Economic Impact Analysis of Mixed-Species Green Manure on Organic Tomato: Evidence from the Northeastern United States

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Abstract

With shifting preferences of consumers towards healthier food, organic food demand has been on the rise for the past two decades. This increased demand has created an opportunity for farmers to shift from conventional to organic production. However, there are risks and uncertainties associated with organic farming. The management of an organic farm in the absence of organic-based disease and pest suppressing strategies constrains farmers from adopting organic vegetable production. The use of cover crops to control soil-borne diseases and suppress weeds and other pests has increased because of its sustainable and environmental friendly nature. This study of the economic impact of the cover crops on organic tomato production in the three states Ohio, New York, and Maryland showed mixed results. In Maryland, mixed forage radish and hairy vetch was projected to have a net present value over 15 years that was $1.53 million higher than single species hairy vetch, assuming maximum adoption level of 50 percent. In New York, mixed rye and turnip gave the higher return with a net present value of $2.61 million. In Ohio, the highest projected return was from mixed hay compared to hairy vetch with a net present value of $3.12 million when used without adding compost amendments. In Maryland and New York when bare ground was also used as a control, only mixed forage radish and hairy vetch in Maryland produced better returns compared to bare ground. A probit regression assessing the factors affecting the decision to adopt mixed species green manure technology indicated that farmer experiences in organic production, farmer age, access to the internet access, and farmers' perceptions about the benefits of using mixed species green manures were significant factors. Each variables and factors except age had a positive influence. Similarly, probit results for microbial inoculants indicated that education, gender, and access to the internet were significant determinants, and had a negative effect on the probability of adoption. Access to the internet was significant for both mixed species green manures and microbial inoculants but with opposite sign, positive for mixed species green manures and negative for microbial inoculants.

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Table of Contents

List of Tables

List of Figures

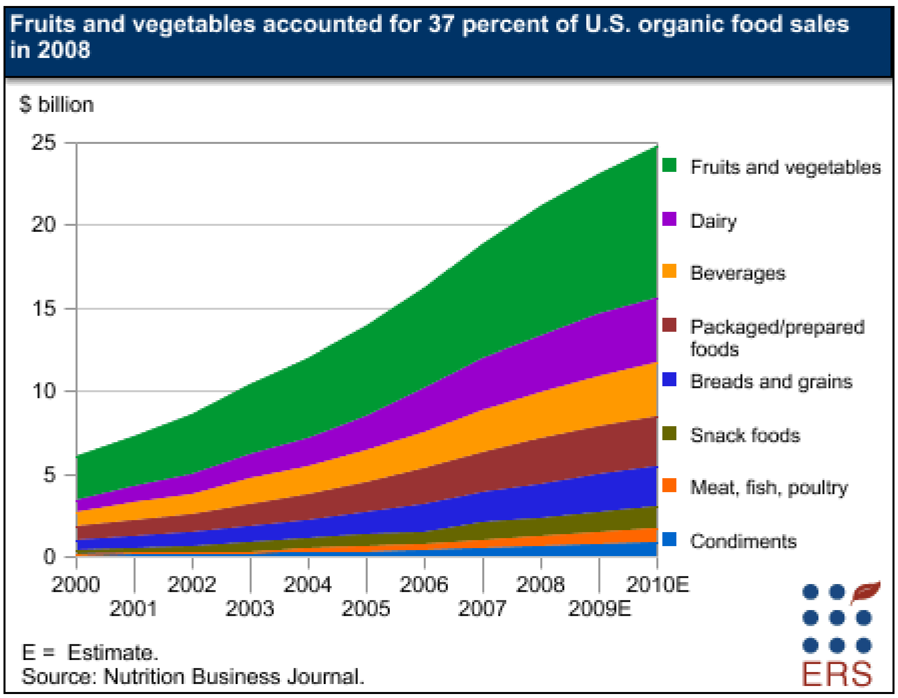
Chapter1. Introduction

Soil-borne disease is one of the major factors contributing to low yields of organic products. Over 35% of organic growers in the United States have reported disease as a significant factor affecting productivity (Walz, 2004). Soil-borne diseases are increasing in economic importance, and difficult to manage in existing systems of crop rotation, and with improved disease-resistant varieties. Research in organic farming has emphasized finding ways to combat soil-borne disease through organic treatments. Organic growers need cost-effective measures to control soil- borne diseases and supplement nutrients in the soil to increase productivity and meet market demand.

Consumer demand is growing rapidly for organic food in the United States (Batte, et al., 2007). Organic production has expanded rapidly over the last decade and is one of the fastest growing sectors in U.S. agriculture, with a sustained growth of approximately 20% per year for the last two decades. The United States had been a net exporter of organic foods for many years, but by 2002, the imports of organic products exceeded organic exports by a ratio of more than 8 to 1, primarily due to the rapid increase in domestic demand (Rawson, 2008). Several studies have argued that organic farming is a cornerstone for improving long-term farm profitability and sustainability (Cacek and Langner, 1986).

The demand for organic products is also increasing as people are informed about the benefits of organic produce. Based on the information from Nutrition Business Journal, USDA reported that fruits and vegetables have been the top selling category since the organic food industry started selling products through retail outlet for last three decades and are still outselling other categories of organic products (USDA, 2009).

Figure 1.1: Organic fruits and vegetables sales in 2008



Source: USDA/ERS, 2009

Organic farming system has become a well-defined alternative to conventional farming system in countries such as the United States. However, soil-borne diseases are problems especially in high value fruits and vegetable crops. Soil- borne disease is also a critical problem in crops transitioning from conventional to organic systems of farming. The change in management systems with a transition to organic systems may affect crop yield (Stone, et al., 2005). Bio-pesticides are developed to control these problems, but their efficiency has been variable because these pesticides are specific to disease and time of treatment (McGrath, et al., 2011). There is a need for research studies to design strategies and techniques that can mitigate soil-borne diseases in organic vegetables by increasing and diversifying soil organic matter and enhancing soil quality.

Research has been undertaken to improve soil fertility and reduce disease incidence sustainably (Walz, 2004). In the past, farmers used crop rotation to maintain soil fertility and break the cycle of insects, diseases, and weeds. Since the 1950s, chemical fertilizers, pesticides, and improved seeds have increased. The use of intensive cropping for the past 60 years has resulted in negative effects such as increased environmental degradation. These concerns have translated into increased demand for organic products.

1.1. Organic food production in the United States

The United States Department of Agriculture National Organic Program (USDA, NOP) has defined organic farming as "a *production system that is managed in accordance with the Organic Food Production Act and regulation … to respond to sites specific conditions by integrating cultural, biological, and mechanical practices that foster cycling of resources, promote ecological balance, and conserve biodiversity*" (Rawson, 2006 pp. 3). In other word, farming that puts value on resource efficiency and ecological harmony.

U.S. agricultural output increased substantially for four decades after World War II, almost annually setting new records in crop production and labor efficiency. During this period, US farms became heavily mechanized and specialized, as well as heavily dependent on chemical fertilizer and pesticides. Today people are more aware of the adverse environmental and health effects of agricultural chemicals. The concern over health issues associated with pesticides grew in the 1960s and 1970s after the publication Rachael Carson's *Silent Spring* (1962), which created public awareness of ecological problems associated with the use of agricultural chemicals in general, and the use of synthetic insecticides in particular. The Organic Foods Production Act of 1990 mandated national rules for organic certification. Organic production picked up momentum with the introduction of standards in 1990 (Thilmany, 2006).

US certified organic farmland including cropland and pasture constituted about 2.7 million acres in 2008 with 1.3 million used for growing certified organic crops. The quantity of land planted to vegetables and fruit, the top-selling organic category, has grown steadily since 1997, and the percent of vegetables farmland that was certified organic by 2008 reached almost 5%. The fresh produce continues to grow as the most popular organic category in retail sales averaging 15% a year between 1997 and 2007 (Dimitri and Oberholtzer, 2009). California was the leading state in certified organic cropland, with over 430,000 acres, of which 40 percent was used for fruit and vegetable production. Florida, Wisconsin, North Dakota, Minnesota, and Montana are other top states for certified organic cropland(USDA, 2010).

The growth in adoption of organic farming systems averaged 15% annually from 2002 to 2008. Despite high growth in the adoption rate of 15%, overall adoption remains low, and total US acreage for organic farmland is 4.8 million accounts for only 0.7 percent of all the U.S. cropland in 2008. Of the 4.8 acres of organic farmland, 2.7 acres are organic certified. High managerial costs, risks of shifting to new management practices, limited awareness of organic farming systems, lack of marketing and infrastructure, and low economies of scale are some of the obstacles to adoption of organic production systems (USDA, 2010).

Organic produce in the United States as in other countries is guided by certain standards and regulations. Congress passed the Organic Foods Production Act of 1990 to establish national standards for organically produced commodities, and USDA promulgated final rules for implementing the legislation in December 2000, which was revised in 2002. In 2008, Congress included new provisions in the Food, Conservation, and Energy Act that expanded support for the organic production sectors. The 2008 Farm Act increased mandatory funds for national certification cost share program, a data initiative, and increased mandatory organic research funds five-fold from levels mandated in 2002 Act (USDA, 2009). These regulations require that all except the small organic growers (less than $5000 in sales) to be certified by a state or private agency accredited under the uniform standards developed by Agriculture and Marketing Service USDA. Fifty-nine organic certification organizations, including 17 state programs and 3 county programs in

California were in operation for third-party certification of organic production and handling (USDA, 2010)

The certification requires farming without prohibited materials such as synthetic fertilizers, pesticides, and genetically modified organisms for three years prior to harvest of the first certified organic crops produced during this period in transition from conventional to organic production. The crops produced during these period are considered transitional organic. Organic production system also requires implementing an organic system plan, excluding proactive fertility systems, conservation measures, manure management, weed, disease and pest management, and soil-building crop rotation systems. Under these regulations, organic farmers rely heavily on crop rotation, crop residues, composted or non-composted animal manures, and organic wastes to supplement soil fertility. Nevertheless, organic farmers are prohibited from applying chemical fungicides in transition from conventional to organic production causing extensive crop loss. Disease management is therefore a critical issue in organic vegetable production (Koike, et al., 2000).

1.2. Cover crops green manures and microbial inoculants

Research initiatives have been undertaken to identify the measures to replace inorganic synthetic fertilizers, soil fumigants, and fungicides with organic-based fertilizers and pesticides. Green manures can fix nitrogen, add significant biomass, and suppress weeds, and soil-borne diseases while improving yields of high value organic vegetables.

Cover crops are planted primarily to improve soil characteristics and weed control, suppress plant diseases, and for environmental reasons. Cover crops such as clover and lupine possess disease-suppressing effects, and legume cover crops increase yield. The mixes of cover crops can manipulate nitrogen cycles, control different types of weeds, and influence insect populations (SAN, 2007). Green manures act through multiple processes, several of which are well established. For example, Graminaceous species (e.g. rye, barley, and sudan grass) provide relatively high carbon inputs and more intensive rooting patterns that can promote better soil structure. Leguminous species (e.g. hairy vetch and clovers) provide added soil nitrogen because of their ability to fix nitrogen. Buckwheat has disease-suppressing characteristics under certain conditions. A report to the Oregon Processed Vegetable Commission, Stone, et al. (2005) highlighted a greater reduction in corn radical and root rot severity in cover-cropped than in fallow treatments. Cover crops provide soil-improving characteristics in terms of both soil nutrient levels and disease suppression effects. In addition, cover crops have positive externalities of reduced pollution, erosion, weed pressure, and human and animal health effects. The cover crops help to reduce fertilizer costs by contributing nitrogen to crops; reduce the need for herbicides by suppressing weeds, and mitigate damage caused by diseases, insects, and nematodes. Cover crops improve yields by enhancing soil health through speeding infiltration of excess surface water, prevent soil erosion, conserve soil moisture, protect water quality, and help safeguard public health. While a number of studies have identified benefits for single species cover crops, the added benefits of different combinations of green manures have not been systematically assessed. The range of benefits can be increased by using different mixes of cover crops, alternating the frequency and length of cover crops between cash crops (Bowman, et al., 1998).

Microbial inoculants (MI) are organic amendments that use beneficial microbes to promote plant growth. These consist of microbial species in a liquid suspension such as arbuscular mycorrhizal fungi *Azospirillum* and *Pseudomonas* that improve crop production through improved nutrient uptake by plants, sequestration of atmospheric nitrogen, or control, inhibition, or competition with plant pathogens and pests. Mycorrhizal fungi may colonize roots of the host plant internally or externally, which increases the volume of nutrient uptake (Park, et al., 2010) .

1.3. Technology adoption defined

The contribution of a new technology to economic growth can only be realized when the technology is widely diffused and used. The diffusion results from a series of individual decisions to begin using a new technology based on a comparison of uncertain benefits of an innovation with uncertain costs of adopting it. The development of an innovation and its diffusion do not follow the same speed. Diffusion is a continuous and slow process, and this process determines the rate of change of productivity and associated benefits.

Diffusion of technology can be studied at the farmer's or at an aggregate level. According to Feder et al. (1985, pp 256), individual level adoption is defined as "*the degree of use of a new technology in long-run equilibrium when farmer has full information about the technology and its potential*". They defined aggregate level adoption as "*the process of spread of a new technology within a region*" (Gershon, et al., 1985), and this is measured by the aggregate level of use of a technology in a given geographical area or by a given population. The introduction of new technologies results in a period of disequilibrium behavior where there is inefficient use of resources until a new equilibrium is reached. There is increase in supply, which is reflected by the rightward shift of supply curve. This paper focuses on the research induced benefits in the form of consumer and producers surplus due to adopting mixed-species green manure (MSGMs) in organic tomato farming in the United States and potential determinants of diffusion process. The analysis is based on the project undertaken by Ohio State University titled, "*Enhancing productivity and Soil-borne Disease Control in Intensive Organic Vegetable Production with Mixed-Species Green Manures"* in three states, New York, Maryland, and Ohio.

1.4. Overview of the project

The Enhancing Productivity and Soil-borne Disease Control in Intensive Organic Vegetable Production with Mixed-Species Green Manures (MSGMs) is an integrated research and extension project aimed at enhancing productivity and soil-borne disease in organic vegetable production by the application of green manures. The project funded by USDA Organic Research Extension Initiatives (OREI) utilizes participatory research to determine the efficacy of MSGMs and facilitate communication and participation among end-users, researchers, and extension teams. The goal of the project is to improve on-farm production efficiency and soil-borne disease management through effective and value-driven applications of mixed-species green manures in organic vegetable cropping systems. The main objectives of the project include

a. evaluation of the efficacy and value of mixed–species green manures in contrasting cropping systems, using a participatory approach;

b. characterization of the linkages between microbial community structure and soil-borne disease suppression in different organic vegetables systems;

c. evaluation of novel microbial inoculants to enhance the disease suppressive effects of mixed-species green manures; and

d. estimating the value of added green-manure adoption by organic growers using multi-criterion decision analysis (MCDA).

The project is multi-disciplinary in that it combines expertise in vegetable agronomy, plant pathology, microbial ecology, agricultural economics, and commercial bio-pesticides development to quantify and develop biological controls to manage sustainably soil-borne disease of vegetables crops. It also includes innovative research and extension expertise to ensure that the outcomes of this project will be transferred to end-users.

The project is implemented in Ohio (OH), Maryland (MD), New York (NY), and Virginia (VA), and is led by the Ohio State University. Field efficacy trials of green manure treatments are established in the first two years of the project. Scientists in OH, MD, and NY are working with local growers who have successfully deployed MSGM strategies. Virginia is only involved with impact assessment. The project aims to assess farmers' practices and their impacts on soil-borne diseases. These assessments conducted as both natural descriptive experiments and planned replicated plots determine the relative utility of single and mixed-species green manures at multiple sites.

Six different experimental treatments included as best strategies are: mixed-species hay and hairy vetch and rye (OH), mix hay, rye and hairy vetch, forage radish and hairy vetch (MD), turnip and rye, red clover and rye, and hairy vetch and rye. One or two site-specific industry standards (e.g. rye only, vetch only in OH), and an untreated check are included as positive standards and negative controls in all locations.

For estimating research-induced benefits of MSGM, this study accounts for an analysis of the effects of MSGM on tomatoes. Tomato is one of the fundamental crop for plant-microbe interaction. According to Subedi (2009), about 200 diseases are associated with tomato. In addition, tomato is the nation's fourth most popular fresh-market vegetable next to potatoes, lettuce, and onions in terms of consumption (USDA, 2009). The per-capita use of tomatoes has been increasing over past few decades indicating its increasing demand.

1.5. Tomato production and its market

The United States is one of the world's leading producers of tomatoes, second to China. In 2005, tomato was the second most important organic vegetable in acreage representing 7% of all organic vegetable acreage (Dimitri and Oberholtzer, 2010). The sale of fresh and processed tomatoes provides more than $2 billion in annual farm cash receipts. According to USDA, tomato is the second-largest fresh vegetable with an export value of $208 million in 2008, and accounting for 6% of total domestic produce (USDA, 2009).

Approximately 6% of tomato products consumed by Americans today are imported. Canada is the largest exporter of tomatoes to the United States, accounting for more than 40% of imported processed tomato products which include mostly catsup and sauces. California and Florida are the leading producers of tomatoes in the United States accounting for more than two thirds of all commercially produced fresh-market tomatoes in the United States. Florida is the second-largest tomato-producing (including processing tomatoes) state next to California, and it has been the largest producer of fresh tomatoes for decades except in 2008. Other major producers in terms of acreage are Ohio, Virginia, Georgia, and Tennessee (USDA, 2009).The total national acreage for tomato in 2009 was 442,100, of which 331,900 acres were used for processed and the rest for fresh tomatoes (USDA, 2010). Total certified producers have increased by 77 percent (from 7,312 to 12,941) since 2002 (USDA, 2010).The total certified acreage for organic tomatoes in the United States was 9,237 acres, of which California accounted for 8,291 acres in 2008 (USDA, 2010). The US acreage for organic tomato has risen by 200% from 2000-2008 (3063 acres to 9237 acres). Efforts are being made to increase production of organic tomatoes to meet domestic demand and expanding international tomato market. One of the areas being extensively explored is combating yield loss due to diseases and pests using organic-based fertilizers and pesticides.

1.6. Problem statement

Organic tomatoes are grown on 9,237 acres of land. The production of organic vegetables including tomatoes is limited by factors such as soil-borne diseases, pests, and foliar diseases of vegetables that are known to negatively affect both yield and quality of vegetables. Root diseases caused by fungal and nematodal soil-borne pathogens are common on many vegetables in the northeast region of the United States, and elsewhere (Abawi and Widmer, 2000). To meet demands of economically competitive organic agriculture, growers must be able to manage soil-borne diseases and microbial populations that suppress them. Moreover, organic growers are required to use organic-based inputs for enhancing soil quality and controlling soil-borne diseases, pest and insects. One of the two research priorities specified in the 2008 Farm Act is to study the conservation and environmental outcomes of organic practices (USDA, 2010). The Food, Conservation, and Energy Act of 2008 (Farm Act), was enacted into law in June 2008, which governs the bulk of Federal agriculture and related programs for the next 5 years, which has increased the opportunities to research related to organic production.

MSGM and MI can play a key role in developing effective biological-based practices for root diseases. However, to make practical progress with MSGM & MI, identification and quantification of beneficial effects are crucial. A better understanding of how MSGM and & MI affect ecology of the soil-borne pathogens and their natural antagonists, and dissemination of information related to MSGM & MI are important to help growers make adoption decisions on new practices.

The use of the soil management practices that increase quantity and diversity of total soil microbes, beneficial organisms, lower incidence, and intensity of crop pests are crucial in increasing organic vegetable yield and quality. Mixed-species cover crops can confer multi-dimensional effects on the soil enhancing soil quality and beneficial microbial activities that suppress disease occurrence.

Despite the positive effects of MSGM & MI and efforts of numerous research scientists and extension agents, farmers are not fully aware or informed about MSGM & MI and their subsequent benefits. There is a knowledge gap concerning how farmers obtain information on improved farming practices like green manure management and their use. Different factors affect adoption, and analyzing these factors provides useful information to orient farmers on the benefits of MSGM & MI use. Evidence of benefits of MSGM & MI can provide decision makers with information on the welfare effects because of their adoption, and helps in planning and budgeting for related programs to encourage farmers to adopt the practices. Welfare can be in the form of producer or/and consumers economic benefits from adopting of the technology. Producers gain from an increase in yield and a decrease in cost of production. Consumers benefit from a decline in the price of a commodity resulting from its increased production and supply. However, mixed-species green manure has been used only recently. There are few research and diffusion efforts in this area. Only about 10% of the CRIS reports related to green manures and cover crops are related to soil-borne disease suppressions, and these studies have focused primarily in the use of single-species cover crops. Current research lacks a comprehensive synthesis of the effects of mixed species cover crops in multiple certified organic systems, and an assessment of the potential value added of using multispecies cover crops and green manures is necessary for its wider application.

This study assesses the economic benefits associated with the adoption of MSGM in organic tomatoes developed and extended by the project. It undertakes an analysis to project adoption of MSGM & MI practices in multiple certified organic cropping systems with different mixes of cover crops. It also assess economic benefits of MSGM at the societal level.

1.7. Objectives of the study

The overall purpose of this study is to conduct an economic analysis of the benefits of MSGM treatment on organic tomatoes.

Specific objectives

a. identify determinants of adoption of the MSGM and MI technologies, and
b. assess economic benefits from the use of MSGM and their distributionto producers and consumers.

Hypotheses

- The adoption of MSGM & MI increases as farmer's level of education increases
- Adoption of MSGM & MI is related positively to training participation
- The adoption of MSGM & MI decreases with farmer's age and experience
- Membership in farmers' organizations positively affects adoption of MSGM and MI

1.8. Organization of the thesis

The paper has six sections. Chapter two presents an overview of the literature on adoption of agricultural innovation and the use of economic surplus analysis to evaluate research benefits. The detailed methodological framework used for the analysis including the description of study sites, data sampling and collection technique is presented in chapter three. The results and discussion of the findings are outlined in chapter four. Chapter five highlights the conclusion and potential areas of future research.

Chapter2: Literature Review

Several studies have been undertaken related to agricultural technology adoption and subsequent economic benefits associated with it. This chapter summarizes the outcome of important and relevant studies concerning agricultural technology adoption, variables affecting technology diffusion, and economic analysis of the benefits of agricultural practices.

2.1. Adoption of new technology

The contribution of technology to production of agricultural commodities can be realized when technology is widely diffused and used, and identifying variables that influence adoption may increase the speed of technology diffusion. Feder et al. (1985) have identified variables such as lack of credit, limited access to information, aversion to risk, inadequate incentives associated with farm tenure arrangements, insufficient human capital, absence of equipment, labor shortages, inadequate and irregular supply of complementary inputs, and inappropriate transportation infrastructures. Some of these constraints can be reduced by developing transportation infrastructure, improving access to credit, and participating in educational programs such as training and orientation. The adoption behavior of farmers varies across socioeconomic groups (Feder, et al., 1985), agro-climates, and locations (Feder and Umali, 1993). A study conducted in Australia, Guerin and Guerin (1994) identified constraints to adoption of new technologies and innovation to be: complexity of technology, financial costs, farmers' beliefs and opinions towards a technology, farmers' level of motivation, farmers' perceptions of the relevance of the technology, and attitudes towards risk and change.

In one study, Wilson et al. (2008) argued that the quality of information and process of communications among researchers, extension agents, and end-users are important determinants in the diffusion of integrated weed management techniques. Integrated weed management and herbicide resistant strategies have relied primarily on the innovation diffusion methods used in the United States and several other countries. These techniques involve encouraging an innovation to be adopted first by a few innovative farmers, followed progressively by an increasing number of farmers. The authors argued that the quality and the process of delivering the information should be appropriate to farmer's level of knowledge and skills to influence farmers' adoption decisions. Identifying and recognizing popular knowledge provide baseline information for developing appropriate educational and communication strategies.

Ricker-Gilbert et al. (2008) argued that the effectiveness of diffusion methods depends on the extension agents' ability to extend integrated pest management practices and combinations of practices of differing complexity to farmers. The IPM practices can be categorized by the level of complexity based on the extent of knowledge required for their successful implementation. For a simple IPM practice, a farmer may only need a limited understanding of why it works. However, for a complex IPM practice, a farmer may need significant management ability and an awareness of ecosystem relationships. Ricker-Gilbert et al. categorized diffusion methods into three levels of intensity. Less intensive mass media methods, medium intensive methods with periodic visits of extension agents to instruct and advise farmers in related topics, and highly intensive methods involving farmer field schools (a participatory, experiential learning involving weekly small group training sessions on IPM over the whole crop season for a specific crop). Field days were found to be the least expensive means of diffusing IPM technologies where farmers were most likely to adopt simple practices. They found that farmer field school was an expensive means of diffusing IPM when farmers adopted intermediate and complex practices. Therefore, the nature and effectiveness of extension services depended on the nature of the technology in use in terms of intensiveness and complexity.

Bonabana-Wabi (2002) analyzed the determinants of adoption of eight IPM technologies in the Kumi district, Eastern Uganda; the relative contribution of each factor affecting IPM adoption; and the level of adoption of eight IPM technologies on cowpea, sorghum, and groundnuts in Kumi. Low adoption (< 25%) was found with five technologies, while high adoption (> 75%) was found with the other three technologies. Using univariate and multivariate logit models, eight practices were analyzed. She found that access to information positively affected adoption of IPM technologies. She also found that social variables did not affect technology adoption decisions, except for *celosia* (an exotic legume that reduces striga) for which gender was found to affect adoption decisions. Males adopted the technique of intercropping sorghum with *Celosia* more than females. Farm experience positively affected timely planting of cowpea. In sorghum, adoption of crop rotation was found to reduce weed problems. In the case of cowpea, intercropping served as a land-saving technology as well as a pest management strategy.

