10.1 If yes, what did you hear or learn?

10.2 Did you try to find out more about the IPM technologies you heard about? Yes No

11. Have you ever seen information about IPM in the newspaper or in a pamphlet?

Yes No

11.1 If yes, what did you read or learn?

12. Did you try to find out more about the IPM technologies you saw?

Yes () No ()

13. Do you use IPM in your agriculture farm? Yes () No () None ()

Please indicate the IPM technologies that you currently use?

() Mulching () Soil amendment (i.e. poultry refuse, neem cake)

() Bagging () Grafting

() Bio-pesticides () Pheromone Traps

() Bio-fertilizers () Soil solarization

Other; specify _____

14. Have you (or your spouse) received training on grafting/ IPM? Yes () No ()

14.1 If yes, when? And who trained you?

14.2. Have you (or your spouse) applied the training in field? Yes () No ()

14.3. If no, why did not use the knowledge and skill in the field? Reasons:

15. Do you (or your spouse) have problems of going to attend training/workshop, meetings, social work, selling product for overnight halt or outside districts?

Yes () No ()

15.1 If yes, what are the reasons?

16. Are you (or your spouse) service provider of grafting/IPM? Yes () No ()

16.1 If yes, what type of services are you providing?

16.2 What are the problems for service dissemination to the farmers?

17. Are women getting equal opportunities as men to participate in the group, group's management, training, workshop, field demonstration for their self-development?

Yes () No ()

17.1 If yes, how they are getting opportunities?

17.2 If no, provide the information in the following topic

SN	Problems	Explanation, why it is a problem?
1	Money	
2	Land	
3	Loan	
4	Less opportunity	
5	Mobility	
6	Work load	
7	Child marriage	
8	Domestic violence	
9	Other (Specify)	

18. Who (male or female, boy or girl) does works and how long (in hours) in following activities in your house?

SN	Activities	Hours in a day			
		Men	Women	Boys	Girls
1	Domestic Activities (household chores)				
2	Taking care of children and schooling				
3	Rearing and caring of the animals				
4	Working in vegetables production				
5	Service/ daily wages				
6	Enterprise business				
7	Selling products				
8	Buying agriculture inputs				
9	Selection of seeds				

18.1 Who involves and how long (in hours) in the following IPM packages in your house?

SN	Activities	Sex and hours in a day			
		Men	Women	Boys	Girls
A	Grafting operation				
1	Nursery development of wild and preferred variety				
2	Grafting				
3	Grafted seedling management				
B	Other IPM packages				
1	Seed selection				
2	Nursery management				
3	Bio-fertilizer and bio-pesticides application				
4	Weeding				
5	Bagging				
6	MIT management and use				
7	Fixing price of products in the field				
8	Fixing price of products in the market level				

19. Do you have to access and control over resources (in terms of ownership and selling) in your house?

S.No.	Description	Access to Resource		Control over resource	
		Yes	No	Yes	No
	House				
	Land				
	Sales of Agriculture product				
	Cattle				
	Cash				

20. Are you accessing potable drinking water? Yes () No ()

21. Are you accessing irrigation water for agriculture/vegetable production?
Yes () No ()

22. Are you a member of any community forest? Yes () No ()

23. Do you get credit/ loan easily from 'Bank'/ 'Cooperative'/ 'Group'?
Yes () No ()

24. Please could you give some information of yearly income of your household?

N	Economic activities/Income sources	Sex	
		Male	Female
1	Vegetable production and sells	Rs.	Rs.
2	Grafted seedling development and sells		
3	Services (in country)		
4	Overseas employment		
5	Cattle rearing and sells		
6	Other Activities (Specify)		

25. Do you make decision yourself or with your spouse in following activities (Please write the answer in percentage)

SN	Description of taking decision in different activities	Who makes decision		
		Yes	No	Together
1	Household budget			
2	Agriculture or IPM inputs buying			
3	Vegetable production/ sells and use of money			
4	Nursery growing/ sells and use of money			
5	Cattle sells and use of money			
6	Making loan and use			
7	Acquire properties			
8	Employment			
9	Children's education			
10	Involving in IPM (grafting, and other IPM packages)			
11	Going to outside from home for training/workshop			
12	Working in the group			

26. Do you (your spouse or both) have knowledge about non-chemical and eco-friendly, IPM technology? Yes () No ()

26.1 If yes, how does it affect our health?

27. Do you (your spouse or both) have experience of the adverse effect of chemical fertilizer/ pesticide? Yes () No ()

28. Do you (your spouse or both) know about the sustainability of product using non-chemical technology? Yes () No ()

29. Do you (your spouse or both) know that bio-pesticide/bio-fertilizer helps to maintain bio-diversity? Yes () No ()

30. Do your family members have access to nutrient vegetables (pesticide free vegetables) in your home? Yes () No ()

31. Who often become sick in your family member within one year?
a) male, b) female, and c) children (under 5 years of age), a) none
a. If yes, what types of sickness? And who are victimized?

32. How is the women's health in your family within one year?
a) healthy, b) malnutrition

33. How can you grade health of your children? a) healthy, b) malnutrition

34. Can you prioritize the women's needs to increase their participation in development through grafting/IPM program?

Thank you very much!

A.3 Questionnaire to Estimate Adoption of IPM Practices in Bangladesh

Name of Respondent:

Position at BARI:

Date Completed:

Directions: This questionnaire aims to obtain adoption estimates for six different IPM practices. Each question has six parts. For each part please indicate how many people you think would adopt the IPM practice. Enter your answer in the shaded boxes.

Completed questionnaires should be returned to leahmh@vt.edu.

1. Imagine that **paper media (pamphlets, newspapers, brochures, etc.)** was used to provide 100 farmers with information about six different IPM practices. Assuming that the farmers did not know about the practices beforehand, **how many of the 100 farmers would you expect to adopt each of the following practices?**

a. Handpicking pests:

I would expect that out of 100 farmers would adopt handpicking practices.

b. Soil amendments (poultry refuse, MOC):

I would expect that out of 100 farmers would adopt soil amendments.

c. Tricho-compost:

I would expect that out of 100 farmers would adopt Tricho-compost.

d. Sex pheromones (pheromone traps):

I would expect that out of 100 farmers would adopt sex pheromones.

e. Biological controls (i.e. parasitic wasps):

I would expect that out of 100 farmers would adopt biological controls.

f. Grafting:

I would expect that out of 100 farmers would adopt grafting.

2. Imagine that **electronic media (radio, television, etc.)** was used to provide a different group of 100 farmers with information about six different IPM practices. Assuming that the farmers did not know about the practices beforehand, **how many of the 100 farmers would you expect to adopt each of the following practices?**

a. Handpicking pests:

I would expect that out of 100 farmers would adopt handpicking practices.

b. Soil amendments (poultry refuse, MOC):

I would expect that out of 100 farmers would adopt soil amendments.

c. Tricho-compost:

I would expect that out of 100 farmers would adopt Tricho-compost.

d. Sex pheromones (pheromone traps):

I would expect that out of 100 farmers would adopt sex pheromones.

e. Biological controls (i.e. parasitic wasps):

I would expect that out of 100 farmers would adopt biological controls.

f. Grafting:

I would expect that out of 100 farmers would adopt grafting.

3. Imagine that **field days (or field demonstrations)** provided a different group of 100 farmers with information about six different IPM practices. Assuming that the farmers did not know about the practices beforehand, **how many of the 100 farmers would you expect to adopt each of the following practices?**

a. Handpicking pests:

I would expect that out of 100 farmers would adopt handpicking practices.

b. Soil amendments (poultry refuse, MOC):

I would expect that out of 100 farmers would adopt soil amendments.

c. Tricho-compost:

I would expect that out of 100 farmers would adopt Tricho-compost.

d. Sex pheromones (pheromone traps):

I would expect that out of 100 farmers would adopt sex pheromones.