Waller et al. (1998) emphasized that the nature of technology in terms of cost and complexity was an important factor influencing farmers' adoption decision-making. Supplementing this author's argument, Norton and Swinton (2009) modeled IPM adoption as a function of age, education, land tenure, income, distance to market, number of farm organizations, and IPM training. In a household survey in Uganda, Moyo et al. (2007) found age, household size, and family income were negatively related to adoption of hybrid or improved varieties of maize and other crops including peanuts. In contrast, education was positively related to adoption of these crops. Males were found to adopt the technology more than females. Greater access to land was positively correlated with adoption because households with more access to land were more likely to receive information from extension agents related to crop production and marketing.

Mauceri (2007) studied adoption of IPM technologies in potato production in Carchi, Ecuador using an ordered probit model. The variables she used in the adoption analysis were age, farm size, education, family size, number of family members 14 years and older; landholdings per capita, pesticides' health effect on farmer and the family, and farmer field school attendance. In contrast to Moyo et al., she found that apart from information dissemination factors, the only socio-economic variables that was significant was household size, and it affected adoption negatively.

Adesina and Zinnah (1993) argued that a farmer's perception of the technology might significantly influence adoption decisions. This variable was defined as whether or not the farmer sees the technology as appropriate for solving the particular problem. Using a tobit model, they tested their hypothesis on 124 rice farmers in Sierra Leone. They found that the perception variable was a major determinant of adoption decision and that traditionally used variables (technology diffusion factors) were not significant in determining the decision.

Chaves and Riley (2001) analyzed the factors affecting IPM adoption to control a coffee berry-borer problem in Colombia. They categorized the factors affecting adoption as social, economic, institutional, and environmental. Using logit analysis, different factors were analyzed at different times with four of the recommended IPM practices and other variables likely to affect adoption of these practices. Education was an influential factor, positively affecting adoption under all scenarios. Size of the coffee plots was found to be important in all cases in most years, and household wealth was also found to be an influential variable affecting adoption decisions.

In addition to the above determinants, Napit et al. (1988) included variables such as farming experience, race, and value of products sold annually in an analysis of adoption of IPM programs. According to their model, experience was included to capture possible wisdom effects on technology adoption, and was likely to offset the potential negative influence of age. Race was included to account for the possible effect of differences in program promotion on respondents' ability to adopt new technology. The value of products sold was included to reflect its influence on ability to invest in new technologies. In seven out of their nine studies, authors found that a higher value of farm products sold annually or a higher share of family income from farming or both contributed positively to respondents' decisions to adopt IPM practices. Education and frequency of contact with extension agents were also found to be positively related to adoption decisions.

Saka and Lawal (2009) examined the status of adoption of improved rice varieties and its impact on rice production among farmers in southwestern Nigeria. They used an adoption index to assess the adoption rate, a logit model to determine factors affecting technology adoption, and stochastic frontier model to assess the impact on farmer's profitability. Their study revealed that adoption could be increased by increasing farm size, and the quantity of improved seeds and fertilizer. They found that land area cultivated for rice, frequency of extension contacts, and yield rating were the significant determinants of farmers' decisions to adopt improved rice varieties.

D'Souza Filho et al. (1999) used duration analysis to analyze the determinants of farmers' decisions on whether or not to adopt low- external-input and sustainable agriculture (LEISA). Their results suggested that the probability of a farmer adopting new technology increased if a farmer was more integrated with farmer organizations, had contacts with non-governmental organizations, was aware of the negative effects of chemicals on health and the environment, could rely on family labor, and had a farm located in an area with better soil conditions. On the other hand, the probability of adoption was reduced with an increase in farm size. The authors found that access to information positively affected adoption because of increased awareness of negative effects of pesticides use.

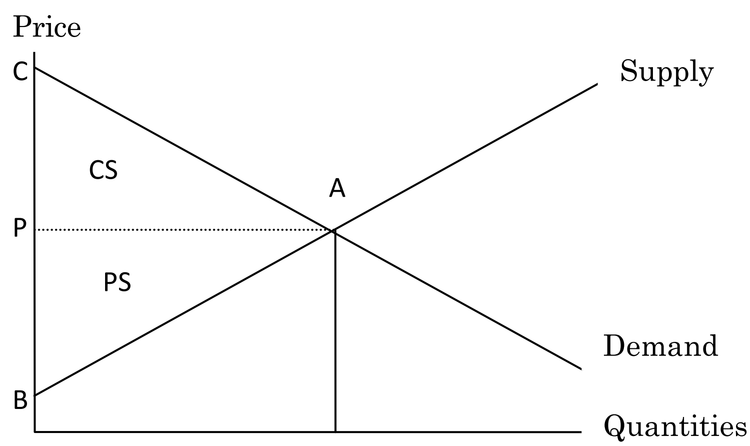
To summarize, several variables associated with socio-economic, institutional, and technological characteristics affect farmers' adoption decisions. Among the socio-economic determinants, education was found to have significant positive correlation with adoption whereas age was negatively correlated. Some studies found farm size to have negative affect but others found it to have positive effects; value of product sold annually had positive effects. Institutional characteristics like extension agents' contacts and affiliation with farmers' organizations, and information dissemination approach appropriate to technology were found to have positive effects. Cost and intensiveness of the technology were other variables found to affect adoption decisions. Gender, race, farmers' perception of the technology, wealth, family size, working family members, yield rating, and area cultivated for the crop were also significant in affecting adoption decisions.

2.2. Measuring economic impacts of agricultural technology

Economic surplus analysis combine with benefit-cost analysis is perhaps the most common approach used to measure the market level impacts of agricultural technologies. Economic surplus analysis measures changes in consumer surplus and producer surplus (PS) that result from adoption of a new technology.

Consumer surplus represents consumers' willingness to pay more for a good than the market price. Producer surplus (PS) measures returns to producer fixed or quasi-fixed inputs. A graphical representation of CS is presented in figure 2.1 as

Figure 2.1: Consumer and producer surpluses in a partial equilibrium analysis



area of PAC. It is the total surplus received by the consumer minus the marginal cost of buying quantity Q of a good at price P. Produer surplus is represented by area of PAB. PS is the total revenue minus the total cost of producing quantity Q of a good. Any changes in CS, PS, can be measured as a changes in these areas.

Alston et al. (1995) presented an economic surplus model to evaluate welfare effects from use of new agricultural technologies under different assumptions on market conditions. They formulated different models based on a single closed market economy and various open market scenarios. Economic surplus methods have been used in recent years to assess the impact of research-induced benefits. In an assessment of the potential economic impacts of genetically modified (GM) transgenic salinity and drought resistant (SDR) rice in Bangladesh, Alpuerto, et al. (2009) found an incremental benefit of $934 per hectare, and the number varied from district to d.istrict.

In another study, Kostandini et al. (2009) attempted to assess yield increases and yield variance, and estimated annual benefits of US $178 million to the private sector suggesting significant incentives for transgenic drought tolerance research. Research on virus-resistant peanut varieties in Uganda found a yield increase of 67 percent per hectare with about a 50 percent increase in per-hectare input costs (Moyo, et al., 2007). Song & Swinton (2009) studied soybean aphid, a major invasive pest that has caused substantial loss resulting in increased use of insecticides. Their study focused on estimating the economic benefits of U.S. research and outreach for IPM of soybean aphid, and estimated an ex-ante net benefit of $1.3 billion, for an internal rate of return of 124 percent over 15 years from the beginning of soybean aphid research.

In an attempt to assess the impact of IPM practices on the level and variability of net returns to farmers and aggregate benefits to producers and consumers from IPM programs in thirteen states, Napit et al. (1988) found that, except in North Carolina tobacco, high users of IPM received higher returns per hectare than did low users or nonusers. However, out of nine crops considered, cotton in Texas and Mississippi and alfalfa seed in the Northwest showed large differences in returns to management per hectare across user levels. Napit et al. carried out a net return analysis using partial budgets, and their study results indicated that some states had significantly different pesticide costs across user levels. The consumer and producer surplus calculated for those states had significant net returns. The resulting annual rates of return on investment in IPM were high and varied across different states.

Baez (2004) studied the potential economic benefits from plaintain IPM adoption in the case of rural households along the coastal region of Ecuador and found a significant reduction in plaintain production because plantain is susceptible to diseases and insects. The economic surplus change was calculated over 15 years with a discount rate of 4 percent and maximum adoption level of 17 percent. The net benefits were found to be approximately $49 million without using fungicides and $46.5 million with use of fungicides. Hristovska (2009) presented a summary table of different IPM CRSP impact studies. Table 2.2 gives a brief summary of the different studies related to adoption new IPM technologies, and the net benefits resulting from adoption of IPM and improved varieties of seeds.

Table 2.1: Summary table of benefits from the IPM CRSP impact studies

Place/Authors	Country	Crop	Benefits/ achievements/ impacts
East Africa Moyo, et al.(2007)	Uganda	Peanuts	Open economy NPV ranging from $43.0 to $35.6 million Closed economy: NPV ranging from $41.1 to $34.0 million
Debass (2000)	Uganda	Beans Maize	NPV was about $ 202 million, IRR was 250% NPV was about $36 million, IRR was 250
West Africa Nouhoheflin et al. (2009)	Mali		Closed Economy: NPV was about $11.64 million,IRR was 102%. NPV was about $10.3 million, IRR was 134%. NPV was about $1.5 million, IRR was 50%. Open Economy: NPV was about $12.4 million,IRR was 102%. NPV was about $10.9 million, IRR was 134%. NPV was about $1.6 million, IRR was 50%.
Southeast,South Mamaril and Norton(2006)	Philippines Vietnam ROW	Rice Rice Rice	Gains were $270 (range from $136-276) million Gains were $329 (range from $159-415) million Gains were $20 (range from $10-26) million
Southeast, South Asia Mishra (2003)	Bangladesh Philippines India	Eggplant Eggplant Eggplant	NPV gains range from $25 to $69 million NPV gains range from $19 to $53 million NPV gains range from $279 to 773 million
Southeast Asia Cuyno (1999)	Philippines	None-Health	Reduced risk to: human health and farm animals by 64% beneficial insects by 61% fish and other aquatic species by 62% birds by 60%
South Asia Alponi (2003)	Bangladesh	Vegetables: eggplant Cabbage	Cabbage and eggplant yields were higher 10-50% and 13-61% respectively Eggplant Eggplant seedlings mortality rate was 5-10% Cabbage seedlings mortality rate was 1-4%
Southeast Asia Mutuc (2003)	Philippines	Eggplant	Case 1: Nueva Ecija: Total daily calorie intake/capita increased b/w 0.09 to 0.6 kilocalories (5% bacterial wilt) and b/w 0.9 to 6.0 kilocalories (50% bacterial wilt) Case 2: Pangasinan Total daily calorie intake/capita increased b/w 0.07 and 0.22 kilocal. (5% bacterial wilt) and b/w 0.15 and 0.49 kilocal. (50% bacterialwilt)
South Asia	Bangladesh	Birnjal (Eggplant)	NPV was about $29million, the IRR was 684% NPV was about $26 million, the IRR was 696%

Debass (2000)		Cabbage	
Latin America Rakshit (2008)	Bangladesh	Cucurbit Crops	NPV was about $3.99 million, IRR was 151%.
South America Cole et al. (2002)	Ecuador	Potato	Active fungicide amount decreased by 50% Insecticide use decreased by 75% Production costs decreased from $104 to $80/t
South America Baez (2004)	Ecuador	Plantain	Producer, consumer and laborer net benefits range from $46.5 to $49 million, $4.2 to $4.4 million and $8 to $9.5 million, respectively.
Daku (2002)	Albania	Olives	Net IPM research benefits varies between $39 and $52 million (assuming farmers move from no spray and fill pesticide to IPM program/ practice directly.

Source: Hrisvotska (2009) pp.32

2.3. Conceptual framework

The benefits from agricultural innovation depend on farmers' decisions to adopt an innovation, which are assumed to be based on maximization of their expected utility or benefits. A farmer's utility depends on optimization of productivity and minimizing costs to achieve the greatest profits in the face of uncertainty. Therefore, farmers' MSGM adoption decisions are assumed to be based on theory of utility maximization (Adesina and Zinnah, 1993). According to Adesina and Zinnah, the non-observable underlying utility function that represents the preference of the *ith* farmer is given by $U(H_{ij}, A_{ij})$, where H is a vector of farm and farmer-specific characteristics of adopters, and A is a vector of attributes related to the *jth* technology.

In this case, the new technology represents adoption of MSGM or MI, where the unobserved utility functions are represented by

$$U_{i1} = \beta_i H_{i1} + \delta_i A_{i1} + e_{i1} \quad (2.1)$$

$$U_{i0} = \beta_i H_{i0} + \delta_i A_{i0} + e_{i0} \quad (2.2)$$

Where U_{i1} and U_{i0} are the utilities with and without MSGMs or MIs adoption for *ith* farmer respectively, and e_{i1} and e_{i0} are error terms. Because the utility U_{ij} is random, the *ith* farmer will select MSGMs or MIs $j = 1$ if $U_{i1} > U_{i0}$, which means the utility obtained from adopting MSGM or MI is greater than it is for alternate practices. The decision to adopt MSGMs or MIs occurs if the non-observable variable $Z_i = U_{i1} - U_{i0} > 0$; $Z_i = U_{i1} - U_{i0} < 0$ if otherwise.

Chapter 3: Methods

This chapter presents the brief description of the study sites and different methods used in adoption analysis and economic impact assessment. The economic impact analysis of MSGM & MI considered in this paper focuses on tomatoes and contains two components. Those components include the adoption analysis of MSGM and MI to identify different factors that affect farmer's adoption decision and measuring the project's aggregate or market level economic benefits of MSGM and MI using the economic surplus method.

3.1. Study sites:

Study sites comprised the Northeastern states of Ohio, Maryland, New York, Virginia, Michigan, and Pennsylvania. Table 3.1 presents a brief description of each of the states pertaining to farmland and producers' characteristics.

Table 3.1: Farm and farmer characteristics in surveyed states

States	Farmland in acres[a]	Av. Farm size[b]	Ownership[c]	Av. Age	Female[d]
Maryland	2,051,756 (32.8)	160	70.4	47.3	16.2
Michigan	10,031,807 (27.7)	179	70.2	56.3	14.7
New York	7,134,743 (23.8)	197	67.6	56.2	18
Ohio	13,956,563 (53)	184	67.5	55.7	12
Pennsylvania	7,809,244 (27.3)	124	70.6	55.2	13.5
Virginia	8,103,925 (32.1)	171	67.8	58.2	16.5

Source: USDA ERS, 2011

[a] Number in the parentheses are the percentages of farmland to the total land area of the respective states.[b] Unit of farm size is acres. [c] Percentage of farmers owning farmland

[d] Percentages of women in the agricultural production sector in the respective states

Ohio has the highest percentage (53) of farmland compared to total land, followed by Maryland (32.8), and Virginia (32.1). The average farm size varied from 124 to 197 acres. More than 67 percent of farmers in all the states own their farmland. The average age of farmers in these states ranged from 47 to 59 years. The percentage of female farmers was below 20 in all the states. Among the selected states, New York had the highest total organic acreage at 131,932, including organic tomato acreage of 222, and 803 organic certified operations. Virginia had total organic tomato acreage of 66, followed by Maryland with 16, and Michigan with seven. The organic acreages for Ohio and Pennsylvania are not available.

Table 3.2: Brief summary of state-based organic production facts

States	Organic acreage	Certified Operation	Organic Tomato Acreage
US	2,643,221	12,941	9,237
Maryland	5,655	119	16
Michigan	53,938	171	7
New York	131,932	803	222
Ohio	43,024	419	-
Pennsylvania	34,127	420	-
Virginia	13,353	171	66

Source: USDA ERS, 2011

3.2. Sampling and Data:

A mail survey was conducted in the months of May-June 2011. The farmers were selected from the Ohio Ecological Food and Farm Association (OEFFA), Pennsylvania Certified Organic (PCO), Michigan Organic Food & Farm Alliance

(MOFFA), Northeast Organic Farming Association-New York (NOFA-NY), Indiana Certified Organic (ICO), Maryland Organic Certification Program (MOCP), Kentucky Organic Certification Program (KOCP), and US Department of Agriculture (USDA). Information was collected through mail surveys, direct interviews from organic vegetable producers, extension agents, project farmers, project collaborators, and scientists from within and outside the project area. For the mail surveys, a letter was sent to the farmers mentioning the objectives and use of data from the survey. A week after sending the letter, the survey instrument package along with a cover letter was mailed to all those to whom the letter was sent. After two weeks, a post card reminder was sent to encourage them to complete the surveys. Upon the receipt of the completed survey, a thank you note along with a five-dollar Walmart gift card was mailed to the respondents.

In the mail survey, producers were asked to provide information under four categories. Farmers' demographic information included age, sex, education attainment, and membership in farmer and other related organizations. Organic farming related activities included type of farm, location of farm, amount of labor, production techniques, experience with organic farming, acres of organic vegetables produced, information on cover crops and variable costs associated with inputs. Organic growers' perspectives on soil-borne disease management included perceptions on impacts of various chemical and physical characteristics of the soil, information sources, and organic management practices. Other information received from the surveys includes modes of communication, access to information, and participation in training and learning activities. Scientists and project collaborators provided information on the proportionate change in variable cost per acre and the proportionate yield change per acre. Interviews with scientists also provided information on the present rate of adoption, expected maximum rate of adoption, and the time the adoption should reach the maximum.

The selected producers indicated their farm location in one of eight states. For analysis, data from West Virginia and Kentucky were combined with Ohio because they had only one observation each and their location was near Ohio. Table 3.3 shows the states locations of the farmers surveyed.

Table 3.3: Survey response rate

States	Survey sent	Male	Female	Total	Response %
Illinois	5	0	0	0	0
Indiana	13	0	0	0	0
Kentucky	6	1	0	1	17
Maryland	70	14	8	22	31
Michigan	27	2	0	2	7
New York	43	4	0	4	9
Ohio	77	25	8	35	43
Pennsylvania	92	18	4	22	24
Virginia	33	4	4	8	24
West Virginia	4	1	0	1	23
*Wrong addresses and targets (dairy and mushroom producers) =22 (dropped)					
Total	348	69	24	93	27

Source: Mail survey, 2011

The sample consisted of 348 organic vegetable farmers from eight states of which 93 farmers returned the questionnaire. Of the 93 respondents, 26% were female. Ohio had the highest response rate with 43% followed by Maryland 31%. Michigan only had 7 percent. Response rates for both Illinois and Indiana were zero. Among the states where the project is being implemented, New York had the lowest response rate with only nine returned. The overall response rate for the whole sample was 27%, which may be considered reasonable for a mail survey.

Respondents' ages ranged from 20 to 80 years, and about 87 percent were between 35 to 65 years. Women constituted only about 26% of the respondents. About 85% of respondents had a high school education or higher while only 18% were college graduates. About 40% of the respondents reported a problem of *early blight* and another 40% reported problem of *Septoria leaf spot*. Ninety-eight percent of respondents owned land and an average of 7.8 acres were used in organic crop production. About 78% of the respondents used less than 10 acres, and only 5% used more than 30 acres of land in organic production. Seventy-one percent of respondents were certified organic producers. Hundred percent farmers grew tomatoes in open fields. Respondents employed an average of 4-5 people.

3.3. Adoption analysis:

Various types of models can be used to analyze survey data. Linear regression is not an appropriate method in adoption studies for several reasons including non-normality of error term and the possibility of expected value of predicted '*y*' lying outside 0,1 range. Continuous linear regression typically uses ordinary least squares (OLS) estimators for making predictions. In the case of adoption, where the dependent variable takes a limited number of values and the error term is not normally distributed, the OLS regression can produce biased results. In addition, OLS predictions can lie outside the 0 and 1 range and cannot thus be interpreted as probabilities of adoption. Moreover, the linear regression model assumes no heteroskedascity, the data violates the fifth Gauss-Markov assumption (Wooldridge, 2009). Heteroskedascity occurs when the error term is affected by the value of the independent variables. Although, heteroskedascity does not bias the estimates, it does produce inaccurate t and F statistics. Qualitative response models use Maximum Likelihood Estimation (MLE), and account for the discrete nature of the dependent (adoption) variables (Greene, 1993). According to Wooldridge (2009), for estimating limited independent variable models, maximum likelihood methods are indispensable. Because maximum likelihood estimation is based on the distribution of y given x, the heteroskedasticity in Var(y|x) is automatically accounted for.

Binary response models (i.e. probit and logit) are used where adoption is considered as a 'yes' or 'no' decision by farmers. This study uses a probit model to examine whether or not the adoption of MSGM or MI occurs. Since we assume a normal distribution of the error term in our study, probit would appear to make the most sense but we estimate both probit and logit models because the error term may not be normally distributed as we expect. The effects of independent variables on the dependent variable are then determined by using Maximum Likelihood Estimation.

Probit and logit regression models estimate the probability of adopting of MSGM or MI and measure the relative importance of different variables for the adoption of these practices. According to Green (1993), the general probit and logit model is written as

$$P(y=1|x) = \int_{-\infty}^{x'\beta} \phi(t)dt = \Phi(x'\beta) = \Phi(Z_i^*) \qquad \text{Probit} \qquad (3.1)$$

$$P(y=1|x) = \frac{e^{\beta' x'}}{1+e^{\beta' x}} = \Lambda(\beta' x) \qquad \text{Logit} \qquad (3.2)$$

Where

$\Phi(x'\beta)$ is the cumulative density function evaluated at $x'\beta$

$\phi(.)$ is the standard normal distribution

x' is a vector of independent variable

β is a vector of parameter coefficient to be estimated

$\Lambda(\beta' x)$ is the logistic cumulative distribution function

Both the logit and probit models are derived from an underlying latent variable Z_i, and Z_i* is the expected value of the non-observable variable Z_i. It is assumed that *e* is independent of x and *e* has either a standard logistic (logit) or standard normal (probit) distribution. Assuming Z_i to be function of vectors of social-demographic (*S*), economic (*E*), institutional (*I*), spatial (*G*), and a set of perception related variables (*F*), and α, £, *δ*, *§*, *θ*, and *ξ* are the parameters to be estimated. The non-observable variables can be written as

$$Zi = \alpha + \pounds S_i + \delta E_i + \S I_i + \theta F_i + \xi G_i + e_i \qquad (3.3)$$

and the expected value Zi^* as:

$$Zi^* = E(Zi \mid X) = \alpha + \pounds S_i + \delta E_i + \S I_i + \theta F_i + \xi G_i \qquad (3.4)$$

For the probit model, the likelihood function is

$$L(\beta) = \prod_{i=1}^{n} [\Phi(x_i \beta)]^{y_i} [1 - \Phi(x_i \beta)]^{1-y_i} . \qquad (3.5)$$

The maximum likelihood estimation (MLE) function is obtained by taking the log of (3.5):

$$\ln L(\beta) = \sum_{i=1}^{n} \{ y_i \ln \Phi(x_i \beta) + (1 - y_i) \ln[1 - \Phi(x_i \beta)] \} \qquad (3.6)$$

The maximum likelihood estimator represented by $\hat{\beta}$ maximizes the likelihood function. Because of the nonlinear nature of the maximization problem, we cannot write the formula for probit maximum likelihood estimates. Therefore, under very general conditions MLE for a random sample is consistent, asymptotically normal, and asymptotically efficient.

Marginal effects

In probit analysis, coefficients obtained from regression cannot be directly interpreted as the relative contribution of independent variables to the probability of adoption. The relative contribution is computed to get the partial effects on response probability. The marginal effect on change in $\phi(Z_i)$ relative to change of continuous independent variables is expressed as

$$\frac{\delta\phi(Z_i)}{\delta x_{ij}} = \left(\frac{\delta\phi}{\delta Z_i}\right)\left(\frac{\delta Z_i}{\delta x_{ij}}\right) = \phi(Z_i)\beta_{ij} \qquad (3.7)$$

where $\phi(Z_i)$ is the density function associated with each value of the underlying Z_i. If, x_1 is a binary explanatory variable, then the marginal effect from changing x_1 from 0 to 1, holding all other variables fixed , is

$$\frac{\delta\phi Z_1}{\delta x_1} = (\alpha + \beta_1 + \beta_2 x_2 ....\beta_n x_n) - (\alpha + \beta_2 x_2 ....\beta_n x_n) \qquad (3.8)$$

Specification tests

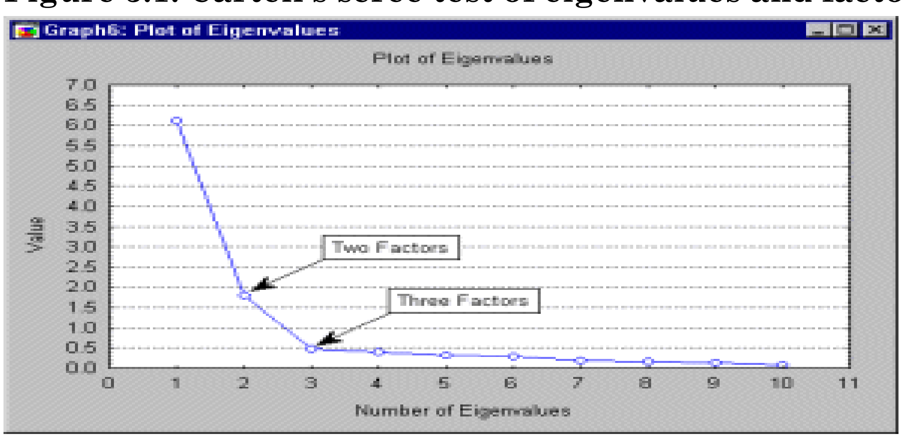
The specification issues arise when there is omission of some of the key variables from the model, which can cause correlation between error term and the explanatory variables resulting to bias and inconsistent estimates. Specification issue also arises if the response variable or link function is incorrectly specified. Therefore, it is a necessary to test for the specification error. A STATA command *linktest* can be used to detect a specification error after the probit command. The idea behind the *linktest* is that if the model is properly specified, there should not be any key relevant variables left out except by chance. After the probit regression, *linktest* uses the predicted value (*_hat*) and the square of predicted value (*_hatsq*) as the predictors to find out if the model is correctly specified. Predicted value *_hat* shows if link function is properly specified. The predictor _hat should be significant because it is the predicted value from the model. If our model is properly specified, *_hatsq* should be nonsignificant and should not have much predictive power other than by chance. The significance of *_hat sq* indicates that *linktest* is significant, which implies omitted variables bias. Therefore, for a good model, *_hat* should be significant and *_hatsq* nonsignificant (Chen, et al.).

3.4. Factor analysis:

There are relatively few observations (93) compared to the number of variables that was selected for the model. Using all the explanatory variables in the model would reduce the degrees of freedom and may result in biased estimates. One potential solution would be to reduce the number of variables through factor analysis. The factor analysis technique can detect structure in the relationships among variables and reduce the number of variables. A regression line can be fitted that represents the best summary of the linear relationship among the variables combining two or more correlated variables into one or a few factors that can be uncorrelated or correlated to each other based on the theoretical explanations. Rotating the factor structure can maximize the variance on the new axes. The factor loadings resulting from the rotation represent how the variables are weighted for each factor, and the sum of these factor loadings is the index for that factor. There are two types of rotations: orthogonal and oblique. Orthogonal rotation (varimax) ensures that the resulting factors remain uncorrelated. On the other hand, oblique rotation (promax) allows the resulting factors to correlate with each other. In theory, the choice of rotation will depend largely on whether or not a researcher thinks that the underlying factors should be correlated. The factors are the linear combination of two or more observed variables. For the factor analysis in this study, the method of principle component factor with varimax rotation was adopted (Field, 2005). The varimax rotation produced *eigenvalues,* which are the variances extracted by the factors. This method assures that the factors obtained are orthogonal, and therefore, mitigates the problem of multi-collinearity. The sum of the *eigenvalues* equals the number of the variables. The *eigenvalue* of the first factor is usually higher, and successive factors have lower eigenvalues. There are two methods to decide how many factors to retain. According to the Kaiser criterion, factors that have *eigenvalues* greater than 1 are retained (Field, 2005).

The Cartell's scree test on the other hand is a graphical method of determining the number of appropriate factors to retain. A scree test involves plotting the

Figure 3.1: Cartell's scree test of eigenvalues and factors



Source: StatSoft, Electronic Statistics Textbook.

eigenvalue measures on the vertical axis against the ordinal eigenvalue numbers on the horizontal axis. The cut off value for the number of factors is where the smooth decrease of *eigenvalues* appear to level off to the right of the plot.

There are different methods to find out if the given sample is appropriate for factor analysis. Generally, absolute sample size and absolute magnitude of factor loadings are important in determining reliable factor solutions. Kaiser –Meyer-Olkin measure of sampling adequacy (KMO) can be calculated using the command "*estat kmo*" in STATA. The KMO of individual factor represents the ratio of the squared correlation between variables to the squared partial correlation between the variables. The KMO statistics vary between zero and one. Higher value of KMO indicates the pattern of correlation is relatively compact, which can yield distinct and reliable factors. Kaiser recommended values below 0.5 are unacceptable, 0.5-0.7 are mediocre, 0.7-0.8 good, 0.8-0.9 great, and above 0.9 the best.

In addition to the KMO test of sampling adequacy, Cronbach's α is used to measure scale reliability, which means it measures how well a set of variables measure the latent aspect of an individual or a new technology. Cronbach's α is represented by

$$\alpha = \frac{N^2 \overline{Cov}}{\sum s_{item}^2 + \sum Cov_{item}} \qquad (3.8)$$

Where N is the number of items, and s is the variance of the item

The value Cronbach's α increases when the correlations between the items increase. Although the value of 0.7 is acceptable when dealing with psychological constructs, acceptable value depends on the number of items on the scale. With increase in number of items on the scale, the value of α tends to increase. Therefore, it is possible to get large value of α if there is large number of items, which is not because of the higher reliability but because of the large number of items (Field, 2005).

3.5. Determinants of adoption decisions:

A number of variables and factors influence the decision to adopt MSGM & MI. Some of the socio-demographic characteristics likely to affect the adoption decision are age, experience, education, and gender. Nature of farm, type of crops grown, size, income from the organic vegetables, and tenure are some of the economic characteristics. Institutional factors assumed to influence adoption decisions are training and learning programs, affiliation with farmers' association, and internet access. The spatial attribute assumed to affect adoption in this case is the location of farms. Another set of variables hypothesized to affect adoption decisions is farmers' perceptions, which are associated with cost and benefits from the MSGM & MI, and importance of sources of disease management information, variables contributing to the severity of soil-borne diseases, importance of different disease management practices. Some of these variables affect adoption positively and others affect negatively.

I. Socio-demographic characteristics

a. Ag*e* is a binary variable. We assume that a*ge* is likely to affect the adoption decision negatively. Generally, older people are accustomed to a particular type of technology, and may not want to give up their existing practices. Young producers may be more inclined to adopt new technologies than are older producers.

b. Education is a binary dummy variable. A positive sign is expected because more highly educated people may be more informed about new practices and information, which increases their probability of adoption.

c. Experience (e*xper*), a binary variable is hypothesized negatively related to adoption. With more years of experience, farmers may tend to stick with what they have been doing and avoid change.

d. Number of laborers *(no_labor)* employed in fields is a continuous variable. This variable is a proxy for labor availability, and is expected to have a positive relation with the MSGM & MI adoption because these are labor-intensive technology.

II. Economic factors

e. Acreage used for organic production (org_acre) is a continuous variable. MSGM & MI is a labor-intensive technology, the larger the farm area available for production, the greater the difficulty in managing it so this variable is expected to negatively affect adoption.

f. Acreage used for tomato production (tom_acres) is a continuous variable that represents the acres of land used for tomato production. This variable is likely to affect the adoption decision negatively because of management problems associated with cover crops use.

g. Farm type (farm) is also a binary variable, which indicate whether a farm is certified or not. This variable is expected to have a positive sign, since the farms that are already certified organic and established may want cost effective and sustainable management practices and more likely to use the technologies.

h. The type of crop grown (*crop*) is a binary variable. It is expected to affect adoption positively because MSGM and MI enhance soil quality and suppress diseases, which can affect multiple crops simultaneously.

i. The opinion of the producer that a cover crop can prevent soil-borne diseases (ccrp_prevnt) is also a binary variable. This variable is likely to affect *MixCC* use positively because a producer's positive belief encourages them to make decision in favor of MSGMs adoption.

j. The opinion of the producer that microbial inoculants can prevent soil-borne disease (mino_prevnt) is also a binary variable. This variable is likely to affect *mino_use* positively because a producer's positive belief encourages him or her to make the decision to adopt microbial inoculants.

III. Institutional factors

k. Training *(trg)* is a binary variable. Training is expected to positively affect adoption. With increased skills, knowledge, and information, farmers are more likely to be motivated to adopt the new technology.

l. Farmers' affiliation (*Assoc*) with farms related organizations, clubs, and cooperatives helps in information exchange and diffusion. Membership in such organizations allows farmers to receive information on factors of production, innovations, marketing of products, financial, and other related assistance. Therefore, a farmer's affiliation to different farming related organizations is expected to positively affect adoption decisions.

m. Internet access (intnet_access) is a proxy variable for access to information. This variable is expected to have a positive sign because with the internet access, farmers have access to information on the profitability of new technologies, which may encourage them to decide in favor of adopting them.

IV. Farmers' Perception

n. Farmers' perceptions constitute their opinions or perceptions on a) costs, b) benefits from adoption, c) sources of disease management information, and d) challenging factors or obstacles in managing an organic farm. Different questions were asked to capture farmers' opinions and perceptions on each of aforementioned elements (see Appendix 1). Factor analysis was performed to explain affect group of elements represented by factors as opposed to considering each question as a variable. The factors extracted were *negimpacts* for costs, *posimpacts* for benefits, *public*, *specific*, and *media* for sources of disease management information, and *mrktng*, *costs*, and *environ* for farmers' opinion on some of the given factors related to challenges and obstacles. Other factors extracted were on the importance of different management practices such as *practice*, *assmt*, and *trtment*. The *negimpacts* is likely to affect adoption decisions negatively, *posimpacts* affects adoption decisions positively; *public*, *specific*, and *media* affect decisions positively; and *mrktng*, *costs*, and *environ* affect them negatively. The factors *practice, assmt,* and *trtment* are likely to impact adoption positively.

V. Spatial characteristics

o. *Maryland* is a dummy variable that takes on a 1 when the respondents were from Maryland and 0 otherwise. Similarly, *NewYork*, *Ohio*, and *Pennsylv* take 1 if they belong to New York, Ohio, and Pennsylvania, and 0 otherwise respectively. Location of farmland may affect adoption positively or negatively based on their geographic characteristics, landscape, rainfall, and temperature.

VI. Dependent variables

The adoption of mixed-species green manures (*MixCC*) and microbial inoculants (mino_use) are the two dependent variables used in the analysis. *MixCC* is a binary variable represented by1 if a producer uses mixed-species green manures and 0 otherwise (including use of other alternative practices or no cover crops at all). Similarly, *mino_use* is 1 for producer using microbial inoculants and 0 for alternative practices or no of use microbial inoculants use.

The detail description of the variables are presented in the table 3.4

Table 3.4: Description of variables related to adoption analysis

Variable name	Variable description	Modalities
Independent Variables		
Socio demographic characteristics		
age	Whether the farmer is older than 50 years or 50 years or less	1 > 50 years 0 <= 50 years
exper	Whether the farmer more than 10 years of experience or 10 years or less	1 > 10 years 0 <= 10 years
edu	Whether the farmer is a college graduate or high school or lower	1 college graduate 0 high school or lower
sex	Sex of the farmer	1 male 0 female
no_labor	Number of labor employed in the farm	Numbers
Economic characteristics		
org_acre	Number of acres used for organic veg. production	Acres
tom_acres	Number acres used for tomato production	Acres
farm	Type of farm whether certified organic or not	1 Certified Organic 0 otherwise
crop	Types of crop grown	1 > 10 types 0<= 10 types
ccrp_prevnt	Opinion on whether MSGMs prevent diseases	1 positive response 0 negative response
mino_prevnt	Opinion on whether MIs prevent disease	1 positive response 0 negative response
Institutional characteristics		
trg	Whether or not participated in the training activities	1 participated 0 never participated
assoc	Membership of the farmers in the farmers or other related organizations	1 has membership 0 no membership
intnet_access	Whether the farmer has access to internet or not	1 has internet access 0 no access
Farmers' perceptions		
negimpacts	Impacts of associated costs of productions	Index points
posimpacts	Impacts of associated benefits of production	Index points
mrktng	Challenges of marketing aspects	Index points
costs	Challenges of costs and insect mgmt issues	Index points
physical	Challenges of environmental aspects	Index points
public	Public sources of information	Index points
specific	Information from organic related sources	Index points
media	Information from media	Index points
practice	opinion on importance of organic mgmt. practices	Index points
assmt	opinion on importance of assessment practices	Index points
trtment	opinion on importance different treatments	Index points

Spatial characteristics		
Maryland		1 for Maryland 0 otherwise
NewYork		1 for New York 0 otherwise
Ohio		1 for Ohio 0 otherwise
Pennsylv		1 for Pennsylvania 0 otherwise
Dependent variables		
MixCC	Whether producer used Mixed Green manure or not	1 uses MSGMs 0 alternative practices
mino_use	Whether producer uses microbial inoculants or not	1 uses MI 0 alternative practices

3.6. Economic impact assessment of MSGM

Studies use various methods for estimating economic benefits of new technologies such as IPM, improved seed varieties, and other management practices. Commonly used methods are enterprise budgeting, economic surplus analysis as mentioned above and benefit cost analysis. Enterprise budgeting is used in this study to estimate expenses and receipts for MSGM and tomatoes. Economic impact analysis of MSGMs treatments included steps to assess their economic profitability to producers relative to current practices and to project their value at a market level to society using economic surplus analysis (Norton and Swinton, 2009).

3.6.1. Enterprise budgeting

Enterprise budgets are important tools for planning on-farm financial management. The budget takes into account variable operating costs including labor cost, fixed costs, and expected production returns. Enterprise budgets help to allocate land, labor, and capital to the most appropriate use in the face of scarce resources. The budgets are usually prepared on a "per unit" basis. In this study, a tomato enterprise budget is computed for a hectare of production. Project collaborators in each state recorded inputs applied, tomato yields with no cover crops, single species, and MSGM treatments. These data, combined with the price of organic tomato were used to measure the net economic benefits per unit area of the tomato production. Budgets are used to assess the change in cost, returns per unit area, and per enterprise with adoption. The budget results for the MSGM treatments were then compared to alternative practices. The benefits of MSGM were expressed in terms of increased yield and changes in cost of production. The yield differential results from a lower incidence of soil-borne diseases and increased yield due to improved soil quality. The simple rate of return per hectare is calculated using the equation given below.

$$\text{Rate of Return} = [(\text{Revenue} - \text{cost})/\text{cost}] \times 100 \qquad (3.9)$$

The information on yield and cost changes was combined with projections on level and timing of adoption in an economic surplus model for organic tomatoes in the project states of Maryland, New York, and Ohio. The cost associated with research is subtracted from producer benefits to find the net benefits. However, these benefits do not reflect the true benefits because the gain is achieved over several years and the value of the per unit net gain is different for different years in terms of present value. We also assume that the current technology will become obsolete, and producers will adopt other alternatives. The potential gain over the years is discounted and net present value is estimated. The benefits of the technology per hectare can be evaluated by comparing the enterprise budgets of different treatments with one for the control group. The cost of MSGM technology is expressed as a proportionate cost change with respect to single species cover crops or bare ground.

3.6.2. Economic impact of technology adoption at the societal level

According to Alston et al. (1995) economic surplus analysis is one of the most common methods for welfare analysis or estimating market-level economic returns in a partial equilibrium framework. The approach has been used in many studies to measure *ex-ante* and *ex-post* research benefits. This study undertakes *ex-ante* analysis to estimate economic surplus due to adoption of MSGM.

The economic surplus method can be used to measure the net returns at the market level from a research project that shifts the supply curve outward to the right. The economic surplus analysis combines data on prices and quantities at the market level, information on the price responsiveness to quantity change (supply elasticity) and demand elasticity in the market, input cost changes, yield changes, and adoption rates with and without the new technology. It can also accommodate any externalities effects if the innovation is spilled over outside the boundary of region where the technology was innovated. The economic surplus analysis is used to measure the changes in producer, consumer, and net benefits because of a program (such as IPM CRSP). Using the economic surplus approach, the dollar value for producers and consumers can be evaluated and can be used to justify the cost of the research project, and to prioritize and recommend implementation of research programs in the future. The following section presents and explains the economic surplus model in more detail.

The basic model of economic surplus analysis includes the assumption of a single closed economy. Under this assumption, when producers adopt new technologies, the shift in the supply curve from S_0 to S_1 is due to an increase in yield or a reduction in costs (figure 3.2). The supply shift results in the increase in production by $\Delta Q=Q_1-Q_0$, and decline in prices of commodity by $\Delta P= P_1-P_0$. The original equilibrium price and quantity, P_0 and Q_0 change to new equilibrium positions P_1 and Q_1 respectively. The new CS is the RbP_1, area below the demand curve and above the new price P_1. New PS is the area P_1I_1b, the new equilibrium point is b, and the new total surplus is the area RbI_1. The gain to consumers from the supply shift is the area P_0P_1ab and the producer gain can be represented by area $I_1P_1b-I_0cI_1$ or area P_1bcd.

The change in total economic surplus (ΔTS) is the sum of the changes in consumer (ΔCS) and producer surpluses (ΔPS). The total net benefit can be shown as a result of the effects on cost savings on the original quantity produced and the economic surplus due to the increment to production and consumption. Graphically, total economic surplus is represented as

$\Delta PS+\Delta CS=\Delta \mathbf{TS}$

$P_0abcd = (P_0acd+abc) = (I_0acI_{1+}abc) = I_0abI_1$ (since $P_0acd= I_0acI_1$) (3.10)

Producers lose part of their gain due to the decline in the price of their output because of increased supply. On the other hand, the increase in supply and decline in price results in a consumer gain. The changes in these surpluses can be expressed algebraically as follows

$\Delta PS = P_0Q_0Z(1+0.5Z\eta)$ (3.11)

$\Delta CS= P_0Q_0(K-Z)(1+0.5Z\eta)$ (3.12)

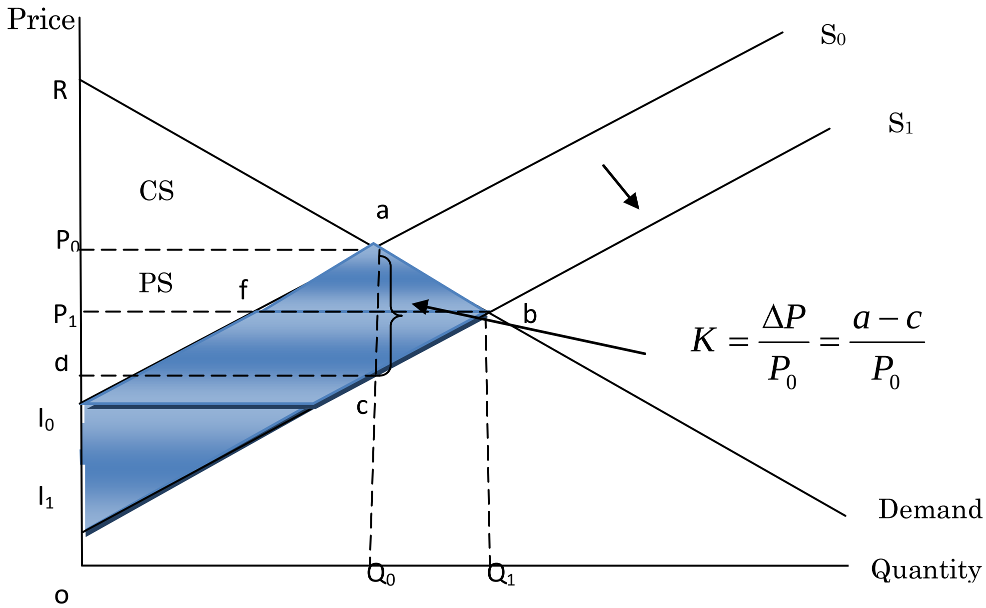
$\Delta TS = P_0Q_0K(1+0.5Z\eta)$ (3.13)

where η is absolute value of demand elasticity, $Z = K\varepsilon/(\varepsilon+\eta)= -(P_1-P_0)/P_0$ is the reduction in price relative to its initial value due to supply shift, and ε is the elasticity of supply. K represents the vertical shift of the supply function expressed as a portion of the initial price (Alston, et al., 1995) and can be calculated using formula

$K= [E(Y)/\varepsilon]-[E(C)/(1+E(Y)]\ pA(1-d)$ (3.14)

where $E(Y)$ is the expected proportionate yield change per unit area under cultivation after adoption of the new technology, $E(C)$ is the expected proportionate change in variable input cost per unit area under cultivation, p is the probability of success with the research, A is the adoption rate for the technology, and *d* is the depreciation rate of the new technology.

Figure 3.2: Change in total surplus with technology adoption in a closed-market economy



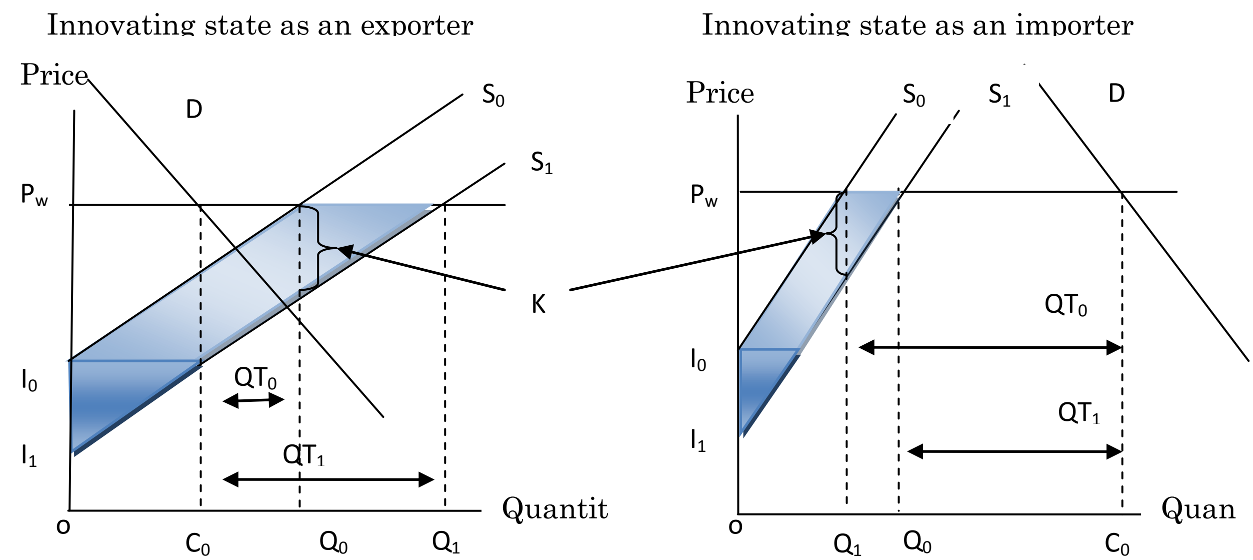
Source: Alston, Norton, and Pardey (1995) p.209

A supply shift due to technological change in a market with a perfectly elastic demand curve changes producer surplus but has no effect on consumer surplus since consumers will still be paying the same price as before the change. This might be the case for a commodity that is traded but for which the production is not enough affect the price.

In a small open economy assumption, the agricultural products are tradable and most regions or countries do not influence the international prices significantly. The impacts of research on a small-state exporter or importer of a commodity are illustrated in figure 3.3. Initial equilibrium is given by the consumption C_0, and production, Q_0 at the world market price, P_w with QT_0 as the traded quantity, which is the difference between consumption and production. Research induced shift of supply curve from S_0 to S_1, and production increases to Q_1. Therefore, export increases for exporter, and import amount decreases for an importer as indicated by QT_1. The states do not affect the market price, the economic surplus change, I_0abI_1 is all producer surplus (Figure 3.3). The research induced technical change from a K percent parallel shift down of supply is represented by the formula

$$\Delta TS = \Delta PS = P_w Q_0 K(1+0.5K\varepsilon) \qquad (3.15)$$

Figure 3.3: Change total surplus with technology adoption in an open market economy



Source: Alston, Norton, and Pardey (1995) p.227

Many innovations require a lengthy period from the time an innovation is available to when it is adopted (Rogers, 1995). Alston et al. (1995) noted that the time after initial investment in generation of pre-technology knowledge through maximum adoption by producers can involve long, variable, and uncertain lags. The process of adoption may be represented by a logistic curve. The adoption increases with time, reaches a maximum level, and later decreases as the technology depreciates or becomes obsolete. The net benefit over time is discounted to obtain its net present value. Swinton and Norton (2009) present a framework for benefit-cost analysis and aggregating or projecting economic surplus over time by calculating the net present value, internal rate of return or benefit-cost ratio. The net present value is calculated for each year, and then the period-specific net present values are summed to find total net present value. Mathematically, the net present value (NPV) of discounted benefits and costs is

$$\text{NPV} = \sum_{t=1}^{T} \frac{R_t - C_t}{(1+i)^t} \tag{3.16}$$

where : R_t = the return in year t, T = the number of years, C_t = the cost in year t (green manure program cost), and i = the discount rate. For this study, the discount rate is assumed at 5%.

3.6.3. Model prediction

This study is an ex-ante assessment of the research induced technology. The benefits resulting from the mixed-species green manure technology are projected for 15 years from the time of technology development. The research trials began in 2010, although there are some farmers already using the single and mixed-species cover crops in their fields. The research will reinforce wider application of mixed-species green manures with scientifically based evidence of the added benefit of mixed-species green manure. The benefits resulting from the adoption of the mixed-species technology are estimated for 15 years from 2010 to 2024 from the time the technology development until the maximum level of adoption, which here is assumed to be 50%. The predictions are made based on the assumptions of a small open and a closed market economy. In a closed market economy, the market price is determined by domestic supply and demand. The market price of the commodity in a small open economy is determined in markets beyond the states; therefore, price is not affected by the local supply. We consider a small open economy here because the states do not produce a large share of US tomato production (or trade with other states or countries). The net present values for all of the different mixes of cover crops are estimated for each of the states under study.

3.6.4. Variables and parameters description

Different variables and parameters required for the estimation are present production of organic tomato in the states, prices of tomato, demand and supply elasticities, expected yield changes, proportionate change in input costs per hectare, adoption rates, probabilities of research success, depreciation rate, and research cost.

Quantity of tomato supplied: Organic tomato supplied obtained from the latest date on organic tomato production 2007 from the USDA ERS web site for all three states (USDA, 2010).

Price of organic tomato: The average price of organic tomato was estimated at $2 per pound (O'Connell, 2008). The information was also obtained from retail farmers' market summary of prices 2008-2010 (Virginia Department of Agriculture and Consumer Services, 2011)

Demand and Supply elasticity: The domestic demand elasticity was obtained from USDA ERS and assumed to be the same for all states, and a supply elasticity of 1 was assumed (Hristovska, 2009). Also, according to Alston et al. (1995), long –run elasticities for most individual agricultural products are greater than one, but even short- or intermediate-run supply elasticities are close to one. Based on this information, we assumed that the elasticity of supply to be one. The demand elasticity of tomato for the study is assumed to be -0.33 (a mean value from different studies) obtained from USDA ERS published in 1999.

Expected yield change: The expected changes in yield due to use of mixed-species green manure were estimated from interviews with project and other scientists involved in developing the mixed-species green manure technology for organic tomato in the project states. The expected proportionate yield change per hectare E(Y) due to the use of mixed-species green manure varied by state, and was validated with budget information available from the states.