- e. **Biological controls (i.e. parasitic wasps):**
I would expect that out of 100 farmers would adopt biological controls.
- f. **Grafting:**
I would expect that out of 100 farmers would adopt grafting.
4. Imagine that **extension agents (SAAO)** provided a different group of 100 farmers with information about six different IPM practices. Assuming that the farmers did not know about the practices beforehand, **how many of the 100 farmers would you expect to adopt each of the following practices?**
- a. **Handpicking pests:**
I would expect that out of 100 farmers would adopt handpicking practices.
- b. **Soil amendments (poultry refuse, MOC):**
I would expect that out of 100 farmers would adopt soil amendments.
- c. **Tricho-compost:**
I would expect that out of 100 farmers would adopt Tricho-compost.
- d. **Sex pheromones (pheromone traps):**
I would expect that out of 100 farmers would adopt sex pheromones.
- e. **Biological controls (i.e. parasitic wasps):**
I would expect that out of 100 farmers would adopt biological controls.
- f. **Grafting:**
I would expect that out of 100 farmers would adopt grafting.
5. Imagine that **farmer field schools** provided a different group of 100 farmers with information about six different IPM practices. Assuming that the farmers did not know about the practices beforehand, **how many of the 100 farmers would you expect to adopt each of the following practices?**
- a. **Handpicking pests:**
I would expect that out of 100 farmers would adopt handpicking practices.
- b. **Soil amendments (poultry refuse, MOC):**
I would expect that out of 100 farmers would adopt soil amendments.

c. Tricho-compost:

I would expect that out of 100 farmers would adopt Tricho-compost.

d. Sex pheromones (pheromone traps):

I would expect that out of 100 farmers would adopt sex pheromones.

e. Biological controls (i.e. parasitic wasps):

I would expect that out of 100 farmers would adopt biological controls.

f. Grafting:

I would expect that out of 100 farmers would adopt grafting.

Additional comments or suggestions are welcome:

Thank you for participating in this questionnaire!

A.4 Questionnaire to Estimate Adoption of Rice IPM in Bangladesh

Name of Respondent:

Position:

Date Completed:

Directions: This questionnaire aims to obtain adoption estimates for rice IPM – which includes using **resistant varieties, biological controls, and perching**. Please indicate how many farmers you think would adopt the IPM package for rice after learning about the practices from each of the following information sources. Enter your answer in the shaded boxes.

Completed questionnaires should be returned to leahmh@vt.edu.

1. Imagine that **paper media (pamphlets, newspapers, brochures, etc.)** was used to provide 100 farmers with information about rice IPM practices. **How many of the 100 farmers would you expect to adopt the IPM technology package?**
 - I would expect that out of 100 farmers would adopt the rice IPM practices.

2. Imagine that **electronic media (radio, television, etc.)** was used to provide 100 farmers with information about rice IPM practices. **How many of the 100 farmers would you expect to adopt the IPM technology package?**
 - I would expect that out of 100 farmers would adopt the rice IPM practices.

3. Imagine that a **field day (or field demonstration)** provided 100 farmers with information about rice IPM practices. **How many of the 100 farmers would you expect to adopt the IPM technology package?**
 - I would expect that out of 100 farmers would adopt the rice IPM practices.

4. Imagine that **extension agents (SAAO)** provided 100 farmers with information about rice IPM practices. **How many of the 100 farmers would you expect to adopt the IPM technology package?**
 - I would expect that out of 100 farmers would adopt the rice IPM practices.

5. Imagine that **farmer field schools** provided was used to provide 100 farmers with information about rice IPM practices. **How many of the 100 farmers would you expect to adopt the IPM technology package?**
- I would expect that out of 100 farmers would adopt the rice IPM practices.

Additional comments or suggestions are welcome:

Thank you for participating in this questionnaire!

APPENDIX B: MAPS

Figure B.1: Map of Survey Areas in Bangladesh



Source: United Nations, www.un.org/Depts/Cartographic/map/profile/banglade.pdf

KEY: ★ = Survey Area

APPENDIX C: ECONOMIC SURPLUS CALCULATION

Table C.1: Helpful Conversion Factors

Land Area			
	1 acre	=	0.4047 hectare
	1 hectare	=	2.47 acre
	1 decimal	=	1/100 acre
	3 bigha	=	1 acre
Weight			
	1 kg	=	2.2 lb.
	1 lb.	=	0.454 kg
	1 metric `ton	=	1000 kg
	1 quintal	=	100 kg
	1 mound	=	40kg
Currency			
	\$1 US	=	69 taka
	1 taka	=	\$0.0145 US
Number System			
	1 lakh	=	100,000
	(1,00,000)		
	1 crore	=	10,000,000
	(1,00,00,000)		

Table C.2: National-Level Production Information for Rice and Selected Vegetable Crops

Crop (average 2006-08)	Annual Production metric tons (1000kg)	Annual Production Area		Average Yield		Price (2004-06)		Aggregate Crop Value		
		Hectare	Acre	kg/ha	kg/ac	tk/kg	\$US/kg	Taka	US\$	
Eggplant (winter + summer averages)	335,511	47,178	116,576	7,111.58	2,878.06	12.50	0.18	4,193,887,500	60,780,978	
Cucurbits (weighted avg.)	608,428	90,252	223,009	6,741.45	2,728.26	10.00	0.14	6,084,275,000	88,177,899	
Tomato	139,997	19,526	48,249	7,169.61	2,901.54	18.00	0.26	2,519,937,000	36,520,826	
	<i>Total Veg.</i>	<i>1,083,935</i>	<i>156,956</i>	<i>387,834</i>				<i>12,798,099,500</i>	<i>185,479,703</i>	
Rice – Aus	1,509,500	912,000	2,252,640	1,655.15	670.10					
Rice – Aman	10,251,500	5,232,000	12,923,040	1,959.38	793.27					
Rice – Boro	16,363,500	4,433,000	10,949,510	3,691.29	1,494.45					
	<i>Total Rice</i>	<i>28,124,500</i>	<i>10,577,000</i>	<i>26,125,190</i>	<i>2,659.02</i>	<i>1,076.53</i>	<i>16.00</i>	<i>0.23</i>	<i>449,992,000,000</i>	<i>6,521,623,188</i>
Total (4 Crops)	29,208,435	10,733,956	26,513,024					462,790,099,500	6,707,102,891	

Data Source: Bangladesh Bureau of Statistics. Dhaka, Bangladesh.

Table C.3: Farm-Level Enterprise Budgets for Rice Production

<u>Input Costs (tk/ha)</u>	RICE	
	<i>All IPM</i>	<i>Non-IPM</i>
Labor* (human, animal, mechanical)	27,531.25	27,531.25
Seeds/Seedlings	3,552.00	3,552.01
Fertilizers	8,783.49	8,783.49
Sex Pheromones/Traps		
Biological Controls		
Pesticides		
<i>insecticide</i>	207.65	830.59
<i>herbicide</i>	30.20	120.80
Irrigation	5,689.14	5,689.14
Perching Materials	100.00	
Total Variable Costs	45,893.73	46,507.27
<i>TVC Change compared to Non-IPM</i>	<i>-0.01</i>	
Land Rent	13,000.00	13,000.00
Interest on operating Capital	4,130.44	4,185.65
Total Production Costs	63,024.16	63,692.92
Yield (kg/ha)	5,085.00	4,842.61
<i>Yield Change compared to Non-IPM</i>	<i>0.05</i>	
Price	16.00	16.00
gross return from paddy	81,360.00	77,481.76
gross return from straw	4,256.70	4,256.70
Gross Return	85,616.70	81,738.46
Gross Margin (Profit)	22,592.53	18,045.54
Benefit Cost Ratio	1.36	1.28

Data Source: BRRI Field Trials. Gazipur, Bangladesh.