Proportionate change in input costs per hectare: The computation of proportionate change in input cost per hectare to achieve the expected yield change was performed using data from enterprise budgets. The information on variable input cost was received from the state of Maryland and Ohio only. The average input cost from Maryland was used for the state of New York. The fixed cost on the land rent and machinery and equipment was obtained from the Rutgers University web site for organic tomato production (Rutgers). The proportionate change in input cost per hectare for the mixed-species green manures compared to no cover crops and single species varied from 0 to 7% across different states.

Adoption level: In the interviews, the project scientists reported present adoption rates of mixed-species green manure to be 5- 15 percent. According to them, the maximum level of adoption may reach 50% percent. However, no information was made available about the number of years that would pass before adoption would be maximum. For our study, we assume that the maximum adoption level would be reached in fifteen years by 2024 based on similar past studies (Baez, 2004, Hristovska, 2009) . The yearly rate of adoption assumed to increase at the rate of 5% point until maximum adoption level is reached. A sensitivity analysis was completed using alternative level of adoption of 25%, 40%, 50%, and 65%.

Probability of research success: The probability of research success is the probability of achieving 100% of the projected yield change. We assumed a probability research success of p=0.9 or a 90% chance of success.

Research Cost: The total cost of the project for 3 years is $1,146,612 with annual budget of $382,204. This is the cost for all the treatments of mixed-species for all the three states. Divided equally among three states, the share of the budget for each state is $382,204 with an annual research budget of $127,401 for three years of research.

Chapter 4: Results and Discussions

Section 4.1 summarizes the descriptive statistics of the data used in the study. The detailed interpretation of the results of the adoption analysis is provided in Section 4.2. The research-induced benefits from the technology use are presented in Section 4.3.

4.1. Descriptive Statistics

4.1.1 Demographic, farmer, farm, and institutional characteristics

Of 93 survey respondents, 48 (52%) have used mixed- species green manures, and 39 (42%) respondents have used microbial inoculants. Eighty-four respondents (90%) grew tomatoes and for 74 (80%), tomato was the top ranking crop in terms of total acreage. About 55% indicated that tomato was the most susceptible to disease among all the vegetables grown on their farm. When asked “How familiar are you with soil-borne disease management practices?” about 52% of respondents replied that they are somewhat familiar. In questions related to whether respondents think cover crops and microbial inoculants can help in preventing soil-borne disease in vegetables, 75% said they believe cover crops can prevent disease incidence in vegetable production. Similarly, 64% believe that the microbial inoculants can prevent disease incidences.

The demographic statistic show that the age of respondents ranged from 20 to 80 years and 60% of the respondents were older than 50 years with about 53% of people between the ages of 50 and 65 years. Seventy four percent of the respondents were male, and 47% of the respondents had completed college or graduate education. Eighty six percent of respondents were affiliated with farmers' organizations or groups such as organic farming association, commodity groups, or farm bureaus. Fifty five percent have participated one or more times in training and learning programs related to organic production. In a national survey, Walz (2004) found that about 78% of the respondents used the internet and 72% had access to the internet at their home or farm. In our survey, we found that about 83% had internet access of which 85% reported using the internet one or more times a day.

Thirty four percent of the respondents had 6 to 10 years of experience followed by 22% with 11 to 15 years, and 15% with more than 20 years of experience in organic vegetable farming. Eighty-nine percent of the respondents produced more than six types of vegetable crops. Ninety eight percent of respondents own land and 15% also rented. All respondents grew their organic vegetables in open fields. In addition, some (47%) grew in high tunnels and others (38%) in greenhouses. Seventy one percent of farms are reported certified organic operations. About 56% of respondents receive up to 50% of their income from organic production. Of 86 respondents, 84% mobilized five or fewer employees including household members with a mean of 3.8 persons. Table 4.1 presents descriptive statistics of the variables of interest in the study and Appendix C1 presents STATA output for summary statistics.

Table 4.1: Descriptive statistics for variables of interest

Variables	Obs	Mean	Std. Dev.	Min	Max
mixCC	92	0.522	0.5022	0	1
mino-use	92	0.424	0.4969	0	1
min-prevnt	75	0.64	0.4832	0	1
age	93	0.602	0.4921	0	1
exper	91	0.505	0.5027	0	1
edu	93	0.473	0.5019	0	1
sex	93	0.742	0.4399	0	1
trg	93	0.548	0.5004	0	1
assoc	93	0.860	0.3486	0	1
org_acre	92	7.847	10.2603	1	75
farm	93	0.797	0.4563	0	1
no_labor	91	4.860	4.8681	1	32
intnet_access	93	0.828	0.3795	0	1
tom_acres	70	2.067	3.2031	0.1	20
Maryland	93	0.2365	0.4273	0	1
NewYork	93	0.0430	0.204	0	1
Ohio	93	0.3763	0.487	0	1
Pennsylv	93	0.2365	0.427	0	1
specific	90	10.544	2.351	3.63	14.55
Media	87	6.922	2.567	2.29	10.42
posimpacts	87	30.499	3.648	20.63	35.13
negimpacts	79	39.944	12.92	11.48	57.40
physical	90	4.085	1.085	1.27	6.34
practice	89	16.87	3.350	7.45	21.63
trtment	82	11.62	1.990	7.81	15.81

Source: Mail Survey, 2011

4.1.2. Farmers' perceptions

Table 4.2 presents the distribution of response percentages for variables that were found significant in the decisions to adopt. Table 4.2a presents that for the majority of farmers sources of information (friends and family, technical publication, internet, organic farming organizations, extension and university research) are important in accessing information on disease management. The analysis of likert-scale ranking revealed that more than 70% of respondents agree that family and friends, the internet, organic farming organizations, and university research, about 61% for technical publications, and 65% for extension are good sources of information for soil borne disease management.

Table 4.2a: Distribution of farmers' responses (%) (from1= strongly disagree; 5= strongly agree)[a]

Attitudinal Statements	Strongly Disagree (1)	Disagree (2)	Neither agree nor disagree(3)	Agree (4)	Strongly agree(5)
Family and friends	3.3	4.4	17.6	34.0	40.7
Tech. publication	5.6	5.6	27.0	43.8	18.0
Internet	17.6	3.3	5.5	27.5	46.2
Organic farming organizations	0	10.9	7.6	23.9	57.6
Extension	5.4	13.0	16.3	46.7	18.5
University Research	3.3	4.4	20.0	45.6	26.7

Source: Mail Survey, 2011

[a]These responses relate to the question #34, "Please rank each source of disease management information in order of importance to you. (Please mark one answer for each.) See Appendix 1. Only variables on which the farmers agree most were included here.

Producers have very strong opinions on beneficial aspects of using the cover crops represented in table 4.2b. More than 95% strongly agree cover crops confer increased diversity to microbial life, improvement in soil and water quality, reduction in soil erosion, and improvement in nutrient cycling efficiency. More than

80% agree with the notion that cover crops enhance beneficial microbial populations, improve crop yield and quality, and 79% agree with the statement that cover crops can help in pest and disease suppression. About 50% agree that the use of cover crops could bring additional income while 30% believe they provide social benefits.

Table 4.2b: Distribution of farmers' responses (%) (from1= strongly disagree; 5= strongly agree)[a]

Attitudinal Statements	Strongly Disagree (1)	Disagree (2)	Neither agree nor disagree (3)	Agree (4)	Strongly agree(5)
Increases diversity of soil life	0	0	3.3	18.5	78.3
Improves soil and water quality	0	0	4.4	19.6	76.1
Reduces soil erosion	0	1.1	1.1	9.4	78.5
Improves nutrient cycling efficiency	0	0	5.4	25.0	69.6
Enhances wildlife habitat	2.2	1.1	20.9	27.5	48.4
Enhances beneficial microbial population	0	0	15.2	18.5	66.3
Pest and diseases suppression	0	1.1	20.9	30.8	47.3
Improves yield and quality	1.1	0	14.1	21.7	64.0
Additional income	4.6	6.9	37.9	28.7	21.8
Social benefit	6.6	8.8	55.0	12.1	17.6

Source: Mail Survey, 2011

[a]These responses relate to the question #35, "To what extent do you agree or disagree that the following can be positive impacts or benefits of using cover crops to manage soil-borne disease? (Please mark one answer for each.) See Appendix 1.

On the other hand, the use of cover crop is associated with negative views in terms of time requirements, establishment problems, fuel costs, seed costs, management problems, shortened growing period, reduced cropping options, and yield losses due to delayed planting (table 4.2c). More than 70% of the respondents agree with the view that seed cost is the major constraint in adopting cover crops and about 60% agree that establishment and management problems with some of cover crops, appropriate equipment, and labor availability are constraints that can affect farmers' adoption of organic farming. The regulation or certification costs[1] do not seem to be a major problem. This might be because of the certification cost share program mandated in the Farm Bill 2008.

Table 4.2c: Distribution of farmers' responses (%) (from1= strongly disagree; 5= strongly agree)[a]

Attitudinal Statements	Strongly disagree(1)	Disagree (2)	Neither agree nor disagree(3)	Agree (4)	Strongly agree(5)
Grower's time	17.8	11.1	16.7	30.0	24.4
Increases risk of other disease and pest	20.9	13.2	25.3	28.6	12.1
Germination and establishment problems	19.8	4.4	15.4	29.7	30.1
Labor availability/costs	12.5	11.2	18.0	29.2	29.2
Regulation costs	19.1	4.5	42.7	20.2	13.4
Fuel cost	10.1	6.6	26.4	23.1	33.0
Seed cost	5.5	6.6	14.3	29.7	44.0
Appropriate equipment	14.3	1.1	22.0	22.0	40.7
Management problem with cover crops	12.0	4.4	19.6	33.7	30.4
Shortened growing period	15.4	8.8	17.6	23.1	35.2
Reduces cropping options	16.5	7.7	27.5	20.1	7.5
Yield loss due to delayed planting	19.6	14.1	12.5	14.1	40.2

Source: Mail Survey, 2011

[a] These responses relate to the questions #36, "To what extent do you agree or disagree that the following can be negative impacts of using cover crops to manage soil-borne diseases? (Please mark one answer for each.) See Appendix 1.

The respondents had differing responses on factors listed as challenges or obstacles to manage organic farms. For the majority, variables such as low market prices, record-keeping requirements, lack of organic marketing networks, higher labor costs, handling and distribution problems, food safety requirements, soil fertility, and weather were major constraints. More than 50% indicated availability of reliable information and technical support, record keeping requirements, organic certification cost, high input costs, labor cost, weed management, insect

[1] Farmers are required to certify their farmland and produce as organic to receive premium for their products, and the cost associated with certification is the certification cost.

management, and disease management were challenges to managing organic farms. Table 4.2d presents a tabular representation of the distribution of respondents' responses on the challenges faced in managing organic farms.

Table 4.2d: Distribution of farmers' responses (%) (from1=strongly disagree; 5=strongly agree)[a]

Attitudinal Statements	Strongly Disagree (1)	Disagree (2)	Neither agree nor disagree(3)	Agree (4)	Strongly agree(5)
Availability of reliable info and technical support	14.3	8.8	15.4	54.9	6.6
Low market prices	13.0	18.5	29.4	33.7	5.4
Lack of organic marketing networks	17.8	37.8	26.7	12.2	5.6
Record keeping requirements	6.7	11.1	23.3	44.4	14.4
Organic certification costs	8.9	8.9	19.1	33.7	29.2
High input costs	4.4	13.0	15.2	29.4	38.0
High labor costs	6.7	11.1	22.2	28.9	31.1
Handling and distribution problems	17.0	31.8	36.4	13.6	1.1
Weed management	1.1	5.4	6.5	30.4	56.5
Insect management	0	5.4	9.8	42.4	42.4
Disease management	2.1	3.2	18.3	35.5	40.9
Food safety requirements	5.5	6.6	36.3	38.5	13.2
Soil fertility	7.3	19.4	36.6	26.9	9.7
Weather	3.3	12.2	42.2	24.4	17.8

Source: Mail Survey, 2011
[a]These responses relate to the questions #28, "To what extent do you agree or disagree that the following factors are challenges or obstacles you face in managing your organic farm? (Please Mark one answer for each.) See Appendix 1.

Farmers were found to have different opinion on the disease control practices as summarized in table 4.2e. Eighty-seven percent agreed that using manure and compost from their own farm could prevent diseases, and about 80% agreed that national organic standards (NOS) allowed chemical inputs. About 87% agreed that improved drainage could control diseases in farms whereas 87% agreed that using treated water irrigation could control soil-borne diseases. On the other hand, 67% agreed that using disease resistant varieties also prevent soil-borne diseases. Since most of the diseases spread while handling, 85% agreed that using soilless growing media for transplant could be one way to prevent soil-borne diseases.

Table 4.2e: Distribution of farmers' responses (%) (from1= strongly disagree; 5= strongly agree)[a]

Attitudinal Statements	Strongly Disagree (1)	Disagree (2)	Neither agree nor disagree(3)	Agree (4)	Strongly agree(5)
Disease diagnosis by a laboratory services or professional	14.3	8.8	15.4	55.0	6.6
Aggressive sanitation	6.7	11.1	23.3	44.4	14.4
Frequent tillage	9.0	9.0	19.1	33.7	29.2
Soil solarization	4.4	13.0	15.2	29.4	38.0
Improved drainage	6.6	11.1	22.2	28.9	31.1
Use of treated water for irrigation	1.1	5.4	6.5	30.4	56.5
Use soilless growing media for transplant	0	5.4	9.8	42.4	42.4
Use of disease resistant varieties	2.2	3.2	18.3	35.5	40.9
Use of cover crops	1.1	2.2	2.0	20.9	53.9
Use of NOS allowed chemical inputs	5.5	5.5	7.7	40.7	40.7
Use of bio-pesticides	8.0	4.6	39.8	28.4	19.3
Use of microbial inoculants	4.5	5.6	41.6	36.0	12.4
Manure and compost from own farm	2.2	2.2	8.8	22.0	64.8
Application of balanced organic material	4.4	2.2	22.0	44.0	27.5

Source: Mail Survey, 2011

[a] These responses relate to the questions #37, " How important are each of the following practices in managing plant diseases on your farm? (Please mark one answer for each.) See Appendix 1

4.2. Adoption analysis of the mixed-species green manures and microbial inoculants

Various characteristics associated with household, farmer, farm, technology, and institutional characteristics influence technology adoption decision-making. The following section presents an overview of the situation in which the mixed-species green manures have been used in organic vegetable production. The first part presents the explanation for the factor analysis of some of the perception related questions, which are later used in the probit regression to assess their effects on adoption of MSGM and MI.

4.2.1. Factor Analysis:

It was difficult to include all the variables of interest in the regression model as predictors because of the small sample size and potential problems associated with multi-collinearity when highly correlated variable are used. We used factor analysis to extract a few interpretable variables (factors) from several items measured on likert-scales.

Table 4.3: Factors, item variables and Cronbach's alpha

Factor[a]	Items or variables	Cronbach's α[b]
public	info_nmag, info_fbur, info_gov , info_indus	0.683
specific	info_comm, info_oorgn, info_exten, info_urc	0.471
media	info_tvrad, info_net, info_webcom	0.773
posimpacts	b_soillife, b_swqual, b_erosion, b_nutrcyc, b_wildlife b_micpopnb, b_pdsupp, b_yldqual, b_addlinc, b_socben	0.862
negimpacts	n_grwstime, n_incdis, n_germest, n_effcons, n_weedprb, n_labcost, n_regcost, n_fuelcost, n_sdcost, n_appequip, n_mgmtprb n_shgrtim n_redopts n_yldloss	0.959
costs	ch_mprice, ch_certcst, ch_inptcst, ch_wdmgt, ch_inmgt, ch_dismgt	0.821
mrktng	ch_avinfo, ch_lkntwrk, ch_hndlprb	0.607
physical	ch_soilfer, ch_wthr	0.493

practice	im_rcdhis im_frqtlg im_soilsol im_trtwtr im_soilles im_disres	0.821
assmt	im_labser, im_disass im_nosinpt	0.523
trtment	im_rotat im_ccrp im_bpes im_mino im_bofrtl	0.616

Sources: Mail Survey, 2011
[a]Factors are the linear combination of two or more variables or items extracted using principle component factors method. An item or a variable correspond to response to each of the questions or likert-scale items.
[b] Cronbach's alpha measures of the reliability of scale or internal consistency, that is, how closely related a set of items are as a group.

Table 4.3 outlines the factors, items constituting the factor, and their Cronbach's alpha coefficient. The factors condense the opinion of respondents on importance of disease-management information sources, positive and negative aspects of using cover crops, and challenges in managing organic farms into fewer factors. We use the factor score of these new variables to ascertain their relationship to the usage of mixed-species green manures and microbial inoculants. Cronbach's alpha measures how well a set of variables hang together, i.e., the internal consistency of the scale. Cronbach's alpha ranges from 0 to 1 with 0.6 as an acceptable measure. The higher the value, the greater is the internal consistency, however, a value greater than 0.9 indicate high level of item redundancy. The factors used for adoption analysis in this study have Cronbach's alphas ranging from 0.471 to 0.958 as shown in the table 4.3.

The correlation matrix revealed that it is possible to combine highly correlated variables into factors, which could take into account the variation explained by the variables of interest with fewer factors. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy resulted in values of more than 0.6 among the variables in all the groups of variables used to extract factors (Table 4.4). A KMO measure of 0.6 is considered to be satisfactory and an acceptable measure of sampling adequacy (Field, 2005).

Table4.4: Kaiser- Meyer- Olkin measure of sampling adequacy

Statements	Factors extracted[a]	KMO Coefficient[b]
Importance of disease-management information sources	3	0.6456
Beneficial aspects of cover crops	1	0.8586
Negative aspects of cover crops	1	0.9094
Challenges in managing organic farm	3	0.6408
Importance of disease-management practices	3	0.6180

Source: Mail Survey, 2011

[a] The numbers in the column represent the number of factors extracted from the set of variables related to corresponding statements. See appendix 1 for complete statements.

[b] KMO coefficient is the ratio of squared correlation between the variables to the squared partial correlation between the variables. The KMO measure higher than 0.6 is acceptable, which indicate that the pattern or correlation is relatively compact, and the data is appropriate for factor analysis.

We only considered those perception variables that were highly correlated with mixed-species green manures and microbial inoculant use. A three-factor solution was adopted, choosing the factors having an eigenvalue greater than 1. The first factor (*public*) relates to public information sources such as newsletters and magazines, farm bureau, government agencies, and industry as sources of disease-management information. The second factor (*specific*) relates to farming related specific sources such as commodity groups, organic farming organizations, extension agents, and university research centers. The last factor (*media*) relates to information from mass media such as televisions and radios, internet, and web-based community groups. These three factors together explain 57% of the variation of the set of variables associated with the question, “To what extent do you agree or disagree that the following can contribute to the severity of soil-borne diseases?” The factor analysis of the benefits of using cover crops resulted in a single factor (*posimpacts*) that explained 51% of the total variation in the data set related to Question #34 (See Appendix A). Similarly, the factor analysis of different risks associated with cover crop use resulted in a single factor (*negimpacts*) that

Table 4.5: Percent of variation explained by the set of factors

Factor	% of variation explained[a]
public, specific, and *Media*	57
posimpacts	51
negimpacts	67
cost, mrktng, and *physical*	55
practice, assmt, and trtment	48

Source: Mail Survey, 2011

[a] The percentages represent the relative weight of each factor in the total variance. The total variance is the sum of all the eigenvalues, and is equal to the total number of variables associated with corresponding statement or question.

explained 67% of the total variation of the associated risks. Another set of variables was associated with challenges faced in managing an organic farm. Three factors extracted were *costs*, *mrktng*, and *physical,* and they explained 55% of the total variation of the question "To what extent do you agree or disagree that the following factors are challenges or obstacles you face in managing your organic farm?" The factor *costs* included elements such as low market prices, certification costs, high input costs, weed-management, insect-management, and disease-management. The *mrktng* factor included the availability of reliable information and technical support, a lack of organic marketing networks, handling, and distribution problems. The factor related to soil fertility and weather was represented by *physical* (see table 4.5).These factors were used in the probit regression analysis to assess their effects on the adoption of MSGM and MI. The STATA output for factor analysis includes a KMO test and a Cronbach's α test for one of a set of perception variables and is presented in Appendix B.

4.2.2. Assessment of determinants of adoption decision of MSGM and MI

Probit regression was used to identify the influential factors determining farmers' decisions to adopt MSGM or MI. Six models were estimated. The variables or factors were added or deleted from the model based on the correlation between the variables or factors to *MixCC*. In the model 1, only demographic and institutional related variables were used. In the model 2, the less significant variables such as education, gender, and membership in a farmer related organization were omitted, while farm related variables were included. Model 3 included all the variables from model 2. The variables included perception variables *posimpacts* and *practice* that were highly correlated (posimpacts=0.5087, practice=-0.3843) with the dependent variable mixed species green manure. Although *trtment* was also highly correlated with MixCC, it was not included because of its high correlation with *posimpacts* and *practice*. In model 4, a different set of perceptions variables physical, Media, and *trtment* were added to Model 2. Model 5 included all the variables from model 2, and all the perception variables used in model 3 and model 4. The models were also run with the state variables *Maryland, NewYork, Ohio,* and *Pennsylv*. However, none of the state variables was significant, therefore, they were dropped in all the models. Table 4.6 presents the results of the estimation of MSGM (*MixCC*) for all the five models. The final model included all the variables in model 5 excluding the variable *trtment*. The factor treatment was dropped because it was highly correlated with *posimpacts*, and the correlation of *posimpacts* with *MixCC* was higher than *trtment*. The coefficient estimates of the final model along with the marginal effects coefficients are presented in the table 4.6.

Table 4.6: Probit results showing coefficient estimates, standard errors and *p values* of five different models

Variables[a]	Model 1	Model 2	Model 3	Model 4	Model 5
age	-0.6062[b] (0.3175)[c] (p=0.056)[d]**	- 0.8360 (0.3299) (p=0.011)***	-0.9791 (0.3659) (p=0.007)***	-0.5558 (0.3948) (p=0.159)***	-0.7762 (0.4135) (p=0.060)*
exper	0 .775 (0.3038) (p=0.011)***	0.8515 (0.3217) (p=0.008)***	0.9574 (0.4092) (p=0.019)**	1.3014 (0.4069) (p=0.001)***	1.1581 (0.4389) (p=0.008)***
edu	0.3297 (0.3089) (p=0.286)	------	------	-----	------
sex	-0.0018 (0.3471) (p=0.996)	------	------	-----	------

assoc	-0.208 (0.4204) (p=0.621)	------	------	-----	------
trg	0.4677 (0.3124) (p=134)	0.3066 (0.3336) (p=0.358)	0.1823 (0.3995) (p=0.648)	-----	-----
intnet_acces	0.8836 (0.4598) (p=0.055)**	0.9238 (0.4348) (p=0.034)**	1.0164 (0.4997) (p=0.042)**	3.629 (0.1.1662) (p=0.002)***	3.1115 (1.1403) (p=0.006)***
org_acre	-----	0.0436 (0.0261) (p= 0.096)*	0.0332 (0.0298) (p=0.265)	0.0034 (0.0304) (p=0.909)	0.0101 (0.0344) (p=0.770)
no_labor	------	0.0082 (0.0481) (p=0.864)	0.0186 (0.0501) (p=0.710)	-----	------
***f**arm*	-----	-0.2538 (0.3316) (p=0.444)	-0.0980 (0.4035) (p=0.808)	-0.3706 (0.4010) (p=0.355)	-0.2985 (0.4740) (p=0.529)
posimpacts	-----	-----	0.1267 (0.0583) (p=0.030)**	------	0.1025 (0.0711) (p=0.149)
practice	-----	-----	-0.144 (0.0644) (p=0.823)	------	-0.0202 (0.0796) (p=0.800)
physical	-----	-----	-----	-0.2477 (0.1929) (p=0.197)	-0.3473 (0.2365) (p=0.142)
Media	-----	-----	-----	-0.4731 (0.1744) (p=0.007)***	-0.3885 (0.1778) (p=0.029)**
trtment				0.3512 (0.1340) *(p=0.009)****	0.2798 (0.1615) *(p=0.083)**
_cons	-0.9475 (0.6255) (p=0.130)	-1.004 (0.5215) (p=0.054)	-5.3356 (2.5543) (p=0.037)**	-2.5798 (1.4426) (p=0.074)**	-4.2694 (3.0579) (p=0.163)
N	=90	=89	=79	=74	=69
Prob>chi2	=0.0026	=0.0003	=0.0009	=0.0000	=0.0000
PseudoR2	=0.1760	=0.2352	=0.3192	=0.3959	=0.4442
Loglikelihood	=-51.3877	=-47.1399	=-37.2752	=-0.30.7221	=-26.4793

Source: Mail Survey, 2011

*** = significant at 1%
** = significant at 5%
* = significant at 10%
[a] *age, exper, edu, sex, assoc, trg, intnet_access, org_acre, no_labor, farm* are the simple variables and *posimpacts, practice, physical, Media, trtment* are the factors related to farmers' perceptions.
[b] coefficients estimates
[c] Values in the parenthesis represent standard errors
[d] Values in the parenthesis represent *p* values

In all five models presented in table 4.6, the three factors found to affect the decision to adopt MSGM significantly were *age*, experience (*exper*), and farmers' access to the internet (*intnet_access),* except for age in model 4, which was found non-significant. *Age* was significant at the 1% in models 2 and 3, and at the 5% level in the models 1 and 5. Similarly, experience (*exper*) was significant at the 1% level except in model 3, where it was found significant at the 5% level. Adding farm related variables in model 2 and the perception related variable in the models 3, 4, and 5 did not affect the significance of the variable experience. Access to the internet was significant at the 5% level in the models 1, 2, and 3. However, with the addition of other perception variables including Media, which is related to the perception on source of information on disease management, resulted into greater significance of the variable *intnet_access.* The variable *posimpacts* was significant at the 5%level in model 3 and was no longer significant in the model 5. The variables *Media* and *trtment* were significant at the 1% level in model 4. However, these variables lost their significance, and were only significant at the 5% level only in model 5 with the addition of variables *posimpacts* and *practice* from model 3. Different models were ran to see how these models behaved when different variables or factors were added to the model, and also to see if the significant variables and factors were consistent across all the models.