Table C.4: Farm-Level Enterprise Budgets for Eggplant Production

Input Costs (tk/ha)	EGGPLANT					
	<i>Soil amendments (MOC and PR)</i>	<i>Tricho- Compost</i>	<i>Sex Pheromones</i>	<i>Biological Controls</i>	<i>Grafting</i>	<i>Non-IPM</i>
Labor* (human, animal, mechanical)	37,861.00	34,329.00	37,429.00	36,751.00	40,800.00	37,948.25
Seeds/Seedlings	15,510.15	15,510.15	17,233.50	17,233.50	21,541.00	17,233.50
MOC	3,536.00					
PR	1,658.00					
Tricho-Compost		28,700.00				
Manure (cow dung)	1,723.00		1,169.00	1,368.00	1,211.00	3,437.25
Fertilizers	20,966.00	5,186.00	19,517.00	21,723.00	21,820.00	21,507.25
Sex Pheromones/Traps			4,000.00			
Biological Controls				750.00		
Pesticides	4,719.69	4,719.69	4,719.69	5,663.63	4,719.69	18,878.75
Irrigation	4,210.00	4,210.00	5,991.00	5,890.00	5,890.00	2,850.00
Perching Materials						
Total Variable Costs	90,183.84	92,654.84	90,059.19	89,379.13	95,981.69	101,855.00
<i>TVC Change compared to Non-IPM</i>	<i>-0.11</i>	<i>-0.09</i>	<i>-0.12</i>	<i>-0.12</i>	<i>-0.06</i>	
Land Rent	11,000.00	11,000.00	11,000.00	11,000.00	11,000.00	11,000.00
Interest on operating Capital	8,116.55	8,338.94	8,105.33	8,044.12	8,638.35	9,166.95
Total Production Costs	109,300.38	111,993.77	109,164.51	108,423.25	115,620.04	122,021.95
Yield (kg/ha)	25,857.00	27,404.00	26,520.00	26,299.00	26,741.00	22,100.00
<i>Yield Change compared to Non-IPM</i>	<i>0.17</i>	<i>0.24</i>	<i>0.20</i>	<i>0.19</i>	<i>0.21</i>	
Price	12.50	12.50	12.50	12.50	12.50	12.50
Gross Return	323,212.50	342,550.00	331,500.00	328,737.50	334,262.50	276,250.00
Gross Margin (Profit)	213,912.12	230,556.23	222,335.49	220,314.25	218,642.46	154,228.05
Benefit Cost Ratio	2.96	3.06	3.04	3.03	2.89	2.26

Data Source: BARI Field Trials. Gazipur, Bangladesh.

Table C.5: Farm-Level Enterprise Budgets for Tomato Production

Input Costs (tk/ha)	TOMATO			
	<i>Soil amendments (MOC and PR)</i>	<i>Tricho-Compost</i>	<i>Grafting</i>	<i>Non-IPM</i>
Labor* (human, animal, mechanical)	55,037.33	55,037.33	55,730.00	54,526.00
Seeds/Seedlings	13,014.60	13,014.60	33,500.00	14,460.67
MOC	4,596.00			
PR	1,907.00			
Tricho-Compost		38,000.00		
Manure (cow dung)	1,796.31		1,953.14	1,953.14
Fertilizers	25,783.80	8,594.60	35,202.00	34,378.40
Sex Pheromones/Traps				
Biological Controls				
Pesticides	8,642.10	7,201.75	7,201.75	28,807.00
Irrigation	9,020.00	9,020.00	10,496.00	8,200.00
Perching Materials				
Total Variable Costs	119,797.15	130,868.28	144,082.89	142,325.21
<i>TVC Change compared to Non-IPM</i>	<i>-0.16</i>	<i>-0.08</i>	<i>0.01</i>	
Land Rent	11,000.00	11,000.00	11,000.00	11,000.00
Interest on operating Capital	10,781.74	11,778.15	12,967.46	12,809.27
Total Production Costs	141,578.89	153,646.43	168,050.35	166,134.48
Yield (kg/ha)	46,800.00	47,800.00	50,350.00	39,456.25
<i>Yield Change compared to Non-IPM</i>	<i>0.19</i>	<i>0.21</i>	<i>0.28</i>	
Price	18.00	18.00	18.00	18.00
Gross Return	842,400.00	860,400.00	906,300.00	710,212.50
Gross Margin (Profit)	700,821.11	706,753.57	738,249.65	544,078.02
Benefit Cost Ratio	5.95	5.60	5.39	4.27

Data Source: BARI Field Trials. Gazipur, Bangladesh.

Table C.6: Farm-Level Enterprise Budgets for Cucurbit Crop Production

Input Costs (tk/ha)	CUCURBIT				
	<i>Soil amendments (MOC and PR)</i>	<i>Tricho-Compost</i>	<i>Sex Pheromones</i>	<i>Biological Controls</i>	<i>Non-IPM</i>
Labor* (human, animal, mechanical)	50,859.00	50,859.00	53,800.00	55,000.00	52,607.00
Seeds/Seedlings	6,115.50	6,115.50	6,795.00	6,795.00	6,795.00
MOC	5,720.00				
PR	1,658.00				
Tricho-Compost		28,700.00			
Manure (cow dung)	3,247.00		3,720.00	3,720.00	5,610.00
Fertilizers	15,545.00	3,803.00	17,422.00	17,422.00	17,422.00
Sex Pheromones/Traps			1,760.00		
Biological Controls				750.00	
Pesticides	3,857.25	3,857.25	3,857.25	3,857.25	15,429.00
Irrigation	4,261.00	2,619.00	5,261.00	5,261.00	4,329.00
Perching Materials					
Total Variable Costs	91,262.75	95,953.75	92,615.25	92,805.25	102,192.00
TVC Change compared to Non-IPM	-0.11	-0.06	-0.09	-0.09	
Land Rent	11,000.00	11,000.00	11,000.00	11,000.00	11,000.00
Interest on operating Capital	8,213.65	8,635.84	8,335.37	8,352.47	9,197.28
Total Production Costs	110,476.40	115,589.59	111,950.62	112,157.72	122,389.28
Yield (kg/ha)	21,527.00	22,098.00	23,432.00	22,479.00	19,050.00
Yield Change compared to Non-IPM	0.13	0.16	0.23	0.18	
Price	14.00	14.00	14.00	14.00	
Gross Return	301,378.00	309,372.00	328,048.00	314,706.00	0.00
Gross Margin (Profit)	190,901.60	193,782.41	216,097.38	202,548.28	-122,389.28
Benefit Cost Ratio	2.73	2.68	2.93	2.81	0.00

Data Source: BARI Field Trials. Gazipur, Bangladesh.

Table C.7: Projected Adoption Rates for IPM Practices

<u>LOW ADOPTION</u>						
Category	1	2	3	4	5	6
	Soil Amendment	Tricho-compost	Sex Pheromone	Biological Control	Grafting	Rice IPM
Paper Media	0.020	0.000	0.020	0.000	0.000	0.013
Electronic Media	0.100	0.020	0.100	0.020	0.000	0.040
Field Day	0.200	0.150	0.400	0.100	0.150	0.125
Agent Visit	0.100	0.100	0.200	0.050	0.050	0.075
FFS	0.120	0.150	0.400	0.050	0.100	0.175
<u>AVERAGE ADOPTION</u>						
Category	1	2	3	4	5	6
	Soil Amendment	Tricho-compost	Sex Pheromone	Biological Control	Grafting	Rice IPM
Paper Media	0.048	0.028	0.063	0.018	0.018	0.025
Electronic Media	0.175	0.105	0.213	0.088	0.065	0.080
Field Day	0.550	0.388	0.625	0.250	0.263	0.250
Agent Visit	0.275	0.225	0.350	0.138	0.138	0.150
FFS	0.430	0.338	0.550	0.213	0.200	0.350
<u>HIGH ADOPTION</u>						
Category	1	2	3	4	5	6
	Soil Amendment	Tricho-compost	Sex Pheromone	Biological Control	Grafting	Rice IPM
Paper Media	0.070	0.070	0.100	0.050	0.050	0.038
Electronic Media	0.300	0.200	0.350	0.160	0.150	0.120
Field Day	0.800	0.600	0.700	0.400	0.350	0.375
Agent Visit	0.500	0.500	0.500	0.250	0.250	0.225
FFS	0.600	0.500	0.700	0.300	0.300	0.525

Source: BARI Scientists, Gazipur, Bangladesh.