The final model, presented in table 4.7, included all the variables except the variable *trtment*, which was dropped because it was highly correlated to *posimpacts*. *Age*, *exper, intnet_access,* and *posimpacts* were all significant at the 1% level. The marginal effects estimated for this model showed that the variables *age, exper, intnet_access,* and *posimpacts* were significant at the 1% level. The marginal effect of *age* was –0.1171, which implied that the probability of adopting MSGM was 12% lower for people greater than 50 years than for those with people 50 years old or younger. The marginal effect of *exper* was 0.37, which means the probability of adopting was 37% higher for people with more than 10 years experience than for people with 10 or less years of experience, which was in contrast to our assumption where we assumed adoption to decline with experience. Such a result could be because it could have substituted for education, which was assumed to affect adoption positively. Similarly, the marginal effect of *intnet_access* was 53% higher for producers who had internet access that for those who did not. The *posimpacts* had a marginal effect of 0.07, which means that a one index point increase in *posimpacts* increases the probability of adopting MSGM by 7%. The variables education (Chaves and Riley, 2001, Moyo, et al., 2007, Napit, et al., 1988), sex (Bonabana-Wabbi, 2002, Moyo, et al., 2007), association with farms related organizations (De Souza Filho, et al., 1999), acres of land farmed(Moyo, et al., 2007), which were significant in past studies were nonsignificant in this study. The detailed output from STATA including the specification test for the model is presented in Appendix C(1) .

Table 4.7: Probit results showing coefficient estimates and marginal effects of final model for mixed species green manure

Variables[a] (Std. error)	Coef Est. (Std. error)	p=value	Marginal effects	p=value
age	-1.1171 (0.3914)	0.004	-0.3029 (0.1138)	0.008***
exper	0 .9646 (0.4132)	0.020	0.3651 (0.1439)	0.011***
int*net_acces*	1.6385 (0.4598)	0.16	0.5284 (0.1401)	0.000***
org_acre	0.0179 (0.0344)	0.433	-0.0068 (0.0089)	0.442
farm	-0.0405 (0.4046)	0.920	0.0155 (0.1552)	0.920
posimpacts	0.1885 (0.0622)	0.002	0.0718 (0.0237)	0.002***
practice	-0.0132 (0.0690)	0.848	0.0050 (0.0261)	0.847
physical	-0.0138 (0.1568)	0.930	-0.0052 (0.0597)	0.930
Media	-0.1362 (0.0957)	0.155	-0.0519 (0.0359)	0.148
_cons	-6.2362 (2.6381)	0.018		
N =74	Prob>chi2=0.0000	PseudoR2=0.3646	Log-likelihood = -32.522682	

Source: Mail Survey, 2011
*** = significant at 1%
** = significant at 5%
* = significant at 10%
Values in the parenthesis represent standard errors
[a]In this table*, age, exper, intnet_access, org_acre, farm* are the simple variables and *posimpacts, practice, physical, and Media* are the factors related to farmers' perceptions.

The specification test showed that all of the models were properly specified, and *_hat*s were significant, which implied that all the variables used are relevant to the model and link function was appropriately specified. In addition, *_hatsq*s were not significant except in model 5, indicating that no relevant variables were omitted from the model. However, in model 5, *_hatsq* was significant at the 10% level, which indicated some variables could have been omitted from the model. The significance test for the final model also showed that *_hat* is significant (_hat=0.000) and *_hatsq* insignificant (_hat sq=0.467), which implied that all the included variables are relevant to the model, and relevant variables were not omitted from the model.

Although we assumed error term to have standard normal distribution and used probit regression, we estimated logit models because the error term may not be normally distributed as we expect. Estimation using logit regression showed similar result to the probit final results with coefficient of *age, exper, intnet_access,* and *posimpacts* significant at 1% level. However, the marginal effects of *exper* and *intnet_access* significance at the 1% level *posimpacts* at the 5% level and age at the 10% level (See Appendix C 2 for detail). The specification test showed that *_hat* was significant (*_hat*=0.000), which implied that the link function is appropriately specified and variables included are relevant to model. Insignificance of *_hat sq* *(_hat sq*=0.212*)* implied that no relevant variables were omitted from the model.

Similarly, probit results for microbial inoculants (MI) revealed that *specific* and *trtment* were significant at the 1% level (table 4.8). Sex of the respondent was significant at the 5% level. The level of education was significant at the 10% level. The marginal effects were computed at the mean for continuous variables such as *tom_acres*, *specific*, and at 1 for discrete variables *edu* and *sex*. The results showed that the correlation of education to probability of the adoption of MI was negative with a marginal effect of 0.296, which implies that the probability of adoption is 30% lower for farmers who have a college and graduate education than for other groups (people with high school education or lower). The probability of adoption for males was 41% lower than females, which does not confirm our hypothesis. Access to the internet (*intnet_access*) was significant at the 10% level in its marginal effects estimation but was negative, which implied that the probability of adoption of MI was 42% lower for farmers with access to the internet than those without it, which is in contrast to our hypothesis and results for the mixed species green manures. The specification test showed that the link function was appropriately specified, the model included all the relevant variables (*_hat* =0.000), and none of the important variables were omitted because _hatsq was nonsignificant (*_hat sq*=413). The detailed output from STATA including the specification test is presented in Appendix D(1)

Table 4.8: Probit regression results showing coefficient estimates and marginal effects for microbial inoculants use

Variables[a] (S.E).	Coef.est (S.E.)	*p* value	Marg. Effs	*p*-value
exper (	0.2234 0.4498)	0.619	0.0306 (0.0616)	0.620
edu	-1.058 (0.6022)	0.079*	-0.2960 (0.1637)	0.071*

sex	-1.3657 (0.6287)	0.030**	-0.4170 (0.1952)	0.033**
intnet_access	-1.3735 (0.6467)	0.034**	-0.4201 (0.2499)	0.093*
tom_acres	-00001 (0.0982)	0.999	0.0000 (0.0157)	0.999
farm	- 0.2696 (0.5815)	0.589	-0.0513 (0.1035)	0.620
specific	-0.3305 (0.1421)	0.014***	-0.056 (0.0361)	0.122
trtment	-0.5532 (0.1715)	0.001***	-0.0883 (0.0553)	0.110
_cons	-0.2933 (1.9868)	0.883		
Number of obs. = 58	Prob>chi2 =0003	Pseudo R2= 3703	Log likelihood= -24.527234	

Source: Mail Survey, 2011
*** = 1% significance level
** = 5% significance level
* = 10% significance level
Values in the parentheses indicate standard errors
[a]*age, exper, intnet_access, org_acre, farm* are the simple variables and *posimpacts, practice, physical, and Media* are the factors related to farmers' perceptions.

Estimation using the logit regression showed that all four variables found significant in the probit regression were also significant, which validates our results. In addition to the variable *specific* was significant at the 1% level, the variable *trtment* was significant at the 1% level, education which was significant at the 10%, and access to the internet (*intnet_access*) and *sex* at the 5% level. The marginal effects analysis of the logit model showed that *gender* was significant at the 5% level and *intnet_access* at the 10% level. The marginal effect of *sex* was negative 0.427, which implied that the probability of adoption was 43% lower for males than for females. The marginal effect of *intnet_access* was a negative 0.44, which implied that probability of adoption is 44% lower for those who have the internet access than for those who do not. This is in contrast with the finding for mixed species green manures where access to the internet positively affected the adoption decision. STATA output for the logit model for microbial inoculants is given in Appendix D (2).

4.2.3 Discussion on factors affecting adoption of MSGM and MI

Numerous reports demonstrate that green manures can control soil-borne disease in vegetable crops (Bulluck and Ristaino, 2002, D.O, 2006, Stone, et al., 2004). Use of cover crops is one of the most sustainable technologies for managing organic farms because it is widely believed that disease suppression follows directly from the chemical activities of degrading plant materials (SAN, 2007). However, different aspects related to its use limit use of cover crops. One of the significant factors identified in this study was the perception by farmers of different aspects of using cover crops. Farmers' opinions on the use of cover crops were extrapolated by using five-point scale questions.

Access to the internet significantly affected adoption of mixed-species cover crops positively and microbial inoculants negatively. About 70% of the respondents reported using the internet once or more per day. The internet is one of the easiest ways to access related information on any technology. Other institutional factors such as membership in related organizations and training were found nonsignificant and so inconsistent with our prediction. One of the reasons could be use of the internet for accessing information as a replacement for other information sources.

Among the demographic factors, age was negatively related and experience was positively related, while education and gender were nonsignificant in the case of mixed-species green manures. The nonsignificance of education could be due to farmers acquiring knowledge through learning by doing. With age, one becomes experienced and more knowledgeable about the various types of management practices, and reluctant to change from existing practices. In this case, experience might have served the purpose of education and affected adoption positively while education was nonsignificant. Farm characteristics such as acres of land used for tomato or organic vegetables and income from the farm were found to have no effects on adoption of mixed-species green manure, which did not confirm our hypothesis. In addition, adoption of MSGM did not depend on whether farmers used certified organic farm or not.

Adoption of mixed-species cover crops is affected by farmers' perceptions of the benefits of using the cover crops, complexity of managing the practice, sources of disease management information, and climatic considerations. The variable *posimpacts* was significant at the 1% level, which implied that perceptions of farmers on the positive benefits[2] had positive effects on the adoption decision. The

[2] Positive benefits include yield gain, pest and diseases suppression, improved yield quality and quantity, enhancement of soil quality and other environmental benefits such as reduced soil erosion, enhancement of wild life, water quality, and diversity in soil microbial population.

marginal effect analysis showed that a one-index point increase in *posimpacts* increased the probability of adoption of MSGM by 7% percent. Other perception variables were nonsignificant both economically and statistically.

4.3. Enterprise budget analysis

It was assumed that the adoption of MSGM would result in increased yield of organic tomatoes and cost savings due to reduction in input costs from reduced use of insecticides and fertilizers. In an effort to find a solution to the problem of soil-borne diseases, experimental trials for MSGM in organic tomato production have been conducted have shown mixed results across different treatments in the states where the project is being implemented. Different trials were set up in three different states. Maryland had two mixed-species, two single-species, and a no cover crop control. In New York, there were three mixed- species, a single species, and a no cover crop control. In Ohio, the treatments were two mix species and three single species. We considered only marketable yield in this analysis.

A summary of the yield information with different cover crops is presented in table 4.9. There were three rounds of harvesting in the month of August. Two sets of yield information are presented in the table to give a sense of actual production capacity. The marketable yield consists of red (ripened) tomatoes ready to sell. The greens were harvested during the last round along with the red ones. The numbers in parentheses of the table indicate the yield information consisting of red marketable and green tomatoes for Maryland and New York. However, the numbers in the parentheses for Ohio represent organic tomato yield without a compost amendment. The tomato yield comparison showed that the green tomatoes constituted a significant portion of the total yield, and the benefit could be larger if green yield was included in the analysis. For instance, in Maryland, red tomato yield was 4.82 metric tons per hectare while the total of red and green tomato yield was 11.76 tons. We found similar results with all the treatment of cover crops. In Ohio, the organic tomato experiment was conducted in two settings with different cover crop treatments. The yield in the compost application setting showed a more than twofold yield increase compared to in the no compost application setting as shown in the table 5.11. The yields in the parentheses are for the no compost application setting.

Table 4.9: Summary of marketable tomato yields (metric tons) per hectare with different cover crops treatments[a]

Cover crops	Maryland	New York	Ohio
Bare ground	4.82 (10.67)	9.62 (13.81)	-------
Single species			
Hairy Vetch	6.59 (11.43)	--------	78.28 (26.58)
Winter Rye	--------	6.75 (12.65)	75.52 (30.44)
Tillage Radish	--------	--------	68.19 (36.78)
Mixed-species			
Mix Hay	5.68 (12.56)	--------	74.73 (49.99)
Rye &Vetch	4.37 (9.72)	7.88 (13.29)	65.02 (34.83)
F. Radish & H. Vetch	7.28 (13.72)	--------	--------

Rye& Turnip	--------	8.64 (14.78)	--------
Rye & Clover	--------	7.69 (13.33)	--------

Source: Project Scientists, 2011

[a]The numbers in the parenthesis are the total tomato yield (red+green) for Maryland and NewYork. For Ohio, the numbers represent tomato yield (metric ton) with compost application and numbers in the parenthesis indicate yield without compost application.

In Maryland, the net return of tomato production per hectare was highest with use of mixed forage radish and hairy vetch, which was about $21,067 per hectare with a rate of return on total input cost of 192% followed by hairy vetch with a net return of $18,017, and a rate of return of 164%. The use of hairy vetch and rye was found to produce the lowest net return of $8,504, with a rate of return of 79%, lower than the return from bare ground of $10,585. The net return of organic tomato production per hectare with use of mixed hay was $14,087.

In New York, the highest return was from bare ground with a net return of $31,833 and a rate of return of 301%. In an email statement, the collaborator from New York mentioned that this result is from 2010, and they might get different results in 2011. Moreover, they are conducting another year of experiments to validate their results.

In Ohio, data showed an exceptionally high return for all the treatments, the highest being for hairy vetch with a net return of $339,660 per hectare, and with a return of 7120%. The lowest net return was from a mix of hairy vetch and rye at $324,072 per hectare, and a rate of return of 6840%, and the yields without compost application was almost half than that with compost applications for all the cover crops. These calculations presented are for the production with compost amendments only. The detailed budgets are presented in appendix E.

Table 4.10: Summary of net returns (dollar) per hectare and rates of return[a] in parentheses

Maryland	New York	Ohio	
Bare ground	10,585(100)	31,752 (301)	---------
Single species			
Hairy vetch	18,017 (164)	----------	339,660 (7120)
Winter rye	----------	18,915 (175)	327,602 (6990)
Tillage radish	----------	----------	295,582 (6640)
Mixed-species			
Mix hay	14,087 (129)	----------	324,072 (6840)
Rye&Hairy vetch	8,504 (79)	23,261 (204)	281,316 (5900)
Forage radish&vetch	21,067 (192)	----------	---------
Rye/ turnip	---------	27,236 (253)	---------
Rye/clover	---------	22,909 (210)	---------

Source: Project Scientists, 2011
[a]Rate of return to total cost (variable+fixed costs)

The comparison of mixed-species cover crops with single species showed inconsistent results. Not all the mixed-species cover crops were as profitable as single species. In Maryland, the increase in yield of organic tomato with the use of mixed forage radish and hairy vetch over single species hairy vetch was 0.69 metric tons per hectare, a proportionate yield increase of 10%, with a proportionate cost decrease of 0.13% as shown in table 4.11. None of the other mixed species cover crops such as hairy vetch and rye and mixed hay were found to be profitable. Only the mixed forage radish and hairy vetch was found to be profitable when compared to single species hairy vetch. Therefore, analyses for the rest of the cover crops were not performed. The detailed calculation for net returns is provided in appendix E(1).

Table 4.11: Yield (tons) difference, proportionate yield, and variable cost change per hectare of mixed species cover crops for Maryland (%)

	Forage Rad. & H.Vetch	Mix Hay	Hairy Vetch&Rye
Yield change[a]			
Hairy Vetch	0.69(10%) ↑	0.91(16%) ↓	2.22(50%) ↓
Cost change[b]	$14 (0.13%) ↓	$74(0.7%) ↓	$255 (2.5%) ↓

Source: Maryland Project site, 2011

[a] Yield difference and proportionate yield change (in parentheses) per hectare for mix of forage radish and hairy vetch, mixed hay, mix of hairy vetch and rye as compared to single species hairy vetch. Downward facing arrows indicate decrease in yields or proportionate yield decrease and upward arrows indicate increase in yield or proportionate yield increase per hectare of land.

[b] Variable cost change and proportionate variable cost change (in parentheses) per hectare for mixed species of forage radish and hairy vetch, mixed hay, mix of hairy vetch and rye and single species hairy vetch. Downward facing arrows indicate decrease in variable cost or proportionate variable cost decrease and upward arrows indicate increase in variable cost or proportionate variable cost increase per hectare of land.

In New York, a similar analysis between mixed-species treatments and single species revealed that all mixed-species cover crops had benefits over single species. The tomato yield increase with mixed-species rye and turnip compared to single species rye was 1.89 metric tons per hectare, a proportionate yield increase of 28% with a proportionate cost decrease of 0.1%, which was the highest percentage change compared to all other mixed-species cover crops. The mix of rye and clover had a yield increase of 0.94 metric ton, a proportionate increase of 14% with a proportionate cost increase of 1.3% over single species rye. Similarly, a mix of rye with hairy vetch had a yield increase of 1.13 metric ton per hectare, a proportionate increase of 17% over rye with a proportionate cost increase of 5.8% as shown in the table 4.12. However, the proportionate yield change is negative with all the mixes of cover crops including single species rye when compared to bare ground, which implies that the green manure technology is not profitable. According to the principal investigator, such a result could be due to a lack of enough time for the breakdown of the cover crop biomass to be incorporated into the soil. The detailed partial budget calculation is presented in appendix E (2).

Table 4.12: Yield difference (metric ton), proportionate yield, and variable cost change per hectare of mixed species cover crops for New York (%)

	Rye &Turnip	Rye & Clover	Rye & Vetch
Yield change[a]			
Rye _	1.89 (28%) ↑	0.94 (14%) ↑	1.13 (17%) ↑
Cost change[b] _	$6 (0.1%) ↓	$141 (1.3%) ↑	$626 (5.8%) ↑

Source: New York Project site, 2011

[a] Yield difference and proportionate yield change (in parentheses) per hectare for mix of rye and turnip, rye and clover, rye and hairy vetch compared to single species rye. Downward facing arrows indicate decrease in yields or proportionate yield decrease and upward arrows indicate increase in yield or proportionate yield increase per hectare of land.

[b] Variable cost change and proportionate variable cost change (in parentheses) per hectare for mixes of rye and turnip, rye and clover, rye and hairy vetch compared to single species rye. Downward facing arrows indicate decrease in variable cost or proportionate variable cost decrease and upward arrows indicate increase in variable cost or proportionate variable cost increase per hectare of land.

In Ohio, two mixed-species of cover crops, hairy vetch and rye and mixed hay were compared with three of the single species cover crops (hairy vetch, tillage radish, and rye). The comparison was in two different settings. One of the settings was with compost amendment and other without compost. The result showed a decrease in the yield of hairy vetch and rye compared to single species hairy vetch with compost application was 13.26 metric tons, a proportionate decrease of 17% with no change in cost. All the single species cover crops were more profitable than a mix of hairy vetch and rye when used with compost. The mixed hay was also found less profitable than two of the single species cover crops hairy vetch and rye. However, mixed hay was more profitable than tillage radish (table 4.13).

Table 4.13: Yield difference (metric ton), proportionate yield, and variable cost change per hectare in compost application setting in Ohio (%)

	Hairy vetch and winter rye	Mix hay
Yield change (Compost)[a]		
Hairy Vetch	13.26(17%) ↓	3.55(4.5%) ↓
Tillage Radish	3.17(5%) ↓	6.54(9.6%) ↑
Winter Rye	10.5(14%) ↓	0.79(1.1) ↓
Cost change[b]		
Hairy Vetch	$0.32(0%) ↑	$32(1%) ↓
Tillage Radish	$318(7%) ↑	$286(7.7%) ↑
Winter Rye	$86(2%) ↑	$54(1.4%) ↑

Source: Ohio Project site, 2011

[a] Yield difference and proportionate yield change (in parentheses) per hectare for a mix of hairy vetch and rye and mixed hay compared to single species hairy vetch, tillage radish, and rye. Downward facing arrows indicate decrease in yields or proportionate yield decrease and upward arrows indicate increase in yield or proportionate yield increase per hectare of land.

[b] Variable cost change and proportionate variable cost change (in parentheses) per hectare for a mix of hairy vetch and rye and mixed hay compared to single species hairy vetch, tillage radish, and rye. Downward facing arrows indicate decrease in variable cost or proportionate variable cost decrease and upward arrows indicate increase in variable cost or proportionate variable cost increase per hectare of land.

The comparison of organic tomato yields with different treatments of single and mixed-species cover crops in a no compost application setting was rather promising as presented in table 4.14. The result showed an increase of 8.25 metric tons per hectare, a proportionate increase of 31% with the use of hairy vetch and rye over single species hairy vetch. The analysis showed a similar yield increase of 4.39 tons per hectare, a proportionate increase of 14% for a mix of rye and hairy vetch over the single species rye in a no compost application setting. However, single species tillage radish was found to be more profitable than the mix of hairy vetch and rye. The comparison of mixed hay with single species hairy vetch, tillage radish, and winter rye showed that mixed hay was more profitable than all single species cover crops used in the state. The detailed budget is presented in Appendix E (3 and 4).

Table 4.14: Yield difference (tons), proportionate yield, and variable cost change per hectare in no compost application setting in Ohio (%)

	Winter rye and hairy vetch	Mixed hay
Yield change[a] (No Compost)		
Hairy Vetch	8.25 (31%) ↑	23.41(88%) ↑
Tillage Radish	1.95 (5%) ↓	13.21(0.36%) ↑
Winter Rye	4.39 (14%) ↑	19.55(64%) ↑
Cost change[b]		
Hairy Vetch	$0.32(0%) ↑	$32(1%) ↓
Tillage Radish	$318(7%) ↑	$286(7.7%) ↑
Winter Rye	$86(2%) ↑	$54(1.4%) ↑

Source: Ohio Project site, 2011

[a] Yield difference and proportionate yield change (in parentheses) per hectare for a mix of hairy vetch and rye and mixed hay compared to single species hairy vetch, tillage radish, and rye. Downward facing arrows indicate decrease in yields or proportionate yield decrease and upward arrows indicate increase in yield or proportionate yield increase per hectare of land.

[b] Variable cost change and proportionate variable cost change (in parentheses) per hectare for a mix of hairy vetch and rye and mixed hay compared to single species hairy vetch, tillage radish, and rye. Downward facing arrows indicate decrease in variable cost or proportionate variable cost decrease and upward arrows indicate increase in variable cost or proportionate variable cost increase per hectare of land.

4.3.1. Discussion on budget analysis

The budget analyses of the different cover crops with organic tomato production showed mixed results in different states. In Maryland, the mix of forage radish and hairy vetch had the highest production and return over total costs. The return was even higher when green tomatoes were included. In New York, bare ground had the highest return followed by mixed turnip and rye. In Ohio, single species hairy vetch had the highest return with compost application. However, the highest return was from mixed hay when used with no compost.

Enterprise budget analysis of treatments of mixed-species over single species showed mixed results. In Maryland, a mix of forage radish and hairy vetch produced the highest yield increase, and was the most profitable but otherwise, all other mixed species were less profitable than single species hairy vetch. The reason for low profitability of the other mixed-species cover crops may be the lack of time for biodegradation of the cover crops residue to replenish the soil fertility and add soil-borne diseases suppressive elements to the soil. In addition, agricultural inputs such as irrigation, types of organic amendments used along with the cover crops, soil conditions, and weather are crucial to the organic tomato yields. In New York, the yield increase of organic tomato was highest with the mix of rye and turnip. None of the mixed-species cover crops produces tomato yields more than on bare ground. However, while comparing mixed and single species cover crops, mixed turnip and rye was found to be most profitable. In Ohio, both mixed species hairy vetch and mixed hay were profitable over single species hairy vetch, tillage radish, and rye except mixed hairy vetch and rye compared to tillage radish when used without compost. However, the results were opposite when used with compost. There was not a large change in the cost because the only difference was in terms of cover crops seed and labor costs.

Different cover crops had different characteristics in terms of establishment, growth, degradation, and water efficiency. Moreover, timing of cover crop use (seeding and harvesting) and its management is crucial in harnessing maximum benefits from them. One should take into consideration proper timing of cover crop seeding, killing, and biomass management. Another important thing to consider is the matching of the cover crops with the crops that follow them.

4.4. Research-induced economic benefits of using mixed-species green manures on organic tomato production

The economic benefits of mixed-species green manures technology was projected for fifteen years (2010-2024) in all three states. The research outcomes are considered under different mixes of cover crops over single species and no cover crops controls in Maryland and New York. In Ohio, research outcomes of mixed-species cover crops with and without compost application were analyzed. Our calculations present different levels of benefits based on the type of mixed cover crops used by the producers. Sensitivity analyses were conducted using different rates of adoption and different values of the probability of research success. The detailed description of the parameters and calculation of net present value of benefits is presented in Appendix F.

4.4.1. **Assessment of the research-induced economic benefits**

Maryland

The benefit of using mixed-species green manure was assessed for Maryland where this technology is already being used and then projected to the state based on the present level of organic tomato production in the state. The results of the impact assessment are presented in table 4.15.

Table 4.15: Research-induced benefits of mixed of forage radish and hairy vetch compared to single species hairy vetch in Maryland

Adoption rates	25%	40%	50%	65%
Under an open economy assumption				
Net present value (NPV) with				
Yield change= 10%	$766,097	$1,287,328	$1,533,376	$1,715,746
Yield change= 20%	$1,908,762	$2,953,295	$3,461,192	$3,840,975
Under a close economy assumption				
Yield change=10%	$755,227	$1,255,521	$1,494,322	$1,670,044
Yield change=20%	$1,849,326	$2,850,666	$3,329,939	$3,683,464

Source: Maryland Project scientists, 2011

Under an open economy assumption, of the four cover crops used in Maryland, a mix of forage radish and hairy vetch was found to be most profitable with a net present value of $1.53 million when maximum adoption level is achieved over 15 years from the time it is introduced to the farmers. The sensitivity analysis showed nets benefit ranging from $0.76 million with maximum adoption level of 25% to $1.67 million with a maximum adoption level of 65%. Since the research is in the initial stages it may take a few years to bring full fertility to the soil, and there is a possibility of additional yield increases in subsequent years. Sensitivity analysis of different levels of the expected yields revealed that increasing the expected change in yield from 10% to 20% increases the net present value to $1.91 million, $2.95 million, $3.46 million, and $3.84 million for maximum adoption levels of 25%, 40%, 50%, and 65% respectively. Due to the open economy assumption, projected benefits accrue to producers only. The spreadsheet showing detailed calculation is presented in Appendix F (1).