Table C.10: Socio-economic Comparison of Vegetable Farmers

VARIABLE	EGGPLANT						TOMATO						CUCURBITS				
	OBS	MEAN	STD. DEV.	MIN	MAX		OBS	MEAN	STD. DEV.	MIN	MAX		OBS	MEAN	STD. DEV.	MIN	MAX
MALE	133	0.92	0.26	0	1		37	0.86	0.35	0	1		247	0.89	0.32	0	1
AGE	133	41.02	12.63	18	75		37	45.81	14.33	18	75		247	42.42	11.90	17	75
EDUC	133	5.57	4.20	0	14		37	7.51	3.83	0	14		247	5.57	4.27	0	14
EXPER	133	17.51	10.32	2	52		37	22.43	12.93	2	52		247	17.63	10.07	2	52
HHSIZE	133	6.02	1.52	3	9		37	6.05	1.54	3	9		247	5.96	1.50	3	9
FARM_HA	133	1.02	0.60	0.16	3.99		37	0.99	0.58	0.14	2.76		247	1.02	0.66	0.14	3.99
D_MARKET	132	1.40	0.85	0.11	5		37	1.30	0.67	0.25	2.50		247	1.30	0.93	0.11	6
ORG	133	0.56	0.50	0	1		37	0.54	0.51	0	1		247	0.61	0.49	0	1
ADOPT_IPM	133	0.32	0.47	0	1		37	0.27	0.45	0	1		247	0.35	48.00	0	1
JESSORE	133	0.24	0.43	0	1		37	0.11	0.31	0	1		247	0.35	0.48	0	1
BOGRA	133	0.58	0.50	0	1		37	0.89	0.31	0	1		247	0.26	0.44	0	1
NARSINGDI	133	0.18	0.39	0	1		37	0.00	0.00	0	0		247	0.40	0.49	0	1

Data Source: IPM CRSP Baseline Survey, BARI, Gazipur, Bangladesh.

APPENDIX D: LINEAR PROGRAMMING MODEL

Table D.1: List of Decision Making Variables

DMV	Crop - Practice - Extension Method - Budget Level
1	Eggplant - Soil Amendments - Paper Media - Current Budget
2	Eggplant - Soil Amendments - Paper Media - Higher Budget
3	Eggplant - Soil Amendments - Electronic Media - Current Budget
4	Eggplant - Soil Amendments - Electronic Media - Higher Budget
5	Eggplant - Soil Amendments - Field Day - Current Budget
6	Eggplant - Soil Amendments - Field Day - Higher Budget
7	Eggplant - Soil Amendments - Agent Visit - Current Budget
8	Eggplant - Soil Amendments - Agent Visit - Higher Budget
9	Eggplant - Soil Amendments - Farmer Field School - Current Budget
10	Eggplant - Soil Amendments - Farmer Field School - Higher Budget
11	Eggplant - Tricho Compost - Paper Media - Current Budget
12	Eggplant - Tricho Compost - Paper Media - Higher Budget
13	Eggplant - Tricho Compost - Electronic Media - Current Budget
14	Eggplant - Tricho Compost - Electronic Media - Higher Budget
15	Eggplant - Tricho Compost - Field Day - Current Budget
16	Eggplant - Tricho Compost - Field Day - Higher Budget
17	Eggplant - Tricho Compost - Agent Visit - Current Budget
18	Eggplant - Tricho Compost - Agent Visit - Higher Budget
19	Eggplant - Tricho Compost - Farmer Field School - Current Budget
20	Eggplant - Tricho Compost - Farmer Field School - Higher Budget
21	Eggplant - Sex Pheromones - Paper Media - Current Budget
22	Eggplant - Sex Pheromones - Paper Media - Higher Budget
23	Eggplant - Sex Pheromones - Electronic Media - Current Budget
24	Eggplant - Sex Pheromones - Electronic Media - Higher Budget
25	Eggplant - Sex Pheromones - Field Day - Current Budget
26	Eggplant - Sex Pheromones - Field Day - Higher Budget
27	Eggplant - Sex Pheromones - Agent Visit - Current Budget
28	Eggplant - Sex Pheromones - Agent Visit - Higher Budget
29	Eggplant - Sex Pheromones - Farmer Field School - Current Budget
30	Eggplant - Sex Pheromones - Farmer Field School - Higher Budget
31	Eggplant - Biological Controls - Paper Media - Current Budget

32	Eggplant - Biological Controls - Paper Media - Higher Budget
33	Eggplant - Biological Controls - Electronic Media - Current Budget
34	Eggplant - Biological Controls - Electronic Media - Higher Budget
35	Eggplant - Biological Controls - Field Day - Current Budget
36	Eggplant - Biological Controls - Field Day - Higher Budget
37	Eggplant - Biological Controls - Agent Visit - Current Budget
38	Eggplant - Biological Controls - Agent Visit - Higher Budget
39	Eggplant - Biological Controls - Farmer Field School - Current Budget
40	Eggplant - Biological Controls - Farmer Field School - Higher Budget
41	Eggplant - Grafting - Paper Media - Current Budget
42	Eggplant - Grafting - Paper Media - Higher Budget
43	Eggplant - Grafting - Electronic Media - Current Budget
44	Eggplant - Grafting - Electronic Media - Higher Budget
45	Eggplant - Grafting - Field Day - Current Budget
46	Eggplant - Grafting - Field Day - Higher Budget
47	Eggplant - Grafting - Agent Visit - Current Budget
48	Eggplant - Grafting - Agent Visit - Higher Budget
49	Eggplant - Grafting - Farmer Field School - Current Budget
50	Eggplant - Grafting - Farmer Field School - Higher Budget
51	Tomato - Soil Amendments - Paper Media - Current Budget
52	Tomato - Soil Amendments - Paper Media - Higher Budget
53	Tomato - Soil Amendments - Electronic Media - Current Budget
54	Tomato - Soil Amendments - Electronic Media - Higher Budget
55	Tomato - Soil Amendments - Field Day - Current Budget
56	Tomato - Soil Amendments - Field Day - Higher Budget
57	Tomato - Soil Amendments - Agent Visit - Current Budget
58	Tomato - Soil Amendments - Agent Visit - Higher Budget
59	Tomato - Soil Amendments - Farmer Field School - Current Budget
60	Tomato - Soil Amendments - Farmer Field School - Higher Budget
61	Tomato - Tricho Compost - Paper Media - Current Budget
62	Tomato - Tricho Compost - Paper Media - Higher Budget
63	Tomato - Tricho Compost - Electronic Media - Current Budget
64	Tomato - Tricho Compost - Electronic Media - Higher Budget
65	Tomato - Tricho Compost - Field Day - Current Budget
66	Tomato - Tricho Compost - Field Day - Higher Budget
67	Tomato - Tricho Compost - Agent Visit - Current Budget