The benefits of using mixed-species cover crops were also evaluated under a closed economy assumption. The benefits from the only profitable mixed-species cover crop forage radish and hairy vetch as compared to hairy vetch projected over 15 years at a discount rate of a 5%, and a maximum adoption rate of 50% was $1.49 million (see Appendix F 10). Sensitivity analysis showed similar trends of benefits at different rates of adoption as in the open economy model. The net present value of benefits of adopting a mix of forage radish and hairy vetch ranged from $0.75 million to $1.67 million with maximum adoption level of 25% to 65%. The benefits ranged from $1.85 million to $3.68 million with maximum adoption level of 25% to 65% when the increase in expected yield change is 10% to 20%. The results showed that consumers benefit more than producers do with more than three fourths of the total benefits accruing to consumers.

New York

In New York, all the mixed cover crops were profitable over the single species of rye. However, the most profitable mix of cover crops was mixed turnip and rye. Under an open economy assumption, the benefit from using the mixed turnip and rye was evaluated for the project site and then projected to the state of New York (table 4.16). The results are estimates over 15 years, at a 5% discount rate, and maximum adoption level of 50% as projected by the project scientists. The net present value of the investment in research on tomato production with a mix of rye and turnip is $2.61 million when the maximum adoption rate is achieved. Sensitivity analysis using different maximum adoption level gave net present values of the benefits as $1.39 million, $2.21 million, and $2.91 million with maximum adoption levels of 25%, 40%, and 65%. The spreadsheets showing detailed calculation of research benefits over 15 years is presented in Appendix F (2, 3, and 4).

The next most profitable mix of cover crops was rye and clover with a net present value of benefits of $0.97 million with a maximum adoption level of 50% at a discount rate of 5% over 15 years. Similarly, the estimates of research benefits of mixed rye and hairy vetch were slightly lower than for mixed rye and clover. Sensitivity analysis using different rates of adoption is presented in table 4.16.

Table 4.16: Research-induced benefits of a mix of rye and turnip compared to single species rye in New York

Maximum rates of adoption	25%	40%	50%	65%
Under an open economy assumption				
Rye and turnip	$1,386,940	$2,209,004	$2,611,808	$2,914,968
Rye and clover	$435,563	$797,269	$971,855	$1,101,581
Rye and vetch	$385,214	$723,170	$886,154	$1,007,169
Under a close economy assumption				
Rye and turnip	$1,348,453	$2,124,123	$2,496,181	$2,771,137
Rye and clover	$427,468	$779,415	$947,534	$1,071,237
Rye and vetch	$378,114	$707,512	$864,824	$980,636

Source: New York Project scientists, 2011

Under a close economy assumption, estimated benefits of organic tomato production using a mix of rye and turnip over single species rye with a 5% discount rate and a maximum adoption level of 50%, is $2.49 million. Consumers received more benefits than producers (3 to 1) because of a higher elasticity of demand. However, the mixes of rye, clover and rye, and hairy vetch were not profitable under this assumption (see Appendix F 11).

Ohio

In Ohio, organic tomato production using two mixed-species cover crops were compared to three single species cover crops when used with compost. Enterprise budget analysis showed that the proportionate yield change of organic tomato with a mixed hairy vetch and rye was negative compared to all the three single species of cover crops when used with compost application. In addition, the proportionate yield change with mixed hay was found to be negative over two single species except with tillage radish. Therefore, only benefit from the mixed hay compared to tillage radish was used for further analysis. However, under the open-market economy assumption, the assessment of potential research induced benefits from using mixed hay over a single tillage radish projected for 15 years at a 5% discount rate showed a negative result.

However, mixed-species cover crops were found to be profitable when used without compost as presented in the table. The mixed-species cover crops were profitable over all single species cover crops except a mix of hairy vetch and rye over tillage radish. The benefits projected for a period of 15 years at a discount rate of 5% with a maximum adoption level of 50% were $0.771 million and $.087 million for a mix of hairy vetch and rye over single species hairy vetch and rye respectively. Similarly, benefits with mixed hay were projected at $3.12 million, $0.746 million, and $2.07 million over single species hairy vetch, tillage radish, and winter rye respectively. Spreadsheets showing detailed calculation of research benefits over 15 years are presented in Appendix F (5, 6, 7, 8, and 9).

The evaluation of research-induced benefits of mixed-species cover crops over single species in a closed-market economy showed that the net present value of mixed species of hairy vetch and rye over single species hairy vetch and rye was $0.719 million and $0.077 million respectively. The net present value of benefits of mixed hay over hairy vetch, tillage radish, and rye when used without compost were $2.77 million, $0.696, and $1.85 million over 15 years at a discount rate of 5% with a maximum adoption level of 50% (see table 4.17). The distribution of the benefits between consumers and producers was 3 to 1, which implied that consumers received three fourths of the benefits. The spreadsheets showing detailed calculation are presented in Appendix F 12 and 13.

Table 4.17: Research-induced benefits of using mixed species cover crops over single species without compost application in Ohio

	Hairy vetch	Tillage radish	Winter Rye
Under an open economy assumption			
Hairy vetch and rye	$771,511	---------	$87,901
Mixed hay	$3,120,871	$746,305	$2,066,591
Under a close economy assumption			
Hairy vetch and rye	$719,928	---------	$77,932
Mixed hay	$2,770,897	$696,760	$1,854,038

Source: Ohio Project scientists, 2011

4.4.2. Discussion on research-induced benefits of using mixed species green manures

This section of the paper discusses about the benefits of the research-induced benefits of using mixed-species green manures. The project was implemented in three northeastern states of the U.S. to explore the best mix of cover crops for organic tomato production. The project includes three years of experimentation, which began in 2010. The production information from the first year of experimentation showed mixed results across the three states. One of the objectives of the study was to assess the economic benefits of using the mixed-species cover crops over single species cover crops. Most of the mixed-species cover crops were projected to be less profitable as compared to the single species cover crops given the data available to date. In this *ex-ante* impact evaluation, the benefits were projected for the period of 15 years (2010-2024) with a maximum adoption level of 50%.

In Maryland, the only mixed-species cover crop found profitable was mixed turnip and rye. In an open economy, the benefit was projected at $1.53 million for an maximum adoption level of 50%. Because of the small country assumption, there was no change in price to benefit consumers with increased production. Under a closed economy, the net present value of benefit was $1.49 million, and three fourths of the benefit accrued to consumers. Likewise, in New York, under an open economy, all the mixes of cover crops were profitable, and the most profitable was the mix of rye and turnip compared to single species rye. In Ohio, although, the tomato yields are higher with compost application than without, the marginal rate of return is negative for the mixed species cover crops over the single species. However, the both mixed species hairy vetch and rye and mixed hay were found profitable over all the single species except hairy vetch and rye over tillage radish when used without compost. The most profitable mixed species cover crops was the mixed hay over hairy vetch.

Chapter 5: Conclusion, limitations, and further research

5.1. Conclusion

During the last decade, the demand of organic products including vegetables has created a great opportunity for the organic production industry to expand especially for the fresh vegetables. Tomato is the nation's fourth most popular fresh market vegetable behind potatoes, lettuce, and onions in terms of consumption. U.S. consumption of processed tomato has been on the rise over the past two decades because of increased presence of tomato products used in popular food items, and condiments such as pizzas, pastas, salsa, and ketchup. U.S. per capita consumption of processing tomatoes is estimated at 71 pounds in 2008, the highest in the last three years (Naeve, 2009).

The increasing market for both processed and fresh market and shifting trends from conventional to organic products has translated into increased demand for organic tomatoes. However, the production of vegetables, especially tomato, is limited by low yields because of poor soil quality and soil-borne diseases and because organic farmers are prohibited from using chemical-based fertilizers and pesticides. In addition, time and opportunity cost of transition from conventional to organic farming are other limitations for adopting organic farming as it incurs a cost as well. During the transition, farmers do not receive the price premium for three years until their product is organically certified. There are also higher incidences of diseases in transitioning crops.

This study evaluates the economic impacts of mixed-species green manure technology for organic tomato. The technology is designed to address the soil-borne disease problems and enhance productivity by improving the soil quality using organic-based environmentally friendly strategies. Because, single species green manures are already in use in organic vegetable production for suppression of diseases and enhancing soil quality, this study focuses on assessing the added benefits of using mixed-species green manure to help control soil-borne diseases and to enhance soil quality for improved organic production.

According to the baseline survey conducted to identify the factors affecting adoption of mixed-species green manure, 71% of the respondents were certified organic farmers, 100% of whom grew their vegetables in open field. About 40% of the respondents reported problems of early blight and *Septoria leaf spot* in organic tomato production. About 52% of the respondents reported using mixed-species grass/ legumes in their farms. The adoption analysis using survey data revealed that the adoption of mixed species green manures was greatly affected by factors such as farmer's age, experience, access to the internet, and perception on the benefits from the using the cover crops. Other variables such as education, membership in the farmers' or other related organizations, farm type, area used for tomato or organic farming, which were expected to affect adoption were found to be nonsignificant in our analysis. In contrast, education, sex, and access to the internet were found to be significant in the adoption decision for microbial inoculants in addition to access to internet. Only few factors extracted from the responses on farmers' opinions were found significant in the adoption analysis. The factor *posimpacts, practice, Media, physical, trtment specific* affected the adoption analysis estimates. However, only *posimpacts* had significant marginal effects in the case of MSGM.

Interviews were also conducted with scientists/collaborators in the three states, to assess the organic tomato yields, associated input cost changes, present, and expected maximum adoption rates for green manures, and probabilities of research success. Trials were set up in three states where the project is being implemented to assess the benefits of mixed-species green manures over single species. In Maryland, of the three mixed-species green manure used, only the mix of forage radish and hairy vetch was profitable over single species hairy vetch, and the profit generated during experiment was $3036 per hectare. In New York, all three mixed-species cover crops used were profitable. The profits generated for rye and turnip, rye and clover, and rye and hairy vetch compared to single species rye were $8316, $4,136, and $4,972 per hectare respectively. In Ohio, except mixed hay over tillage radish, which gave net benefit of $28,776, other mixed-species were not profitable when used with compost. However, a mixed hairy vetch and rye was profitable over hairy vetch. Mixed hay was found to be profitable over all three single species of hairy vetch, tillage radish, and rye when used without compost. The profit generated was $36,300 per hectare for the mixed hairy vetch and rye compared to hairy vetch and $19,316 when compared to winter rye. Similarly, the profits generated for mixed hay compared to single species hairy vetch, tillage radish, and rye were $103,004, $58,124, and $86,020 per hectare respectively when these cover crops were uses without compost. Since adoption of mixed species green manure depends greatly on the farmers' perception of benefits from the technology, and access to the internet was another significant factors affecting their adoption, internet based informational materials may help producer learn about the benefits, and management techniques encourage farmers adopt mixed species green manures. Therefore, one potential area that needs to be explored could be to design informational materials to orient farmers to the benefits of adopting mixed-species green manures in terms of reduction in soil-borne diseases, insects in addition to improved quality and quantity of production.

The research-induced benefits of mixed-species green manures implemented for different mixes of green manures were projected for Maryland, New York and Ohio. The benefits were projected over 15 years (2012-2026), at a 5% discount rate, and with a maximum adoption level of 50%. Under an open-market economy assumption, the benefits from forage radish and rye were $1.53 million over hairy vetch in Maryland. The net present value of research-induced benefit was $1.49 million under a closed-market economy. Under an open market economy assumption, all mixed species cover crops produced profitable amounts of organic tomatoes in New York. The benefits projected over single species rye were $2.61 million, $0.971 million, and $0.886 million for three mixes of rye and turnip, rye and clover, and rye and hairy vetch. The net present value of benefit under a closed-market economy for the most profitable mix of cover crop turnip and rye was $2.49

million. However, none of the mixed species was profitable when compared to bare ground. In Ohio, net present value of research-induced benefit of mixed hairy vetch and rye over hairy vetch was $0.771 million and $0.087 over rye respectively when used without compost under an open market economy assumption. However, the mixed hairy vetch and rye was not profitable over tillage radish. The benefits for mixed hay over hairy vetch, tillage radish, and rye are $3.12 million, $0.746 million, and $2.07 million when used without compost. However, none of the mixed-species cover crops produced benefits when used with compost. Under a closed market economy, the projected benefits of mixed over single species hairy vetch, tillage radish and rye were $2.77 million, $0.697, and $1.85 million respectively.

Other non-market benefits associated with environmental and social benefits are not included because the comparison here is made with single species green manures, which also has similar externalities as that of the mixed species.

The distribution of the net present value benefits showed that in the case of a small open economy, producers receive all the benefits from the research-induced benefits as there was no change in price of the commodity because of the increased production. However, under the closed market economy because the excess supply is not trade out, there is decline in price of the commodity, which benefits consumers. Based on the assumed absolute value of demand elasticity of 0.33 and supply elasticity of one, consumers benefit more than three times compared to producers.

5.2. Limitations and further research

The project, on which this study is based, has the larger objectives of identifying the relationships between the microbial community activities associated with mixed species green manures and microbial inoculants to control soil-borne disease and improve vegetable production. Since the project is in the initial stage, it was difficult to obtain the more reliable information on yields and associated production costs. Cover crops can build the soil profile steadily over many years to produce better results. Field based information on yields and production costs are only approximate. Moreover, different treatments were used for the trials in different states, which made it difficult to compare results across the states. In addition, since a no-cover crop control was not set up in all the states, mixed species green manure was only compared with single species cover crops. Absence of similar studies on mixed species green manure in the past also restricted the scope of comparison and validation.

Adoption analyses can provide useful information on factors affecting mixed-species green manure adoption. The adoption analysis of mixed species green manures was based on a mail survey conducted to assess the adoption of mixed-species green manure focusing on farmers' perceptions on various factors such as its benefit, costs, risk, challenges, management practices, information dissemination in organic vegetables production in 12 northeastern states of United States. A survey exclusively targeted to organic tomato production for which the economic benefits were assessed might have provided a better picture of current user of mixed-species green manure on organic tomato as management practices and techniques are specific to crops. A more targeted survey in the project states might have given a more accurate picture of existing adoption status. For instance, New York, which has second highest organic tomato acreage (222 acres) next to California (8,291 acres) based on a USDA 2008 dataset had only four observations from the state.

One of the implications for further research would be to set up trials with same treatments and controls at all the sites, which would make it easier to compare and draw conclusion. Data from at least two years of experiments could give more accurate and reliable estimates.

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Appendix A: Farmers' mail survey questionnaire

ORGANIC VEGETABLE SOIL-BORNE DISEASE MANAGEMENT SURVEY

UNDERSTANDING INFLUENCES ON ORGANIC VEGETABLE GROWER DECISION MAKING REGARDING SOIL-BORNE DISEASE

THE OHIO STATE UNIVERSITY
OARDC
EXTENSION

DECEMBER 2010

PART 1. Organic Farming Activities

START HERE

1. How would you describe your farm?

- ☐ Certified organic
- ☐ Non-certified organic
- ☐ Transitional organic
- ☐ Mixed certified/non-certified/transitional organic
- ☐ Mixed organic/conventional

2. Where do you produce organic vegetables? (Please check all that apply.)

- ☐ Indiana
- ☐ Kentucky
- ☐ Maine
- ☐ Maryland
- ☐ Michigan
- ☐ New jersey
- ☐ New York
- ☐ Ohio
- ☐ Pennsylvania
- ☐ Rhode Island
- ☐ Vermont
- ☐ Virginia
- ☐ Other (please specify below)

____

3. Of the land that you farm, how many acres do you own, rent, share crop or control by other means?

- ☐ Own _______acres
- ☐ Rent _______acres
- ☐ Share _______acres
- ☐ Other (please specify below) ________acres

____

4. What percentage of your total annual income is from organic vegetable production?________%

5. How many individuals are employed on your organic farm? (Include yourself, family and non-family members) ________

6. What vegetable production technique(s) do you use in your organic farm? (Please check all that apply.)

- ☐ Open-field
- ☐ High tunnel (hoop houses or tunnel houses)
- ☐ Greenhouse

7. What is the source of your irrigation water? (Please check all that apply.)

- ☐ Rivers or streams
- ☐ Ponds or lakes
- ☐ Ditches
- ☐ Wells
- ☐ City water
- ☐ No irrigation
- ☐ Other (please specify below)

____

8. How long have you been producing organic vegetables?

- ☐ Less than 1 year
- ☐ 1-5 years
- ☐ 6-10 years
- ☐ 11-15 years
- ☐ 16-20 years
- ☐ More than 20 years

9. How many acres of organic vegetables are produced on your farm?__________acres

10. How many different types of organic vegetables are produced on your farm?

- ☐ 1-5
- ☐ 6-10
- ☐ More than 10

11. Please list the top three vegetable crops (in terms of total number of acres) produced on your organic farm in 2010.

Crop **Acres**

Top ranked vegetable ___________ ___________

Second ranked vegetable ___________ ___________
Third ranked vegetable ___________ ___________

12. Please list the top three vegetable crops (in terms of total income) produced on your organic farm in 2010.

Crop **% income**

Top ranked vegetable ___________ ___________
Second ranked vegetable ___________ ___________
Third ranked vegetable ___________ ___________

13. Please list the three vegetable crops produced on your organic farm in 2010 with the most disease problems.

Crop **% yield loss**

Vegetable with the most disease problems ___________ ___________
Vegetable with the second most disease problems ___________ ___________
Vegetable with the third most disease problems ___________ ___________

14. How severely do you believe the following diseases reduce yield and /or quality of your TOMATO crop? If you do not raise tomatoes, please move on to question 15.

Tomato Diseases	**None**	**Somewhat**	**A lot**	**Do not know**
Bacterial diseases				
Viruses				
Anthracnose				
Early Blight				
Septoria leaf spot				
Botrytis gray mold				
Timber rot				

Late blight				
Fusarium wilt				
Verticillium wilt				
Others (please specify)				

15. When are cover crops grown in your rotation? (Please check all that apply.) If you do not use cover crops, please move on to question 20.

- ☐ Fall
- ☐ Winter
- ☐ Spring
- ☐ Summer
- ☐ Do not use cover crops

16. What type of cover crop is used on your farm? (Please check all that apply.)

- ☐ Single species grass
- ☐ Mixed species grass/legume
- ☐ Single species legume
- ☐ Brassica species
- ☐ Other (please specify below)

  ____

17. What quantity of cover crops seeds did you buy last season**?** ____________lbs.

18. What was the unit price of the cover crop seeds? ________________________

19. Do you think that cover crops help in preventing soil borne diseases in vegetables?

- ☐ Yes
- ☐ No

20. Do you use microbial inoculants such as rhizobia, mycorrhizae, and/or microbial biopesticides on your organic farm?

- ☐ Yes
- ☐ No

21. Do you think that microbial inoculants help prevent soil borne diseases in vegetables?

- ☐ Yes
- ☐ No

22. How is soil fertility managed on your farm? (Please check all that apply.)

- ☐ Green manure or cover crop
- ☐ Plant and animal material (composted or not composted)
- ☐ Fertilizers that meet the National Organic Standard (NOS)
- ☐ Soil amendments that meet the NOS
- ☐ Other (please specify below)

  ____

23. Did you apply biopesticides to your vegetable crops fields last season? If you did not apply biopesticides, please move on to question 27.

- ☐ Yes
- ☐ No

24. How did you apply these biopesticides? (Please check all that apply.)

- ☐ Seed application
- ☐ Soil application
- ☐ Root application
- ☐ Foliar application

25. When did you begin application of these biopesticides?

- ☐ Application of materials began prior to conditions favorable for disease development
- ☐ Application immediately following the first symptoms of disease

26. How effective were these biopesticides in managing diseases on your organic farm?

- ☐ Fully controlled disease
- ☐ Controlled disease enough to justify use
- ☐ Marginally controlled disease, but not cost effective
- ☐ Not effective
- ☐ Do not know

27. What percentage of your total variable costs in vegetable production is devoted to each of the following inputs?

Input	**Percent of total variable costs**
☐ Seeds, transplants or grafted plants	____________
☐ NOS allowed chemicals	____________
☐ Biopesticides	
☐ Green manure or cover crop	____________
☐ Microbial inoculants	
☐ Plant and animal material (composted or not composted)	____________
☐ Fertilizers that meet the NOS	____________
☐ Soil amendments that meet the NOS	____________
☐ Labor	____________
☐ Diagnostic tests/services	____________
☐ Certification	____________
☐ Information transfer	____________
☐ Equipment	____________
☐ Fuel	____________
☐ Other (please specify)	____________
TOTAL	**100%**

28. To what extent do you agree or disagree that the following factors are <u>challenges</u> or <u>obstacles</u> you face in managing your organic farm? (Please mark one answer for each.)

Factors	**Strongly agree**	**Somewhat agree**	**Neither agree nor disagree**	**Somewhat disagree**	**Disagree**
Availability of reliable information and technical support					
Low market prices					
Lack of organic marketing networks					

Record keeping requirements					
Organic certification costs					
High input costs					
High labor costs					
Handling and distribution problems					
Weed management					
Insect management					
Disease management					
Food safety requirements					
Soil fertility					
Weather					

PART 2. Organic grower perspective on soil-borne disease management

29. Thinking about ALL of the organic crops you grow, what types of plant disease problems do you generally face? (Please check all that apply.)

- ☐ Soil-borne diseases
- ☐ Foliar diseases
- ☐ Pre-harvest diseases on non-leafy products, for example, tomato or pepper fruits
- ☐ Post-harvest diseases
- ☐ No significant disease problems

30. Which steps in organic vegetable production do you believe to be likely starting points of soil borne diseases? (Please check all that apply.)

- ☐ Seed production
- ☐ Transplant production

☐ Growing in the field, high tunnel or greenhouses

31. How familiar are you with soil-borne disease management practices?

☐ Very familiar
☐ Somewhat familiar
☐ Neither familiar nor unfamiliar
☐ Somewhat unfamiliar
☐ Not at all familiar

32. To what extent do you agree or disagree with each of the following statements regarding soil-borne disease problems. (Please mark one answer for each.)

Statements	**Strongly agree**	**Some what agree**	**Neither agree nor disagree**	**Somewhat disagree**	**Disagree**
I know the cause(s) of soil-borne diseases					
I know where to obtain information regarding soil borne diseases					
Available disease management practices reduce the risk of soil borne diseases					
I am content with the quality of University research on soil borne diseases					
I am content with the quality of Extension-based information and service on management of soil borne diseases					

33. To what extent do you agree or disagree that the following can contribute to the severity of soil-borne diseases? (Please mark one answer for each.)

Factors	**Strongly agree**	**Somewhat agree**	**Neither agree nor disagree**	**Somewhat disagree**	**Disagree**
Pathogen spread or build up					
Susceptible crops					
Nutrient levels					
Temperature					
Soil pH					
Soil texture					
Organic matter content					
Soil type					
Standing water or poor drainage					
Irrigation source and method					
Farm plan or field site selection					
Transplant selection					

34. Please rank each source of disease management information in order of importance to you. (Please mark one answer for each.)

Sources of information	**Very important**	**Somewhat important**	**Neutral**	**Somewhat important**	**Not important**

Family, friends or colleagues					
Commodity groups					
Magazines, newspapers					
Technical publications					
TV-Radio					
Internet					
Web-based community group (ie. e-organic)					
Farm bureaus					
Organic farming organizations					
Government agencies					
Extension					
Industry					
University Research centers					

35. To what extent do you agree or disagree that the following can be positive impacts or benefits of using cover crops to manage soil-borne diseases? (Please mark one answer for each.)

Positive Impacts of cover crops	**Strongly agree**	**Somewhat agree**	**Neither agree nor disagree**	**Somewhat agree**	**Disagree**
Increased diversity of soil life					
Soil and water					

quality					
Reduced erosion					
Nutrient cycling efficiency					
Enhanced wild life habitat					
Enhanced beneficial microbial populations					
Promote pest and disease suppression					
Improved productivity of crop (yield, quality)					
Additional income					
Social benefits (personal, family, community)					

36. To what extent do you agree or disagree that the following can be negative impacts of using cover crops to manage soil-borne diseases? (Please mark one answer for each.)

Risks / negatives of cover crops	**Strongly agree**	**Somewhat agree**	**Neither agree nor disagee**	**Some what**	**Disagree**
Grower's time (investment)					
Increase risk of some					

diseases and pests					
Germination/establishment problems					
Efficacy or consistency					
Increased weed problems					
Labor availability/costs					
Regulation costs					
Fuel costs					
Seed cost					
Appropriate equipment					
Management problems with some cover crops					
Shortened growing season					
Reduced cropping options					
Yield losses incurred from delayed planting of vegetable crops					

37. How important are each of the following practices in managing plant diseases on your farm? (Please mark one answer for each.)

Practices for controlling disease	Very Important	Somewhat important	Neutral	Somewhat unimportant	Not important
Disease diagnosis by a laboratory service or professional					
Recording disease history					
Assessments of disease incidence and					

severity					
Aggressive sanitation					
Frequent tillage					
Soil solarization					
Improving drainage					
Use of drip/trickle irrigation					
Use of treated water for irrigation					
Use soilless growing media for transplants					
Use of disease resistant varieties					
Use of grafted plants					
Reducing crop density					
Crop rotation					
Use of cover crop					
Use of NOS allowed chemical inputs (copper, sulfur, etc)					

Use of biopesticides					
Use of microbial inoculants					
Apply compost or manure from my farm					
Apply balanced organic fertility materials					

PART 3. Response and communication

38. To what extent do you believe that your organic farm is prepared to deal with a soil-borne disease problem if it were to occur?

- ☐ Very prepared
- ☐ Somewhat prepared
- ☐ Somewhat unprepared
- ☐ Unprepared

39. How would you determine if you had a soil-borne disease problem on your organic farm? (Please rank your preferences 1-6 below and rank each group only once.)

_____Experience
_____Ask family, friends or colleagues
_____Get help from groups or organizations
_____Send a sample to plant diagnostic lab
_____Search the Internet
_____Search written (non-electronic) publications

40. Please rank each of the following groups or organizations from top to bottom with regard to which you would get help from during soil-borne disease problem event on your organic farm. Please give a 1 to the group you would contact first, 2 the second group you would

contact, and so on until you have ranked all six groups. (Please rank each group only once.)

_____University extension practitioner
_____Government agencies
_____Farm Bureau
_____Organic farming organizations
_____Private consultants
_____Organic growers

41. How many times a year do you contact groups or organizations to get help with a soil-borne disease problem that is occurring on your farm?

- ☐ None
- ☐ 1-2 times per year
- ☐ 3-4 times per year
- ☐ More than 4 times per year

42. Do you need more information about soil-borne disease management in organic vegetable production?

- ☐ Yes
- ☐ No

43. For which areas of soil-borne diseases would you like more information? (Please check all that apply.)

- ☐ Disease identification
- ☐ Preventive methods for soil-borne disease management
- ☐ Disease management products
- ☐ Disease sources
- ☐ Regulations

☐ Other (please specify below)_________________________

44. How often do you participate in learning programs or training activities to learn about soil-borne disease management?

- ☐ 1-3 times per year
- ☐ 4-6 times per year
- ☐ More than 6 times per year
- ☐ Never

45. What modes of communication do you prefer to receive information regarding soil-borne disease management in organic vegetable production? (Please check all that apply.)

- ☐ Internet (Social networking groups, web-based community group etc.)
- ☐ e-mail
- ☐ Webinar
- ☐ Magazines

- ☐ Factsheets
- ☐ Training sessions
- ☐ Newspapers
- ☐ Television/radio
- ☐ Grower meetings
- ☐ Field days
- ☐ Other (Please specify in the space below)

PART 4. Organic Grower Information

46. What is your age?

- ☐ Under 20
- ☐ 21-35
- ☐ 36-50
- ☐ 51-65
- ☐ 66-80
- ☐ Over 80

47. What is your gender?

- ☐ Male
- ☐ Female

48. What is the highest level of education you have completed?

- ☐ 8th grade or less
- ☐ High school
- ☐ College
- ☐ Graduate school

49. Do you have Internet access in the home and/or on the farm?

- ☐ Yes
- ☐ No

50. How often do you use the Internet?

- ☐ Once or more a day
- ☐ A few times a week
- ☐ A few times a month
- ☐ Hardly ever
- ☐ Never

51. Do you belong to a farmer/grower organization(s)?

- ☐ Yes
- ☐ No

52. If YES, please list the farmer/grower organizations of which you are a member. ________________________________

Please add any comments you may have in the space provided below.

Thank you for your time and participation in this survey.

Appendix B: Factor analysis for attitudes towards the beneficial aspects of MSGM

```
. corr b_soillife b_swqual b_erosion b_nutrcyc b_wildlife b_micpopnb ///
> b_pdsupp b_yldqual b_addlinc b_socben
(obs=87)
```

	b_soil~e	b_swqual	b_eros~n	b_nutr~c	b_wild~e	b_micp~p	b_pdsupp	b_yldq~l	b_addl~c	b_socben
b_soillife	1.0000									
b_swqual	0.7801	1.0000								
b_erosion	0.7023	0.5877	1.0000							
b_nutrcyc	0.7671	0.6768	0.6677	1.0000						
b_wildlife	0.3069	0.3206	0.4056	0.3434	1.0000					
b_micpopnb~p	0.7140	0.5691	0.4678	0.5890	0.1619	1.0000				
b_pdsupp	0.4859	0.3678	0.4645	0.4230	0.0828	0.6002	1.0000			
b_yldqual	0.4011	0.4326	0.4496	0.4008	0.1760	0.3894	0.5674	1.0000		
b_addlinc	0.3412	0.3927	0.3940	0.3447	0.3296	0.2954	0.3468	0.5208	1.0000	
b_socben	0.3175	0.3093	0.3652	0.3699	0.3053	0.2966	0.4354	0.4996	0.6523	1.0000

```
. factor b_soillife b_swqual b_erosion b_nutrcyc b_wildlife ///
> b_micpopnb b_pdsupp b_yldqual b_addlinc b_socben, pcf factors (1)
(obs=87)

Factor analysis/correlation                     Number of obs    =        87
    Method: principal-component factors        Retained factors =         1
    Rotation: (unrotated)                       Number of params =        10
```

Factor	Eigenvalue	Difference	Proportion	Cumulative
Factor1	5.07142	3.75430	0.5071	0.5071
Factor2	1.31712	0.23649	0.1317	0.6389
Factor3	1.08063	0.51585	0.1081	0.7469
Factor4	0.56479	0.04679	0.0565	0.8034
Factor5	0.51799	0.08375	0.0518	0.8552
Factor6	0.43425	0.08974	0.0434	0.8986
Factor7	0.34451	0.06417	0.0345	0.9331
Factor8	0.28034	0.03864	0.0280	0.9611
Factor9	0.24170	0.09446	0.0242	0.9853
Factor10	0.14724	.	0.0147	1.0000

```
    LR test: independent vs. saturated:  chi2(45) =  477.10 Prob>chi2 = 0.0000

Factor loadings (pattern matrix) and unique variances
```

Variable	Factor1	Uniqueness
b_soillife	0.8525	0.2732
b_swqual	0.7913	0.3739
b_erosion	0.7915	0.3735
b_nutrcyc	0.8124	0.3400
b_wildlife	0.4431	0.8036
b_micpopnb~p	0.7411	0.4508
b_pdsupp	0.6793	0.5385
b_yldqual	0.6755	0.5437
b_addlinc	0.6255	0.6088
b_socben	0.6144	0.6226

```
. *rotate, promax blanks(.3) /* factors are correlated*/
. rotate, varimax blanks(.3) /* factors are uncorrelated*/

Factor analysis/correlation                        Number of obs    =      87
    Method: principal-component factors           Retained factors =       1
    Rotation: orthogonal varimax (Kaiser off)      Number of params =      10
```

Factor	Variance	Difference	Proportion	Cumulative
Factor1	5.07142	.	0.5071	0.5071

```
    LR test: independent vs. saturated:  chi2(45) =  477.10 Prob>chi2 = 0.0000

Rotated factor loadings (pattern matrix) and unique variances
```

Variable	Factor1	Uniqueness
b_soillife	0.8525	0.2732
b_swqual	0.7913	0.3739
b_erosion	0.7915	0.3735
b_nutrcyc	0.8124	0.3400
b_wildlife	0.4431	0.8036
b_micpopnb~p	0.7411	0.4508
b_pdsupp	0.6793	0.5385
b_yldqual	0.6755	0.5437
b_addlinc	0.6255	0.6088
b_socben	0.6144	0.6226

```
    (blanks represent abs(loading)<.3)

Factor rotation matrix
```

	Factor1
Factor1	1.0000

```
.

. gen posimpacts = 0.8525*b_soillife+0.7913*b_swqual+0.7915*b_erosion ///
> +0.8124*b_nutrcyc+0.4431*b_wildlife+0.7411*b_micpopnb+0.6793*b_pdsupp ///
> +0.6755*b_yldqual+0.6255*b_addlinc+0.6144*b_socben
(7 missing values generated)
```

```
. estat kmo
```

Kaiser-Meyer-Olkin measure of sampling adequacy

Variable	kmo
b_soillife	0.8324
b_swqual	0.8852
b_erosion	0.8865
b_nutrcyc	0.9244
b_wildlife	0.8578
b_micpopnb~p	0.8520
b_pdsupp	0.8166
b_yldqual	0.8757
b_addlinc	0.8169
b_socben	0.8139
Overall	0.8586

```
. alpha  b_soillife b_swqual b_erosion b_nutrcyc b_wildlife ///
>  b_micpopnb b_pdsupp b_yldqual b_addlinc b_socben, item
```

Test scale = mean(unstandardized items)

Item	Obs	Sign	item-test correlation	item-rest correlation	average interitem covariance	alpha
b_soillife	92	+	0.7636	0.7191	.2483573	0.8452
b_swqual	92	+	0.7228	0.6681	.2487268	0.8469
b_erosion	93	+	0.6922	0.6338	.2509623	0.8479
b_nutrcyc	92	+	0.7472	0.6917	.2434451	0.8441
b_wildlife	91	+	0.5076	0.3550	.2515723	0.8717
b_micpopnb~p	92	+	0.6951	0.6101	.2375292	0.8470
b_pdsupp	91	+	0.6916	0.5957	.2344081	0.8486
b_yldqual	92	+	0.7173	0.6283	.2308337	0.8452
b_addlinc	87	+	0.7183	0.5983	.2181978	0.8498
b_socben	91	+	0.7207	0.5995	.2178495	0.8510
Test scale					.2381632	0.8627

Appendix: C1: STATA output for descriptive statistics

Summary statistics

```
. sum MixCC mino_use mino_prevnt age exper edu sex trg assoc crop inc_org ///
> org_acre farm Maryland NewYork Ohio Pennsylv no_labor intnet_access tom_acres tom_income
> tom_yldloss ccrp_qty ccrp_prevnt natural site cropch public specific ///
> Media posimpacts negimpacts costs mrktng physical practice assmt trtment
```

Variable	Obs	Mean	Std. Dev.	Min	Max
MixCC	92	.5217391	.5022643	0	1
mino_use	92	.423913	.4968847	0	1
mino_prevnt	75	.64	.4832324	0	1
age	93	.6021505	.4921069	0	1
exper	91	.5054945	.5027397	0	1
edu	93	.4731183	.501983	0	1
sex	93	.7419355	.4399413	0	1
trg	93	.5483871	.5003505	0	1
assoc	93	.8602151	.3486433	0	1
crop	93	.516129	.5024484	0	1
inc_org	89	56.19101	31.0505	1	100
org_acre	92	7.847826	10.26135	1	75
farm	93	.7096774	.4563714	0	1
Maryland	93	.2365591	.4272727	0	1
NewYork	93	.0430108	.203981	0	1
Ohio	93	.3763441	.4870938	0	1
Pennsylv	93	.2365591	.4272727	0	1
no_labor	91	4.868132	4.261478	1	32
intnet_acc~s	93	.827957	.3794635	0	1
tom_acres	70	2.067857	3.203056	.1	20
tom_income	82	26.95122	17.77441	2	100
tom_yldloss	84	31.125	21.02321	2	100
ccrp_qty	60	668.3333	1479.368	0	8000
ccrp_prevnt	85	.7529412	.4338609	0	1
natural	89	13.81935	1.894528	5.3208	17.0985
site	88	8.416798	1.59124	4.6494	11.6235
cropch	88	9.916146	.9260457	7.2143	10.6325
public	89	6.90301	2.847251	2.9867	12.7569
specific	90	10.54367	2.350738	3.6256	14.5465
Media	87	6.92286	2.56692	2.2986	10.4234
posimpacts	87	30.49964	3.648273	20.6314	35.133
negimpacts	79	39.94413	12.9183	11.4809	57.4045
costs	89	17.11018	3.428456	7.665	22.0385
mrktng	85	5.662727	1.718487	2.1014	10.507
physical	90	4.116021	1.094712	1.2787	6.3935
practice	89	16.87157	3.350496	7.448	21.6315
assmt	88	6.116171	1.460482	1.8322	8.6499
trtment	82	11.61728	1.990979	7.8104	15.8125

Appendix: C2: STATA output for MSGM probit regression

```
. probit MixCC age exper intnet_access org_acre ///
>         farm posimpacts practice physical Media

Iteration 0:   log likelihood = -51.184731
Iteration 1:   log likelihood = -32.609578
Iteration 2:   log likelihood = -32.522874
Iteration 3:   log likelihood = -32.522682
Iteration 4:   log likelihood = -32.522682

Probit regression                                 Number of obs   =         74
                                                  LR chi2(9)      =      37.32
                                                  Prob > chi2     =     0.0000
Log likelihood = -32.522682                       Pseudo R2       =     0.3646

------------------------------------------------------------------------------
       MixCC |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         age |  -1.117141   .3913743    -2.85   0.004     -1.88422   -.3500613
       exper |   .9649001   .4131781     2.34   0.020      .155086    1.774714
intnet_acc~s |   1.638467   .6823487     2.40   0.016      .301088    2.975846
    org_acre |   .0179436   .0228715     0.78   0.433    -.0268837     .062771
        farm |   .0405181   .4046313     0.10   0.920    -.7525447    .8335809
  posimpacts |   .1884661   .0622386     3.03   0.002     .0664807    .3104514
    practice |   .0132162   .0690433     0.19   0.848    -.1221062    .1485386
    physical |  -.0137659     .15678    -0.09   0.930    -.3210491    .2935173
       Media |  -.1362256   .0957779    -1.42   0.155    -.3239469    .0514957
       _cons |  -6.236163   2.638074    -2.36   0.018    -11.40669   -1.065633
------------------------------------------------------------------------------

. mfx compute, at (age =1 exper =1 intnet_access =1 org_acre= 8 ///
>     farm=1 posimpacts=30 practice=17 physical=4 Media=7)

Marginal effects after probit
      y  = Pr(MixCC) (predict)
         =  .61949146
------------------------------------------------------------------------------
variable |      dy/dx    Std. Err.     z    P>|z|  [    95% C.I.   ]      X
---------+--------------------------------------------------------------------
    age*|   -.3028918       .1138   -2.66   0.008  -.525941 -.079843        1
  exper*|    .3651066      .14391    2.54   0.011   .083043   .64717        1
intnet~s*|   .5284422      .14007    3.77   0.000   .253909  .802976        1
org_acre |   .0068349      .00889    0.77   0.442  -.010587  .024257        8
   farm*|     .015525      .15516    0.10   0.920  -.288587  .319637        1
posimp~s |   .0717887      .02369    3.03   0.002   .025354  .118224       30
practice |   .0050342      .02614    0.19   0.847  -.046194  .056263       17
physical |  -.0052436      .05975   -0.09   0.930  -.122353  .111866        4
   Media |  -.0518898      .03586   -1.45   0.148  -.122167  .018387        7
------------------------------------------------------------------------------
(*) dy/dx is for discrete change of dummy variable from 0 to 1
```

```
. linktest

Iteration 0:   log likelihood = -51.184731
Iteration 1:   log likelihood =  -32.46894
Iteration 2:   log likelihood = -32.270466
Iteration 3:   log likelihood = -32.269121
Iteration 4:   log likelihood = -32.269121

Probit regression                                 Number of obs   =         74
                                                  LR chi2(2)      =      37.83
                                                  Prob > chi2     =     0.0000
Log likelihood = -32.269121                       Pseudo R2       =     0.3696
```

MixCC	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
_hat	1.028166	.2078815	4.95	0.000	.6207255	1.435606
_hatsq	-.1332928	.1830789	-0.73	0.467	-.4921208	.2255352
_cons	.1045627	.22941	0.46	0.649	-.3450727	.5541981

Appendix: C (2): STATA output for MSGM logit regression

```
. logit MixCC age exper trg intnet_access org_acre no_labor farm posimpacts ///
>  practice Media

Iteration 0:   log likelihood = -51.979372
Iteration 1:   log likelihood = -32.715581
Iteration 2:   log likelihood = -32.416332
Iteration 3:   log likelihood = -32.415916
Iteration 4:   log likelihood = -32.415916

Logistic regression                               Number of obs   =         75
                                                  LR chi2(10)     =      39.13
                                                  Prob > chi2     =     0.0000
Log likelihood = -32.415916                       Pseudo R2       =     0.3764
```

MixCC	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
age	-1.926878	.7264955	-2.65	0.008	-3.350783	-.5029731
exper	1.985619	.7804051	2.54	0.011	.4560529	3.515185
trg	1.026158	.722382	1.42	0.155	-.3896842	2.442001
intnet_acc~s	3.148704	1.247557	2.52	0.012	.7035374	5.59387
org_acre	.0341401	.0499531	0.68	0.494	-.0637662	.1320465
no_labor	-.0175711	.0972856	-0.18	0.857	-.2082473	.1731051
farm	-.2219496	.7405093	-0.30	0.764	-1.673321	1.229422
posimpacts	.2751131	.1065915	2.58	0.010	.0661976	.4840286
practice	.0707441	.1172738	0.60	0.546	-.1591082	.3005965
Media	-.2510424	.1649354	-1.52	0.128	-.5743099	.0722252
_cons	-10.80333	4.543634	-2.38	0.017	-19.70869	-1.89797

```
.  mfx compute, at (age =1 exper =1 trg=1 intnet_access =1 org_acre= 7.8 ///
>    no_labor=4.86 farm=1 posimpacts=30.49 practice=16.87 Media=6.92)

Marginal effects after logit
      y  = Pr(MixCC) (predict)
         =  .77445874
------------------------------------------------------------------------------
variable |      dy/dx    Std. Err.     z    P>|z|  [    95% C.I.   ]      X
---------+--------------------------------------------------------------------
    age* |  -.1848633      .10271   -1.80   0.072   -.38617  .016443        1
  exper* |   .4540638      .15576    2.92   0.004   .148772  .759356        1
    trg* |   .2227684      .15821    1.41   0.159  -.087314  .532851        1
intnet~s* |   .6460433      .15784    4.09   0.000    .33669  .955397        1
org_acre |   .0059633      .00936    0.64   0.524  -.012381  .024308      7.8
no_labor |  -.0030692      .01688   -0.18   0.856  -.036148   .03001     4.86
   farm* |  -.0364017      .11885   -0.31   0.759  -.269353  .196549        1
posimp~s |   .0480547      .02309    2.08   0.037   .002802  .093308    30.49
practice |    .012357      .01939    0.64   0.524  -.025643  .050357    16.87
   Media |  -.0438502      .02906   -1.51   0.131  -.100803  .013103     6.92
------------------------------------------------------------------------------
(*) dy/dx is for discrete change of dummy variable from 0 to 1

. linktest

Iteration 0:   log likelihood = -51.979372
Iteration 1:   log likelihood =  -32.48378
Iteration 2:   log likelihood = -32.292504
Iteration 3:   log likelihood = -31.653637
Iteration 4:   log likelihood = -31.651935
Iteration 5:   log likelihood = -31.651935

Logistic regression                               Number of obs   =         75
                                                  LR chi2(2)      =      40.65
                                                  Prob > chi2     =     0.0000
Log likelihood = -31.651935                       Pseudo R2       =     0.3911

------------------------------------------------------------------------------
       MixCC |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        _hat |    1.09171   .2543751     4.29   0.000     .5931436    1.590276
      _hatsq |  -.1421147   .1137921    -1.25   0.212    -.3651432    .0809138
       _cons |   .2748166   .3857741     0.71   0.476    -.4812868     1.03092
------------------------------------------------------------------------------
```

Appendix: D(1) : STATA output for Microbial inoculants probit regression

```
. probit mino_use exper edu sex farm intnet_access tom_acres ///
>        specific trtment

Iteration 0:   log likelihood = -38.952145
Iteration 1:   log likelihood = -25.158397
Iteration 2:   log likelihood = -24.543613
Iteration 3:   log likelihood =  -24.52725
Iteration 4:   log likelihood = -24.527234
Iteration 5:   log likelihood = -24.527234

Probit regression                                 Number of obs   =         58
                                                  LR chi2(8)      =      28.85
                                                  Prob > chi2     =     0.0003
Log likelihood = -24.527234                       Pseudo R2       =     0.3703
```

mino_use	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
exper	.2234086	.4498539	0.50	0.619	-.6582888	1.105106
edu	-1.058262	.6022007	-1.76	0.079	-2.238554	.1220292
sex	-1.365731	.6287446	-2.17	0.030	-2.598047	-.1334138
farm	-.2695839	.498385	-0.54	0.589	-1.246401	.7072328
intnet_acc~s	-1.373514	.646741	-2.12	0.034	-2.641103	-.105925
tom_acres	-.0001112	.0982736	-0.00	0.999	-.192724	.1925015
specific	-.3504967	.1421433	-2.47	0.014	-.6290924	-.071901
trtment	.55329	.1714908	3.23	0.001	.2171743	.8894058
_cons	-.293323	1.986821	-0.15	0.883	-4.18742	3.600774

```
. mfx compute, at (exper =1 edu =1 sex=1 farm=1 intnet_access=1 tom_acres=2 ///
>  specific=11 trtment=12)

Marginal effects after probit
      y  = Pr(mino_use) (predict)
         =  .08799404
```

variable	dy/dx	Std. Err.	z	P>|z|	[95% C.I.	]	X
exper*	.0305526	.06163	0.50	0.620	-.090239	.151344	1
edu*	-.2960224	.16369	-1.81	0.071	-.616845	.0248	1
sex*	-.4170003	.19521	-2.14	0.033	-.799609	-.034392	1
farm*	-.0512709	.10354	-0.50	0.620	-.254211	.151669	1
intnet~s*	-.4201049	.24988	-1.68	0.093	-.909854	.069644	1
tom_ac~s	-.0000178	.01569	-0.00	0.999	-.030768	.030733	2
specific	-.0559704	.03619	-1.55	0.122	-.126897	.014956	11
trtment	.0883541	.05528	1.60	0.110	-.019998	.196706	12

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

```
. linktest

Iteration 0:   log likelihood = -38.952145
Iteration 1:   log likelihood = -24.527421
Iteration 2:   log likelihood = -24.371142
Iteration 3:   log likelihood = -24.231307
Iteration 4:   log likelihood = -24.229609
Iteration 5:   log likelihood = -24.229609

Probit regression                                 Number of obs   =         58
                                                  LR chi2(2)      =      29.45
                                                  Prob > chi2     =     0.0000
Log likelihood = -24.229609                       Pseudo R2       =     0.3780
```

mino_use	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
_hat	1.019519	.2654225	3.84	0.000	.4993001	1.539737
_hatsq	-.1366914	.1668236	-0.82	0.413	-.4636597	.1902769
_cons	.0972242	.2466424	0.39	0.693	-.386186	.5806345

Appendix D (2): STATA output of logit regression for microbial innoculants

```
. logit mino_use exper edu sex farm intnet_access tom_acres ///
>         specific trtment

Iteration 0:   log likelihood = -38.952145
Iteration 1:   log likelihood = -25.172585
Iteration 2:   log likelihood = -24.725438
Iteration 3:   log likelihood = -24.612872
Iteration 4:   log likelihood = -24.612585
Iteration 5:   log likelihood = -24.612585

Logistic regression                               Number of obs   =         58
                                                  LR chi2(8)      =      28.68
                                                  Prob > chi2     =     0.0004
Log likelihood = -24.612585                       Pseudo R2       =     0.3681
```

mino_use	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
exper	.3871924	.7533552	0.51	0.607	-1.089357	1.863742
edu	-1.691082	1.030058	-1.64	0.101	-3.70996	.327795
sex	-2.311836	1.063618	-2.17	0.030	-4.396489	-.2271831
farm	-.4544992	.85956	-0.53	0.597	-2.139206	1.230207
intnet_acc~s	-2.367704	1.128944	-2.10	0.036	-4.580395	-.155014
tom_acres	.0214639	.1667036	0.13	0.898	-.3052691	.3481969
specific	-.5886973	.2451898	-2.40	0.016	-1.069261	-.1081341
trtment	.9585947	.3178365	3.02	0.003	.3356466	1.581543
_cons	-.8370574	3.370364	-0.25	0.804	-7.44285	5.768736

```
. mfx compute, at (exper =1 edu =1 sex=1 farm=1 intnet_access=1 tom_acres=2 ///
>  specific=11 trtment=12)

Marginal effects after logit
      y  = Pr(mino_use) (predict)
         =   .0993388
```

variable	dy/dx	Std. Err.	z	P>|z|	[95% C.I.]		X
exper*	.0296698	.0583	0.51	0.611	-.084601	.14394	1
edu*	-.2750321	.17338	-1.59	0.113	-.614854	.06479	1
sex*	-.4274464	.20505	-2.08	0.037	-.829342	-.025551	1
farm*	-.0486966	.10148	-0.48	0.631	-.247593	.1502	1
intnet~s*	-.4413489	.26662	-1.66	0.098	-.963912	.081214	1
tom_ac~s	.0019204	.01541	0.12	0.901	-.028277	.032118	2
specific	-.0526711	.03358	-1.57	0.117	-.11849	.013148	11
trtment	.085766	.05414	1.58	0.113	-.020338	.19187	12

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

```
. linktest

Iteration 0:   log likelihood = -38.952145
Iteration 1:   log likelihood = -24.780048
Iteration 2:   log likelihood = -24.567245
Iteration 3:   log likelihood = -24.267839
Iteration 4:   log likelihood = -24.262013
Iteration 5:   log likelihood = -24.262004
Iteration 6:   log likelihood = -24.262004

Logistic regression                               Number of obs   =         58
                                                  LR chi2(2)      =      29.38
                                                  Prob > chi2     =     0.0000
Log likelihood = -24.262004                       Pseudo R2       =     0.3771
```

mino_use	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
_hat	1.024803	.2933201	3.49	0.000	.4499066	1.5997
_hatsq	-.0901444	.1011226	-0.89	0.373	-.2883411	.1080523
_cons	.1555007	.4076885	0.38	0.703	-.6435541	.9545554

Appendix E (1): Enterprise budget of mixed-species green manures with respect to single species green manures for Maryland