68	Tomato - Tricho Compost - Agent Visit - Higher Budget
69	Tomato - Tricho Compost - Farmer Field School - Current Budget
70	Tomato - Tricho Compost - Farmer Field School - Higher Budget
71	Tomato - Grafting - Paper Media - Current Budget
72	Tomato - Grafting - Paper Media - Higher Budget
73	Tomato - Grafting - Electronic Media - Current Budget
74	Tomato - Grafting - Electronic Media - Higher Budget
75	Tomato - Grafting - Field Day - Current Budget
76	Tomato - Grafting - Field Day - Higher Budget
77	Tomato - Grafting - Agent Visit - Current Budget
78	Tomato - Grafting - Agent Visit - Higher Budget
79	Tomato - Grafting - Farmer Field School - Current Budget
80	Tomato - Grafting - Farmer Field School - Higher Budget
81	Cucurbits - Soil Amendments - Paper Media - Current Budget
82	Cucurbits - Soil Amendments - Paper Media - Higher Budget
83	Cucurbits - Soil Amendments - Electronic Media - Current Budget
84	Cucurbits - Soil Amendments - Electronic Media - Higher Budget
85	Cucurbits - Soil Amendments - Field Day - Current Budget
86	Cucurbits - Soil Amendments - Field Day - Higher Budget
87	Cucurbits - Soil Amendments - Agent Visit - Current Budget
88	Cucurbits - Soil Amendments - Agent Visit - Higher Budget
89	Cucurbits - Soil Amendments - Farmer Field School - Current Budget
90	Cucurbits - Soil Amendments - Farmer Field School - Higher Budget
91	Cucurbits - Tricho Compost - Paper Media - Current Budget
92	Cucurbits - Tricho Compost - Paper Media - Higher Budget
93	Cucurbits - Tricho Compost - Electronic Media - Current Budget
94	Cucurbits - Tricho Compost - Electronic Media - Higher Budget
95	Cucurbits - Tricho Compost - Field Day - Current Budget
96	Cucurbits - Tricho Compost - Field Day - Higher Budget
97	Cucurbits - Tricho Compost - Agent Visit - Current Budget
98	Cucurbits - Tricho Compost - Agent Visit - Higher Budget
99	Cucurbits - Tricho Compost - Farmer Field School - Current Budget
100	Cucurbits - Tricho Compost - Farmer Field School - Higher Budget
101	Cucurbits - Sex Pheromones - Paper Media - Current Budget
102	Cucurbits - Sex Pheromones - Paper Media - Higher Budget
103	Cucurbits - Sex Pheromones - Electronic Media - Current Budget

104	Cucurbits - Sex Pheromones - Electronic Media - Higher Budget
105	Cucurbits - Sex Pheromones - Field Day - Current Budget
106	Cucurbits - Sex Pheromones - Field Day - Higher Budget
107	Cucurbits - Sex Pheromones - Agent Visit - Current Budget
108	Cucurbits - Sex Pheromones - Agent Visit - Higher Budget
109	Cucurbits - Sex Pheromones - Farmer Field School - Current Budget
110	Cucurbits - Sex Pheromones - Farmer Field School - Higher Budget
111	Cucurbits - Biological Controls - Paper Media - Current Budget
112	Cucurbits - Biological Controls - Paper Media - Higher Budget
113	Cucurbits - Biological Controls - Electronic Media - Current Budget
114	Cucurbits - Biological Controls - Electronic Media - Higher Budget
115	Cucurbits - Biological Controls - Field Day - Current Budget
116	Cucurbits - Biological Controls - Field Day - Higher Budget
117	Cucurbits - Biological Controls - Agent Visit - Current Budget
118	Cucurbits - Biological Controls - Agent Visit - Higher Budget
119	Cucurbits - Biological Controls - Farmer Field School - Current Budget
120	Cucurbits - Biological Controls - Farmer Field School - Higher Budget
121	Rice - Paper Media - Current Budget
122	Rice - Paper Media - Higher Budget
123	Rice - Electronic Media - Current Budget
124	Rice - Electronic Media - Higher Budget
125	Rice - Field Day - Current Budget
126	Rice - Field Day - Higher Budget
127	Rice - Agent Visit - Current Budget
128	Rice - Agent Visit - Higher Budget
129	Rice - Farmer Field School - Current Budget
130	Rice - Farmer Field School - Higher Budget

APPENDIX E: RESULTS FROM LINEAR PROGRAMMING MODEL (BANGLADESH)

Table E.1: Baseline #1 Strategy with Three Different Level of Adoption

	Current Budget		Baseline Model #1					
			Low Adoption		Average Adoption		High Adoption	
Crop	\$ of Budget	%	\$ of Budget	%	\$ of Budget	%	\$ of Budget	%
Eggplant	\$1,033,109	10.4%	\$424,945	4.3%	\$430,737	4.3%	\$407,293	4.1%
Tomato	\$1,033,109	10.4%	\$415,831	4.2%	\$409,272	4.1%	\$418,072	4.2%
Cucurbit	\$1,033,109	10.4%	\$1,153,542	11.6%	\$1,178,345	11.8%	\$1,200,323	12.0%
Rice	\$6,872,257	68.9%	\$7,977,268	80.0%	\$7,953,230	79.8%	\$7,945,897	79.7%
Total	\$9,971,584	100.0%	\$9,971,584	100.0%	\$9,971,584	100.0%	\$9,971,584	100.0%
	Current Budget		Baseline Model #1					
			Low Adoption		Average Adoption		High Adoption	
IPM Practice	\$ of Budget	%	\$ of Budget	%	\$ of Budget	%	\$ of Budget	%
Soil Amendments	\$929,798	9.3%	\$211,082	2.1%	\$215,758	2.2%	\$428,106	4.3%
Tricho-Compost	\$671,521	6.7%	\$199,432	2.0%	\$201,835	2.0%	\$212,939	2.1%
Sex Pheromones	\$568,210	5.7%	\$1,028,148	10.3%	\$1,042,702	10.5%	\$611,323	6.1%
Biological Control	\$361,588	3.6%	\$356,223	3.6%	\$356,223	3.6%	\$570,752	5.7%
Grafting	\$568,210	5.7%	\$199,432	2.0%	\$201,835	2.0%	\$202,569	2.0%
Rice Practices	\$6,872,257	68.9%	\$7,977,268	80.0%	\$7,953,230	79.8%	\$7,945,897	79.7%
Total	\$9,971,584	100.0%	\$9,971,584	100.0%	\$9,971,584	100.0%	\$9,971,584	100.0%
	Current Budget		Baseline Model #1					
			Low Adoption		Average Adoption		High Adoption	
Dissemination Strategy	\$ of Budget	%	\$ of Budget	%	\$ of Budget	%	\$ of Budget	%
Paper Media	\$32,101	0.3%	\$479,787	4.8%	\$449,740	4.5%	\$440,574	4.4%
Electronic Media	\$29,169	0.3%	\$288,959	2.9%	\$319,006	3.2%	\$328,172	3.3%
Field Day	\$93,521	0.9%	\$3,048,652	30.6%	\$3,048,652	30.6%	\$3,048,652	30.6%
Extension Visit	\$9,222,144	92.5%	\$5,824,512	58.4%	\$5,824,512	58.4%	\$5,824,512	58.4%
FFS	\$594,649	6.0%	\$329,674	3.3%	\$329,674	3.3%	\$329,674	3.3%
Total	\$9,971,584	100.0%	\$9,971,584	100.0%	\$9,971,584	100.0%	\$9,971,584	100.0%
	Current Budget		Baseline Model #1					
			Low Adoption		Average Adoption		High Adoption	
Crop	Surplus	%	Surplus	%	Surplus	%	Surplus	%
Eggplant	\$5,790,850	2.5%	\$7,493,483	1.9%	\$13,102,418	1.7%	\$15,629,337	1.3%
Tomato	\$3,253,628	1.4%	\$2,242,677	0.6%	\$6,127,667	0.8%	\$10,318,722	0.9%
Cucurbit	\$10,355,968	4.4%	\$27,374,824	6.9%	\$47,580,821	6.0%	\$63,225,339	5.4%
Rice	\$214,579,693	91.7%	\$361,113,465	90.7%	\$721,509,323	91.5%	\$1,082,169,856	92.4%
Total	\$233,980,139	100.0%	\$398,224,449	100.0%	\$788,320,229	100.0%	\$1,171,343,253	100.0%

Table E.2: Baseline #2 Strategy with Three Different Level of Adoption

	Current Budget		Baseline Model #2					
			Low Adoption		Average Adoption		High Adoption	
Crop	\$ of Budget	%	\$ of Budget	%	\$ of Budget	%	\$ of Budget	%
Eggplant	\$1,033,109	10.4%	\$927,357	9.3%	\$927,357	9.3%	\$927,357	9.3%
Tomato	\$1,033,109	10.4%	\$927,357	9.3%	\$927,357	9.3%	\$927,357	9.3%
Cucurbit	\$1,033,109	10.4%	\$1,236,476	12.4%	\$1,236,476	12.4%	\$1,236,476	12.4%
Rice	\$6,872,257	68.9%	\$6,880,393	69.0%	\$6,880,393	69.0%	\$6,880,393	69.0%
Total	\$9,971,584	100.0%	\$9,971,584	100.0%	\$9,971,584	100.0%	\$9,971,584	100.0%
	Current Budget		Baseline Model #2					
			Low Adoption		Average Adoption		High Adoption	
IPM Practice	\$ of Budget	%	\$ of Budget	%	\$ of Budget	%	\$ of Budget	%
Soil Amendments	\$929,798	9.3%	\$605,423	6.1%	\$633,545	6.4%	\$809,666	8.1%
Tricho-Compost	\$671,521	6.7%	\$463,679	4.7%	\$466,025	4.7%	\$480,324	4.8%
Sex Pheromones	\$568,210	5.7%	\$1,094,348	11.0%	\$1,052,690	10.6%	\$862,270	8.6%
Biological Control	\$361,588	3.6%	\$464,062	4.7%	\$475,253	4.8%	\$475,253	4.8%
Grafting	\$568,210	5.7%	\$463,679	4.7%	\$463,679	4.7%	\$463,679	4.7%
Rice Practices	\$6,872,257	68.9%	\$6,880,393	69.0%	\$6,880,393	69.0%	\$6,880,393	69.0%
Total	\$9,971,584	100.0%	\$9,971,584	100.0%	\$9,971,584	100.0%	\$9,971,584	100.0%
	Current Budget		Baseline Model #2					
			Low Adoption		Average Adoption		High Adoption	
Dissemination Strategy	\$ of Budget	%	\$ of Budget	%	\$ of Budget	%	\$ of Budget	%
Paper Media	\$32,101	0.3%	\$536,954	5.4%	\$536,954	5.4%	\$536,954	5.4%
Electronic Media	\$29,169	0.3%	\$231,793	2.3%	\$231,793	2.3%	\$231,793	2.3%
Field Day	\$93,521	0.9%	\$3,048,652	30.6%	\$3,048,652	30.6%	\$3,048,652	30.6%
Extension Visit	\$9,222,144	92.5%	\$5,824,512	58.4%	\$5,824,512	58.4%	\$5,824,512	58.4%
FFS	\$594,649	6.0%	\$329,674	3.3%	\$329,674	3.3%	\$329,674	3.3%
Total	\$9,971,584	100.0%	\$9,971,584	100.0%	\$9,971,584	100.0%	\$9,971,584	100.0%
	Current Budget		Baseline Model #2					
			Low Adoption		Average Adoption		High Adoption	
Crop	Surplus	%	Surplus	%	Surplus	%	Surplus	%
Eggplant	\$5,790,850	2.5%	\$10,353,333	3.1%	\$23,140,100	3.4%	\$29,030,572	2.9%
Tomato	\$3,253,628	1.4%	\$3,607,773	1.1%	\$7,354,794	1.1%	\$13,210,801	1.3%
Cucurbit	\$10,355,968	4.4%	\$29,541,925	8.7%	\$50,813,083	7.6%	\$67,201,852	6.8%
Rice	\$214,579,693	91.7%	\$294,644,132	87.1%	\$589,477,001	87.9%	\$884,498,608	89.0%
Total	\$233,980,139	100.0%	\$338,147,163	100.0%	\$670,784,978	100.0%	\$993,941,833	100.0%

Table E.3: Baseline #1 Strategy with Varying Rice Costs and Yields

Yield Change (IPM vs. Traditional)	1.0%		3.0%		5.0%		9.0%		5.0%	
Cost Change (IPM vs. Traditional)	-1.0%		-1.0%		-1.0%		-1.0%		10.0%	
	\$ of Budget	% of Budget	\$ of Budget	% of Budget	\$ of Budget	% of Budget	\$ of Budget	% of Budget	\$ of Budget	% of Budget
Eggplant	\$1,051,456	10.5%	\$431,255	4.3%	\$430,737	4.3%	\$431,017	4.3%	\$431,255	4.3%
Tomato	\$873,773	8.8%	\$418,035	4.2%	\$409,272	4.1%	\$402,551	4.0%	\$418,035	4.2%
Cucurbit	\$2,389,745	24.0%	\$1,177,135	11.8%	\$1,178,345	11.8%	\$1,179,186	11.8%	\$1,177,135	11.8%
Rice	\$5,656,610	56.7%	\$7,945,160	79.7%	\$7,953,230	79.8%	\$7,958,831	79.8%	\$7,945,160	79.7%
Total	\$9,971,584	100.0%	\$9,971,584	100.0%	\$9,971,584	100.0%	\$9,971,584	100.0%	\$9,971,584	100.0%
Soil Amendments	\$885,517	8.9%	\$215,758	2.2%	\$215,758	2.2%	\$215,758	2.2%	\$215,758	2.2%
Tricho-Compost	\$432,370	4.3%	\$202,642	2.0%	\$201,835	2.0%	\$201,275	2.0%	\$202,642	2.0%
Sex Pheromones	\$1,414,388	14.2%	\$835,593	8.4%	\$1,042,702	10.5%	\$824,656	8.3%	\$835,593	8.4%
Biological Control	\$1,151,201	11.5%	\$569,789	5.7%	\$356,223	3.6%	\$569,789	5.7%	\$569,789	5.7%
Grafting	\$431,497	4.3%	\$202,642	2.0%	\$201,835	2.0%	\$201,275	2.0%	\$202,642	2.0%
Rice Practices	\$5,656,610	56.7%	\$7,945,160	79.7%	\$7,953,230	79.8%	\$7,958,831	79.8%	\$7,945,160	79.7%
Total	\$9,971,584	100.0%	\$9,971,584	100.0%	\$9,971,584	100.0%	\$9,971,584	100.0%	\$9,971,584	100.0%
Paper Media	\$291,292	2.9%	\$329,094	3.3%	\$449,740	4.5%	\$456,741	4.6%	\$439,653	4.4%
Electronic Media	\$338,951	3.4%	\$462,334	4.6%	\$319,006	3.2%	\$312,005	3.1%	\$329,094	3.3%
Field Day	\$3,048,652	30.6%	\$3,048,652	30.5%	\$3,048,652	30.6%	\$3,048,652	30.6%	\$3,048,652	30.6%
Extension Visit	\$5,824,512	58.4%	\$5,824,512	58.3%	\$5,824,512	58.4%	\$5,824,512	58.4%	\$5,824,512	58.4%
FFS	\$468,177	4.7%	\$329,674	3.3%	\$329,674	3.3%	\$329,674	3.3%	\$329,674	3.3%
Total	\$9,971,584	100.0%	\$9,994,266	100.0%	\$9,971,584	100.0%	\$9,971,584	100.0%	\$9,971,584	100.0%

Table E.4: Baseline #1 Strategy with Varying Vegetable Yields

	Baseline #1		Eggplant Yield Increase by 10%		Tomato Yield Increase by 10%	
	\$	%	\$	%	\$	%
Eggplant	\$430,737	4.3%	\$728,047	7.3%	\$430,371	4.3%
Tomato	\$409,272	4.1%	\$409,272	4.1%	\$418,072	4.2%
Cucurbit	\$1,178,345	11.8%	\$881,036	8.8%	\$1,177,245	11.8%
Rice	\$7,953,230	79.8%	\$7,953,230	79.8%	\$7,945,897	79.7%
Total	\$9,971,584	100.0%	\$9,971,584	100.0%	\$9,971,584	100.0%
Soil Amendments	\$215,758	2.2%	\$356,580	3.6%	\$217,443	2.2%
Tricho-Compost	\$201,835	2.0%	\$201,835	2.0%	\$202,569	2.0%
Sex Pheromones	\$1,042,702	10.5%	\$901,881	9.0%	\$833,318	8.4%
Biological Control	\$356,223	3.6%	\$356,223	3.6%	\$569,789	5.7%
Grafting	\$201,835	2.0%	\$201,835	2.0%	\$202,569	2.0%
Rice Practices	\$7,953,230	79.8%	\$7,953,230	79.8%	\$7,945,897	79.7%
Total	\$9,971,584	100.0%	\$9,971,584	100.0%	\$9,971,584	100.0%
Paper Media	\$449,740	4.5%	\$449,740	4.5%	\$440,574	4.4%
Electronic Media	\$319,006	3.2%	\$319,006	3.2%	\$328,172	3.3%
Field Day	\$3,048,652	30.6%	\$3,048,652	30.6%	\$3,048,652	30.6%
Extension Visit	\$5,824,512	58.4%	\$5,824,512	58.4%	\$5,824,512	58.4%
FFS	\$329,674	3.3%	\$329,674	3.3%	\$329,674	3.3%
Total	\$9,971,584	100.0%	\$9,971,584	100.0%	\$9,971,584	100.0%

Table E.5: Baseline #1 Strategy with Differing Surplus Calculations

	Baseline Model #1		Change in Surplus Calculation	
	\$ of Budget	% of Budget	\$ of Budget	% of Budget
Eggplant	\$430,737	4.3%	\$440,718	4.4%
Tomato	\$409,272	4.1%	\$417,640	4.2%
Cucurbit	\$1,178,345	11.8%	\$1,175,952	11.8%
Rice	\$7,953,230	79.8%	\$7,937,274	79.6%
Total	\$9,971,584	100.0%	\$9,971,584	100.0%
Soil Amendments	\$215,758	2.2%	\$230,452	2.3%
Tricho-Compost	\$201,835	2.0%	\$203,431	2.0%
Sex Pheromones	\$1,042,702	10.5%	\$1,040,773	10.4%
Biological Control	\$356,223	3.6%	\$356,223	3.6%
Grafting	\$201,835	2.0%	\$203,431	2.0%
Rice Practices	\$7,953,230	79.8%	\$7,937,274	79.6%
Total	\$9,971,584	100.0%	\$9,971,584	100.0%
Paper Media	\$449,740	4.5%	\$429,795	4.3%
Electronic Media	\$319,006	3.2%	\$338,951	3.4%
Field Day	\$3,048,652	30.6%	\$3,048,652	30.6%
Extension Visit	\$5,824,512	58.4%	\$5,824,512	58.4%
FFS	\$329,674	3.3%	\$329,674	3.3%
Total	\$9,971,584	100.0%	\$9,971,584	100.0%

APPENDIX F: ECONOMETRICS RESULTS (NEPAL)

Table F.1: Regression Results for Probit Model Measuring Knowledge of IPM

probit knw_ipm_o net_link res_gend res_age res_age2 res_prim res_mhc_ed lalitpur rupandehi
hhszsize crdt_acc hhinc veg_pct, vce(robust)

Probit regression	Number of obs.	=	62
	LR chi2(13)	=	41.06
	Prob > chi2	=	0.000
Log likelihood = -19.158451	Pseudo R2	=	0.5173

KNW_IPM_O	Coef.	Robust Std. Err.	Z	P>z	[95% Conf. Interval]	
NET_LINK**	1.380	0.574	2.40	0.016	0.255	2.505
RES_GEND	0.032	0.543	0.06	0.953	-1.031	1.096
RES_AGE**	-0.533	0.223	-2.39	0.017	-0.969	-0.096
RES_AGE2**	0.008	0.003	2.51	0.012	0.002	0.014
RES_PRIM*	1.603	0.886	1.81	0.070	-0.134	3.340
RES_MHC_ED**	2.192	0.931	2.36	0.019	0.368	4.016
LALITPUR	0.657	0.744	0.88	0.377	-0.802	2.116
RUPANDEHI	-0.808	0.835	-0.97	0.333	-2.445	0.829
HHSIZE*	-0.159	0.095	-1.67	0.094	-0.345	0.027
CRDT_ACC	0.825	0.649	1.27	0.203	-0.446	2.097
HHINC*	0.005	0.003	1.75	0.080	-0.001	0.010
VEG_PCT**	0.036	0.015	2.46	0.014	0.007	0.064
_CONS	3.672	3.230	1.14	0.256	-2.659	10.002

Data Source: Survey for Women's Participation in IPM CRSP, IDE Nepal, Lalitpur, Nepal

* indicates that the coefficient is significant at the 10% level

** indicates that the coefficient is significant at the 5% level

*** indicates that the coefficient is significant at the 1% level

Table F.2: Marginal Effects for Probit Model Measuring Knowledge of IPM

<u>Marginal effects for probit</u>							
y = Pr(knw_ipm_o) (predict)							
= .23415095							
KNW_IPM_O	dy/dx	Robust Std. Err	Z	P>z	[95% Conf. Interval]		\bar{x}
NET_LINK**	0.372	0.153	2.40	0.016	0.597	0.072	0.673
RES_GEND	0.010	0.165	0.06	0.953	0.742	-0.313	0.333
RES_AGE**	-0.163	0.070	-2.39	0.017	36.032	-0.300	-0.027
RES_AGE2**	0.002	0.001	2.51	0.012	1410.710	0.000	0.004
RES_PRIM**	0.547	0.261	1.81	0.070	0.274	0.036	1.059
RES_MHC_ED**	0.666	0.202	2.36	0.019	0.403	0.270	1.062
LALITPUR	0.197	0.207	0.88	0.377	0.532	-0.210	0.603
RUPANDEHI	-0.198	0.170	-0.97	0.333	0.177	-0.532	0.136
HHSIZE*	-0.049	0.029	-1.67	0.094	6.161	-0.106	0.008
CRDT_ACC	0.219	0.158	1.27	0.203	0.710	-0.091	0.529
HHINC*	0.001	0.001	1.75	0.080	166.327	0.000	0.003
VEG_PCT**	0.011	0.004	2.46	0.014	34.677	0.003	0.018

Data Source: Survey for Women's Participation in IPM CRSP, IDE Nepal, Lalitpur, Nepal

* indicates that the coefficient is significant at the 10% level

** indicates that the coefficient is significant at the 5% level

*** indicates that the coefficient is significant at the 1% level

Table F.3: Bivariate Probit Regression Measuring IPM Knowledge

biprobit (knw_ipm_o = net_link res_gend res_age res_age2 res_prim res_mhc_ed lalitpur rupandehi hhsz
 crdt_acc hhinc veg_pct) (net_link = irr_h20 res_gend res_age res_age2 res_prim res_mhc_ed lalitpur rupandehi
 hhsz crdt_acc hhinc veg_pct), vce(robust)

Biprobit Regression		Number of obs.	=	62
		Wald chi2(24)	=	37.57
Log likelihood	= -36.840	Prob> chi2	=	0.038

Variable	Coef.	dy/dx	Robust Std. Err.	Z	P>|z|	[95% Conf. Interval]	
KNW_IPM_O							
NET_LINK***	2.593	0.472	0.539	4.81	0.000	1.536	3.650
RES_GEND	-0.219		0.600	-0.37	0.715	-1.396	0.958
RES_AGE**	-0.477		0.209	-2.28	0.023	-0.886	-0.067
RES_AGE2**	0.007		0.003	2.48	0.013	0.001	0.012
RES_PRIM**	1.071		0.508	2.11	0.035	0.076	2.067
RES_MHC_ED**	1.679		0.749	2.24	0.025	0.212	3.147
LALITPUR	0.242		0.689	0.35	0.725	-1.109	1.593
RUPANDEHI**	-1.360		0.673	-2.02	0.043	-2.678	-0.041
HHSIZE*	-0.160		0.085	-1.89	0.059	-0.327	0.006
CRDT_ACC*	1.106		0.622	1.78	0.075	-0.113	2.325
HHINC	0.002		0.002	0.99	0.324	-0.002	0.005
VEG_PCT*	0.014		0.008	1.76	0.079	-0.002	0.031
_CONS	4.287		3.358	1.28	0.202	-2.295	10.869
NET_LINK							
IRR_H20***	1.699		0.656	2.59	0.010	0.414	2.985
RES_GEND	0.580		0.753	0.77	0.441	-0.896	2.055
RES_AGE	0.151		0.131	1.15	0.249	-0.106	0.407
RES_AGE2	-0.002		0.001	-1.29	0.199	-0.004	0.001
RES_PRIM*	-0.867		0.512	-1.7	0.090	-1.870	0.135
RES_MHC_ED	-0.231		0.706	-0.33	0.744	-1.615	1.153
LALITPUR*	1.150		0.657	1.75	0.080	-0.138	2.438
RUPANDEHI***	7.680		0.837	9.17	0.000	6.039	9.322
HHSIZE	0.095		0.236	0.4	0.686	-0.367	0.558
CRDT_ACC	-0.021		0.575	-0.04	0.970	-1.148	1.105
HHINC***	0.010		0.003	3.56	0.000	0.004	0.015
VEG_PCT**	0.027		0.012	2.31	0.021	0.004	0.051
_CONS**	-7.791		3.677	-2.12	0.034	-14.998	-0.583

Data Source: Survey for Women's Participation in IPM CRSP, IDE Nepal, Lalitpur, Nepal

Table F.4: Suest Results

	Coef.	Robust Std. Err.	Z	P>|z|	[95% Conf. Interval]	
m1						
NET_LINK	1.380	0.574	2.400	0.016	0.255	2.505
RES_GEND	0.032	0.543	0.060	0.953	-1.031	1.096
RES_AGE	-0.533	0.223	-2.390	0.017	-0.969	-0.096
RES_AGE2	0.008	0.003	2.510	0.012	0.002	0.014
RES_PRIM	1.603	0.886	1.810	0.070	-0.134	3.340
RES_MHC_ED	2.192	0.931	2.360	0.019	0.368	4.016
LALITPUR	0.657	0.744	0.880	0.377	-0.802	2.116
RUPANDEHI	-0.808	0.835	-0.970	0.333	-2.445	0.829
HHSIZE	-0.159	0.095	-1.670	0.094	-0.345	0.027
CRDT_ACC	0.825	0.649	1.270	0.203	-0.446	2.097
HHINC	0.005	0.003	1.740	0.08	-0.001	0.010
VEG_PCT	0.036	0.015	2.460	0.014	0.007	0.064
_CONS	3.672	3.230	1.140	0.256	-2.659	10.002
m2_knw_ipm_o						
NET_LINK	2.593	0.539	4.810	0.000	1.536	3.650
RES_GEND	-0.219	0.600	-0.370	0.715	-1.396	0.958
RES_AGE	-0.477	0.209	-2.280	0.023	-0.886	-0.067
RES_AGE2	0.007	0.003	2.480	0.013	0.001	0.012
RES_PRIM	1.071	0.508	2.110	0.035	0.076	2.067
RES_MHC_ED	1.679	0.749	2.240	0.025	0.212	3.147
LALITPUR	0.242	0.689	0.350	0.725	-1.109	1.593
RUPANDEHI	-1.360	0.673	-2.020	0.043	-2.678	-0.041
HHSIZE	-0.160	0.085	-1.890	0.059	-0.327	0.006
CRDT_ACC	1.106	0.622	1.780	0.075	-0.113	2.325
HHINC	0.002	0.002	0.990	0.324	-0.002	0.005
VEG_PCT	0.014	0.008	1.760	0.079	-0.002	0.031
_CONS	4.287	3.358	1.280	0.202	-2.295	10.869

Data Source: Survey for Women's Participation in IPM CRSP, IDE Nepal, Lalitpur, Nepal

m2_net_link						
IRR_H20	1.699	0.656	2.590	0.010	0.414	2.985
RES_GEND	0.580	0.753	0.770	0.441	-0.896	2.055
RES_AGE	0.151	0.131	1.150	0.249	-0.106	0.407
RES_AGE2	-0.002	0.001	-1.290	0.199	-0.004	0.001
RES_PRIM	-0.867	0.512	-1.700	0.090	-1.870	0.135
RES_MHC_ED	-0.231	0.706	-0.330	0.744	-1.615	1.153
LALITPUR	1.150	0.657	1.750	0.080	-0.138	2.438
RUPANDEHI	7.625	0.837	9.110	0.000	5.983	9.266
HHSIZE	0.095	0.236	0.400	0.686	-0.367	0.558
CRDT_ACC	-0.021	0.575	-0.040	0.970	-1.148	1.105
HHINC	0.010	0.003	3.560	0.000	0.004	0.015
VEG_PCT	0.027	0.012	2.31	0.021	0.004	0.051
_CONS	-7.791	3.677	-2.120	0.034	-14.998	-0.583
m2_atrho						
_cons	-15.737	1.050	-14.98	0.000	-17.795	-13.678

Data Source: Survey for Women's Participation in IPM CRSP, IDE Nepal, Lalitpur, Nepal

Table F.5: Hausman-like Test Results

testnl [m1]net_link = [m2_knw_ipm_o] net_link

chi2(1)	=	8.39
Prob > chi2	=	0.0038

Table F.6: Two Step Regression Model Measuring IPM Adoption

treatreg ipm_pct train_ipm res_gend res_age res_age2 res_prim res_mhc_ed lalitpur rupandehi
 hhsz crdt_acc hhinc veg_pct, treat (net_link = irr_h20 train_ipm res_gend res_age res_age2
 res_prim res_mhc_ed lalitpur rupandehi hhsz crdt_acc hhinc veg_pct) twostep

Number of obs.	=	62
Wald chi2(22)	=	53.47
Prob > chi2	=	0.001

	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
IPM_PCT						
NET_LINK***	0.322	0.120	2.690	0.007	0.087	0.557
TRAIN_IPM	0.062	0.077	0.800	0.422	-0.089	0.213
RES_GEND	-0.035	0.076	-0.460	0.643	-0.183	0.113
RES_AGE	-0.020	0.015	-1.310	0.189	-0.050	0.010
RES_AGE2	0.000	0.000	1.440	0.151	0.000	0.001
RES_PRIM	0.016	0.073	0.220	0.829	-0.127	0.159
RES_MHC_ED	0.038	0.078	0.490	0.627	-0.114	0.190
LALITPUR***	-0.284	0.080	-3.530	0.000	-0.441	-0.126
RUPANDEHI***	-0.447	0.114	-3.910	0.000	-0.671	-0.223
HHSIZE	0.016	0.012	1.300	0.192	-0.008	0.039
CRDT_ACC**	0.138	0.069	1.990	0.047	0.002	0.274
HHINC	0.000	0.000	-0.030	0.975	0.000	0.000
VEG_PCT	0.051	0.111	0.460	0.642	-0.166	0.268
_CONS	0.538	0.341	1.580	0.115	-0.130	1.206
NET_LINK						
IRR_H20**	1.565	0.717	2.180	0.029	0.159	2.971
TRAIN_IPM**	1.902	0.816	2.330	0.020	0.302	3.502
RES_GEND	-0.270	0.836	-0.320	0.747	-1.908	1.368
RES_AGE	0.192	0.187	1.030	0.303	-0.174	0.558
RES_AGE2	-0.003	0.002	-1.250	0.212	-0.007	0.002
RES_PRIM	-0.887	0.830	-1.070	0.285	-2.514	0.739
RES_MHC_ED	-0.663	0.873	-0.760	0.448	-2.374	1.048
LALITPUR	0.091	0.786	0.120	0.908	-1.450	1.632
RUPANDEHI	6.872	.	.	.	.	.
HHSIZE	0.221	0.273	0.810	0.418	-0.314	0.756

CRDT_ACC	-0.567	0.841	-0.670	0.501	-2.216	1.082
HHINC**	0.012	0.005	2.170	0.030	0.001	0.022
VEG_PCT*	3.203	1.606	1.990	0.046	0.054	6.351
_CONS	-7.608	4.976	-1.530	0.126	-17.360	2.144
Hazard						
Lambda	-0.148	0.079	-1.880	0.060	-0.302	0.006
Rho	-0.771					
Sigma	0.192					
Lambda	-0.148	0.079				

Data Source: Survey for Women's Participation in IPM CRSP, IDE Nepal, Lalitpur, Nepal

* indicates that the coefficient is significant at the 10% level

** indicates that the coefficient is significant at the 5% level

*** indicates that the coefficient is significant at the 1% level