Organic Tomato Production:Budget per unit of area (hectare) only for marketable					
	FRad/Vet	Hairy Vet/ Rye	Mix_Hay	Hairy Vetch	Bare grnd
Revenue ($)	32032	19228	24992	28996	21208
Yield (Metric ton)	7.28	4.37	5.68	6.59	4.82
Price ($)	4400	4400	4400	4400	4400
Variable costs (Tomato and cover crops)	10209	9968	10149	10223	9867
Tomato	260	260	260	260	260
Cover crop	339	271	363	349	0
Labor	2925	2762	2880	2906	2954
Fuel	286	286	286	286	286
Water	269	269	269	269	269
Manure and other organic fertilizers	841	841	841	841	841
Other expenses	5290	5279	5250	5313	5257
Fixed Costs ($)	756	756	756	756	756
Land (rental rate per year)	247	247	247	247	247
Machinery and Equipment	509	509	509	509	509
Total Cost (Variable + Fixed) ($)	10965	10724	10905	10979	10623
Net return/ha ($)	21067	8504	14087	18017	10585
Rate of return (%)	192	79	129	164	100
Yield change w.r.t. hairy vetch (Metric ton)	0.69	-2.22	-0.91		NA
Proportionate yield chg	0.104704	-0.50801	-0.16		NA
Yield change w.r.t. bare ground (Metric ton)	2.46	-0.45	0.86	1.77	
Proportionate yield chg	0.510373	-0.09336	0.1784	0.37	
Change in V. Cost w.r.t hairy vetch ($)	-14	-255	-74		NA
Proportionate cost change	-0.00134	-0.0249	-0.007		NA
Change in V. Cost w.r.t bare ground ($)	342	101	282	356	
Proportionate cost change	0.034646	0.010236	0.0286	0.036037	

Appendix E (2): Enterprise budget of mixed-species green manures with respect to single species green manures for New York

New York Organic Tomato Production Budget: metric ton per hectare					
	Rye/Turnip	Rye/Clover	Rye/Vetch	Rye	Bare grnd
Total Revenue ($)	38016	33836	34672	29700	42328
Price ($)	4400	4400	4400	4400	4400
Yield (ton/ha)	8.64	7.69	7.88	6.75	9.62
Variable costs ($)	10023	10170	10655	10029	9820
Tomato	260	260	260	259.75	260
Cover crop	205	350.0646	834.7695	210.0388	0
Labor	2886	2886	2886	2886	2886
Fuel	286	286	286	285.93	286
Water	269	269	269	268.75	269
Manure and other organic fertilizers	841	841	841	840.54	841
Other expenses	5278	5278	5278	5278	5278
Fixed Costs ($)	756.4888	756	756	756.4888	756
Land (rental rate per year)	247.2188	247	247	247.2188	247
Machinery and Equipment (interest and depreciation)	509.27	509	509	509.27	509
Total Cost (Variable + Fixed) ($)	10779.95	10926.06	11410.77	10785.5	10576
Net return ($)	27236.05	22909.94	23261.23	18914.5	31752
Rate of return (%)	253	210	204	175	301
Yield change w.r.t rye ($)	1.89	0.94	1.13		
Proportionate yield change	0.28	0.139259	0.167407		
Yield change w.r.t. bare ground ($)	-0.98	-1.93	-1.74	-2.87	
Change in V. cost w.r.t rye ($)	-6	141	626		
Proportionate change V. cost	-0.00055	0.014065	0.062395		

Appendix E(3): Enterprise Budget Analysis of different treatments of cover crops on organic tomato production in Ohio with compost

Ohio: Enterprise budget for marketable organic tomato with compost					
Cover crops	Hairy Vet/ Rye	Mix Hay	Hairy Vetch	Tillage radish	Winter Rye
Revenue ($)	286088	328812	344432	300036	3E+05
Yield (Mt/ha)	65.02	74.73	78.28	68.19	75.52
Price ($)	4400	4400	4400	4400	4400
Variable costs ($)	4016	3984	4016	3698	3930
Tomato	432	432	432	432	432
Cover crop	538	506	538	220	452
Labor	1476	1476	1476	1476	1476
Fuel	286	286	286	286	286
Water	269	269	269	269	269
Compost	198	198	198	198	198
Other expenses	817	817	817	817	817
Fixed Costs ($)	756	756	756	756	756
Land (rental rate per year)	247	247	247	247	247
Machinery and Equipment (interest and depreciation)	509	509	509.27	509.27	509
Total Cost (Variable + Fixed) ($)	4772	4740	4772	4454	4686
Net profit ($)	281316	324072	339660	295582	3E+05
Rate of return	5895	6837	7118	6636	6991
Yield change w.r.t. hairy vetch ($)	-13.26	-3.55			
Proportionate yield change	-0.1694	-0.045			
Yield change w.r.t. tillage radish ($)	-3.17	6.54			
Proportionate yield change	-0.0465	0.0959			
Yield change w.r.t. Rye ($)	-10.5	-0.79			
Proportionate yield change	-0.139	-0.01			
Change in v. cost w.r.t hairy vetch ($)	0.32	-32			
Proportionate v.cost change	8E-05	-0.008			
Change in v.cost w.r.t. tillage radish ($)	318	286			
Proportionate v.cost change	0.0861	0.0774			
Change in v.cost w.r.t ($)	86	54			
Proportionate v.cost change	0.0219	0.0137			

Appendix E(4): Enterprise Budget Analysis of different treatments of cover crops on organic tomato production in Ohio with no compost

Ohio: Budget for marketable organic tomato in **NO** compost application setting					
Cover crops	HVet/ Rye	Mix_Hay	H Vetch	Tillage radish	Winter Rye
Revenue ($)	153252	219956	116952	161832	133936
Yield (metric ton/ha)	34.83	49.99	26.58	36.78	30.44
Price ($)	4400	4400	4400	4400	4400
Variable costs ($)	4016	3984	4016	3698	3930
Tomato	432	432	432	432	432
Cover crop	538	506	538	220	452
Labor	1476	1476	1476	1476	1476
Fuel	286	286	286	286	286
Water	269	269	269	269	269
Compost	198	198	198	198	198
Other expenses	817	817	817	817	817
Fixed Costs	756	756	756	756	756
Land (rental rate per year)	247	247	247	247	247
Machinery and Equipment (interest and depreciation)	509	509	509	509	509
Total Cost (Variable + Fixed) ($)	4772	4740	4772	4454	4686
Net profit ($)	148480	215216	112180	157378	129250
Rate of return(%)	3111	4540	2351	3533	2758
Yield change w.r.t. hairy vetch (m. ton)	8.25	23.41			
Proportionate yield change	0.310383747	0.88074			
Yield change w.r.t. tillage radish (m.ton)	-1.95	13.21			
Proportionate yield change	-0.053017945	0.35916			
Yield change w.r.t. Rye (m.ton)	4.39	19.55			
Proportionate yield change	0.144218134	0.64225			
Change in v. cost w.r.t hairy vetch ($)	0.32	-31.68			
Proportionate v.cost change	7.96876E-05	-0.00789			
Change in v.cost w.r.t. tillage radish ($)	318.315204	286.315			
Proportionate v.cost change	0.086085002	0.07743			
Change in v.cost w.r.t rye ($)	86	54			
Proportionate v.cost change	0.021882952	0.01374			

Appendix F: Economic Surplus Analysis spread sheets

The spread sheets is used to calculate the benefits as a result of MSGM in organic tomato farming in three North-eastern states of the United States where the project *Enhancing Productivity and Soil-borne Diseases Control in Intensive Organic Vegetable Production with Mixed-Species Green Manure* is being implemented. A general format of the spread sheets in presented in table A.

A	B	C	D	E	F	G	H	I	J
Year	ε	η	Max yld. change	Gross cost Change/ton	Input cost Change/ ha	Input cost Change/ton	Net cost change	Prob. of success	Adopt. Rate

K	L	M	N	O	P	Q	R	S	T	U	V	W
Depr. Rate	Kt	Price	Zt	Qty.	ΔTS	ΔCS	ΔPS	Res. Cost	Net benefit	NPV		

Detail description of the table A

Col	Variables	Variable description
A	Year	Number of years used to project the research annual benefits. In this case 15 years (2009-2024)
B	Supply Elasticity	The value of price elasticity of supply
C	Demand Elasticity	The absolute value of the price elasticity of demand
D	% of yield change	Maximum percent expected in yield change per ha *(EY)* due to the adoption of MSGM
E	%of gross cost change per ton	Gross proportion of the reduction in marginal cost per ton of output *E(Y)/ε*
F	% change in input cost per ha	Proportion of the reduction in marginal cost per hectare *E(C)* if any to achieve the expected yield change
G	% change in input per	Proportionate input cost change per hectare to a

	ton of output. Col.F/(Col.D+1)	proportionate input cost change per ton of output *E(C)*/[1+*E(Y)*]
H	Net percent change in cost per ton output. (Col.E-Col. G)	The effect of variable input costs per changes associated wit the yield change to give maximum potential net changes in marginal cost per ton of output
I	Probability of success	The probability (*p*) of the research success to achieve the expected yield change *E(Y)*
J	Adoption Rate	Adoption rate (A_t), defined in relation to years t, from the start of the research work
K	Depreciate rate	Assumed 0.1 in this study
L	% of shift of supply curve	Proportionate shift down in the supply curve in period t due to research K_t
M	Proportionate decrease in price in year t	Reduction in price relative to its initial value, due to the supply shift $Z_t= K_t\ \varepsilon/(\varepsilon+\eta)$
N	Price	The price of organic tomato in the United States. This price is remains constant at P_0 because we assume that the production of organic tomato do not influence world price.
O	Quantity produced	Quantity (ton) of organic tomato in the project area before the research commences. This quantity is constant and equal to the base quantity.
P	Change in total surplus in t years (ΔTS)	The change in total surplus= column M* column N * column O* [1+(column N*column Q)]
Q	Change in consumer surplus in year t (ΔCS)	ΔCS_t = column M* Column N*Column O * [1+(0.5* column O * column C)]
R	Change in producer surplus in year t (ΔPS)	ΔPS_t = Column P –Column Q

S	Research Cost	Annual research cost for the commodity corresponding to expected yield increase and so on. Units are thousands of constant (base year = 2009) dollars
T	Net Benefit	Column P – Column S
U	Net present value	Net present value fusing the formula

Appendix F (1): Open Economy: Economic surplus results for mixed species forage radish and hairy vetch over single species hairy vetch in Maryland

Maryland: Forage radish/HV vs hairy vetch																		
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
Year	E	η	Max yld chg	Grs cost chng /ton	Inpt cost chng /ha	Input cost change /ton	Net cost chn g	p	Adp rate	DF	Kt	Price	Exog. Gr	Quan	ΔTS	Research cost	Net ben-efit	NPV
2010	1	0.33	0.1	0.1	-0.0013	-0.0012	0.10	1	0	1	0	4400	0.2	450	0	127,401	-127,401	$1,533,376
2011	1	0.33	0.1	0.1	-0.0013	-0.0012	0.10	1	0	1	0	4400	0.2	517	0	127,401	-127,401	
2012	1	0.33	0.1	0.1	-0.0013	-0.0012	0.10	1	0	1	0	4400	0.2	595	0	127,401	-127,401	
2013	1	0.33	0.1	0.1	-0.0013	-0.0012	0.10	1	0.1	1	0.01	4400	0.2	684	27526	0	27,526	
2014	1	0.33	0.1	0.1	-0.0013	-0.0012	0.10	1	0.2	1	0.01	4400	0.2	1035	62647	0	62,647	
2015	1	0.33	0.1	0.1	-0.0013	-0.0012	0.10	1	0.2	1	0.02	4400	0.2	904	73136	0	73,136	
2016	1	0.33	0.1	0.1	-0.0013	-0.0012	0.10	1	0.3	1	0.02	4400	0.2	1040	105370	0	105,370	
2017	1	0.33	0.1	0.1	-0.0013	-0.0012	0.10	1	0.3	1	0.03	4400	0.2	1196	145737	0	145,737	
2018	1	0.33	0.1	0.1	-0.0013	-0.0012	0.10	1	0.4	1	0.03	4400	0.2	1375	195970	0	195,970	
2019	1	0.33	0.1	0.1	-0.0013	-0.0012	0.10	1	0.4	1	0.04	4400	0.2	1582	258138	0	258,138	
2020	1	0.33	0.1	0.1	-0.0013	-0.0012	0.10	1	0.5	1	0.04	4400	0.2	1819	334712	0	334,712	
3021	1	0.33	0.1	0.1	-0.0013	-0.0012	0.10	1	0.5	1	0.05	4400	0.2	2092	428642	0	428,642	
2022	1	0.33	0.1	0.1	-0.0013	-0.0012	0.10	1	0.5	1	0.05	4400	0.2	2406	492938	0	492,938	
2023	1	0.33	0.1	0.1	-0.0013	-0.0012	0.10	1	0.5	1	0.05	4400	0.2	2767	566879	0	566,879	
2024	1	0.33	0.1	0.1	-0.0013	-0.0012	0.10	1	0.5	1	0.05	4400	0.2	3182	651911	0	651,911	

Appendix F (2): Open Economy: Economic surplus results for mixed species rye and turnip over single species rye in New York

New York: Rye and Turnip vs Rye																		
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
Year	E	η	Max yld chg	Gross cost chg /ton	Input cost chng /ha	Input cost chg /ton	Net cost cha-nge	Prob. of succes	Adop rate	DF	Kt	Price	Exog .grwth rate	Quan	ΔTS	Research cost	Net benefit	NPV
2010	1	0.33	0.28	0.28	-0.0005	-0.0004	0.28039	0.9	0	1	0	4400	0.15	248	0	127401	-127401	$2,611,808
2011	1	0.33	0.28	0.28	-0.0005	-0.0004	0.28039	0.9	0	1	0	4400	0.15	286	0	127401	-127401	
2012	1	0.33	0.28	0.28	-0.0005	-0.0004	0.28039	0.9	0	1	0	4400	0.15	329	0	127401	-127401	
2013	1	0.33	0.28	0.28	-0.0005	-0.0004	0.28039	0.9	0.1	1	0.025	4400	0.15	378	42476.6	0	42476.6	
2014	1	0.33	0.28	0.28	-0.0005	-0.0004	0.28039	0.9	0.15	1	0.038	4400	0.15	434	73728.5	0	73728.5	
2015	1	0.33	0.28	0.28	-0.0005	-0.0004	0.28039	0.9	0.2	1	0.05	4400	0.15	500	113750	0	113750	
2016	1	0.33	0.28	0.28	-0.0005	-0.0004	0.28039	0.9	0.25	1	0.063	4400	0.15	575	164522	0	164522	
2017	1	0.33	0.28	0.28	-0.0005	-0.0004	0.28039	0.9	0.3	1	0.076	4400	0.15	661	228429	0	228429	
2018	1	0.33	0.28	0.28	-0.0005	-0.0004	0.28039	0.9	0.35	1	0.088	4400	0.15	760	308339	0	308339	
2019	1	0.33	0.28	0.28	-0.0005	-0.0004	0.28039	0.9	0.4	1	0.101	4400	0.15	874	407694	0	407694	
2020	1	0.33	0.28	0.28	-0.0005	-0.0004	0.28039	0.9	0.45	1	0.114	4400	0.15	1005	530622	0	530622	
3021	1	0.33	0.28	0.28	-0.0005	-0.0004	0.28039	0.9	0.5	1	0.126	4400	0.15	1156	682065	0	682065	
2022	1	0.33	0.28	0.28	-0.0005	-0.0004	0.28039	0.9	0.5	1	0.126	4400	0.15	1329	784375	0	784375	
2023	1	0.33	0.28	0.28	-0.0005	-0.0004	0.28039	0.9	0.5	1	0.126	4400	0.15	1528	902031	0	902031	
2024	1	0.33	0.28	0.28	-0.0005	-0.0004	0.28039	0.9	0.5	1	0.126	4400	0.15	1758	1037335	0	1037335	

Appendix F (3): Open Economy: Economic surplus results for mixed species rye and clover over single species rye in New York

New York: Rye and Clover vs Rye																		
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
Year	ε	η	Max yield chng	Gross cost change /ton	Input cost change /ha	Input cost chng/ ton	Net cost chng	Prob. of suc.	Adop. rate	DF	Kt	Price	Exog. otpt grth rate	Quan	ΔTS	Research cost	Net ben-efit	NPV
2010	1	0.33	0.14	0.14	0.013	0.011	0.1286	0.9	0	1	0	4400	0.2	248.4	0	127,401	-127401	$971,855
2011	1	0.33	0.14	0.14	0.013	0.011	0.1286	0.9	0	1	0	4400	0.2	285.7	0	127,401	-127401	
2012	1	0.33	0.14	0.14	0.013	0.011	0.1286	0.9	0	1	0	4400	0.2	328.5	0	127,401	-127401	
2013	1	0.33	0.14	0.14	0.013	0.011	0.1286	0.9	0.1	1	0.01	4400	0.2	377.8	19349.8	0	19349.8	
2014	1	0.33	0.14	0.14	0.013	0.011	0.1286	0.9	0.2	1	0.02	4400	0.2	434.5	33474.3	0	33474.3	
2015	1	0.33	0.14	0.14	0.013	0.011	0.1286	0.9	0.2	1	0.02	4400	0.2	499.6	51474.6	0	51474.6	
2016	1	0.33	0.14	0.14	0.013	0.011	0.1286	0.9	0.3	1	0.03	4400	0.2	574.6	74206.3	0	74206.3	
2017	1	0.33	0.14	0.14	0.013	0.011	0.1286	0.9	0.3	1	0.03	4400	0.2	660.7	102697	0	102697	
2018	1	0.33	0.14	0.14	0.013	0.011	0.1286	0.9	0.4	1	0.04	4400	0.2	759.9	138177	0	138177	
2019	1	0.33	0.14	0.14	0.013	0.011	0.1286	0.9	0.4	1	0.05	4400	0.2	873.8	182119	0	182119	
2020	1	0.33	0.14	0.14	0.013	0.011	0.1286	0.9	0.5	1	0.05	4400	0.2	1005	236282	0	236282	
3021	1	0.33	0.14	0.14	0.013	0.011	0.1286	0.9	0.5	1	0.06	4400	0.2	1156	302768	0	302768	
2022	1	0.33	0.14	0.14	0.013	0.011	0.1286	0.9	0.5	1	0.06	4400	0.2	1329	348183	0	348183	
2023	1	0.33	0.14	0.14	0.013	0.011	0.1286	0.9	0.5	1	0.06	4400	0.2	1528	400410	0	400410	
2024	1	0.33	0.14	0.14	0.013	0.011	0.1286	0.9	0.5	1	0.06	4400	0.2	1758	460472	0	460472	

Appendix F(4): Open Economy: Economic surplus results for mixed species rye and hairy vetch over single species rye in New York

New York: Rye and Vetch vs Rye																		
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
Year	E	η	Max yld chg	Gross cost chg /ton	Input cost chge /ha	Inpt cost chg /ton	Net cost chg	Prob. of suc	Adop rate	DF	Kt	Price	Exog. Otpt grth rate	Quan	ΔTS	Res. cost	Net ben-efit	NPV
2010	1	0.33	0.17	0.17	0.058	0.049573	0.1204274	0.9	0	1	0	4400	0.15	248.4	0	127,401	-127401	$886,154
2011	1	0.33	0.17	0.17	0.058	0.049573	0.1204274	0.9	0	1	0	4400	0.15	285.7	0	127,401	-127401	
2012	1	0.33	0.17	0.17	0.058	0.049573	0.1204274	0.9	0	1	0	4400	0.15	328.5	0	127,401	-127401	
2013	1	0.33	0.17	0.17	0.058	0.049573	0.1204274	0.9	0.1	1	0.010838	4400	0.15	377.8	18113.927	0	18113.927	
2014	1	0.33	0.17	0.17	0.058	0.049573	0.1204274	0.9	0.15	1	0.016258	4400	0.15	434.5	31330.734	0	31330.734	
2015	1	0.33	0.17	0.17	0.058	0.049573	0.1204274	0.9	0.2	1	0.021677	4400	0.15	499.6	48169.581	0	48169.581	
2016	1	0.33	0.17	0.17	0.058	0.049573	0.1204274	0.9	0.25	1	0.027096	4400	0.15	574.6	69429.384	0	69429.384	
2017	1	0.33	0.17	0.17	0.058	0.049573	0.1204274	0.9	0.3	1	0.032515	4400	0.15	660.7	96068.695	0	96068.695	
2018	1	0.33	0.17	0.17	0.058	0.049573	0.1204274	0.9	0.35	1	0.037935	4400	0.15	759.9	129235.83	0	129235.83	
2019	1	0.33	0.17	0.17	0.058	0.049573	0.1204274	0.9	0.4	1	0.043354	4400	0.15	873.8	170304.47	0	170304.47	
2020	1	0.33	0.17	0.17	0.058	0.049573	0.1204274	0.9	0.45	1	0.048773	4400	0.15	1005	220915.75	0	220915.75	
3021	1	0.33	0.17	0.17	0.058	0.049573	0.1204274	0.9	0.5	1	0.054192	4400	0.15	1156	283027.91	0	283027.91	
2022	1	0.33	0.17	0.17	0.058	0.049573	0.1204274	0.9	0.5	1	0.054192	4400	0.15	1329	325482.09	0	325482.09	
2023	1	0.33	0.17	0.17	0.058	0.049573	0.1204274	0.9	0.5	1	0.054192	4400	0.15	1528	374304.41	0	374304.41	
2024	1	0.33	0.17	0.17	0.058	0.049573	0.1204274	0.9	0.5	1	0.054192	4400	0.15	1758	430450.07	0	430450.07	

Appendix F(5): Open Economy: Economic surplus results for mixed species hairy vetch and rye over single species hairy vetch without compost in Ohio

Ohio: No compost application: Hairy vetch and rye and hairy vetch																		
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
Year	E	η	Max yld chg	Gross cost chg /ton	Inpt cost chg /ha	Input cost chg /ton	Net cost chg	Prob. of suc	Adop-tion rate	DF	Kt	Price	Exog. Otpt grth rate	Quan	ΔTS	Res. cost	Net ben-efit	NPV
2010	1	0.33	0.31	0.31	0	0	0.31	0.9	0	1	0	4400	0.15	84	0	127401	-127401	$771,511
2011	1	0.33	0.31	0.31	0	0	0.31	0.9	0	1	0	4400	0.15	97	0	127401	-127401	
2012	1	0.33	0.31	0.31	0	0	0.31	0.9	0	1	0	4400	0.15	111	0	127401	-127401	
2013	1	0.33	0.31	0.31	0	0	0.31	0.9	0.1	1	0.028	4400	0.15	128	15892	0	15892.3	
2014	1	0.33	0.31	0.31	0	0	0.31	0.9	0.15	1	0.042	4400	0.15	193	36337	0	36336.8	
2015	1	0.33	0.31	0.31	0	0	0.31	0.9	0.2	1	0.056	4400	0.15	169	42614	0	42613.5	
2016	1	0.33	0.31	0.31	0	0	0.31	0.9	0.25	1	0.07	4400	0.15	194	61673	0	61672.6	
2017	1	0.33	0.31	0.31	0	0	0.31	0.9	0.3	1	0.084	4400	0.15	223	85682	0	85681.9	
2018	1	0.33	0.31	0.31	0	0	0.31	0.9	0.35	1	0.098	4400	0.15	257	115726	0	115726	
2019	1	0.33	0.31	0.31	0	0	0.31	0.9	0.4	1	0.112	4400	0.15	295	153109	0	153109	
2020	1	0.33	0.31	0.31	0	0	0.31	0.9	0.45	1	0.126	4400	0.15	340	199393	0	199393	
3021	1	0.33	0.31	0.31	0	0	0.31	0.9	0.5	1	0.14	4400	0.15	391	256452	0	256452	
2022	1	0.33	0.31	0.31	0	0	0.31	0.9	0.5	1	0.14	4400	0.15	449	294920	0	294920	
2023	1	0.33	0.31	0.31	0	0	0.31	0.9	0.5	1	0.14	4400	0.15	517	339158	0	339158	
2024	1	0.33	0.31	0.31	0	0	0.31	0.9	0.5	1	0.14	4400	0.15	594	390031	0	390031	

Appendix F(6): Open Economy: Economic surplus results for mixed species hairy vetch and rye over single species rye without compost in Ohio

Ohio:No Compost application_Hairy vetch and rye and rye																		
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
Year	ε	η	Max yld chg	Gross cost chg /ton	Input cost chge /ha	Input cost chg /ton	Net cost chg	Prob. of suc.	Adop rate	DF	Kt	Price	Exog. Otpt grth rate	Quan	ΔTS	Res. cost	Net ben-efit	NPV
2010	1	0.33	0.144	0.144	0.022	0.0192308	0.1247692	0.9	0	1	0	4400	0.15	83.95	0	127401	-127401	$ 87,901
2011	1	0.33	0.144	0.144	0.022	0.0192308	0.1247692	0.9	0	1	0	4400	0.15	96.5425	0	127401	-127401	
2012	1	0.33	0.144	0.144	0.022	0.0192308	0.1247692	0.9	0	1	0	4400	0.15	111.02388	0	127401	-127401	
2013	1	0.33	0.144	0.144	0.022	0.0192308	0.1247692	0.9	0.1	1	0.0112292	4400	0.15	127.67746	6343.7854	0	6343.7854	
2014	1	0.33	0.144	0.144	0.022	0.0192308	0.1247692	0.9	0.15	1	0.0168438	4400	0.15	193.28771	14445.763	0	14445.763	
2015	1	0.33	0.144	0.144	0.022	0.0192308	0.1247692	0.9	0.2	1	0.0224585	4400	0.15	168.85344	16872.996	0	16872.996	
2016	1	0.33	0.144	0.144	0.022	0.0192308	0.1247692	0.9	0.25	1	0.0280731	4400	0.15	194.18145	24322.266	0	24322.266	
2017	1	0.33	0.144	0.144	0.022	0.0192308	0.1247692	0.9	0.3	1	0.0336877	4400	0.15	223.30867	33657.65	0	33657.65	
2018	1	0.33	0.144	0.144	0.022	0.0192308	0.1247692	0.9	0.35	1	0.0393023	4400	0.15	256.80497	45282.017	0	45282.017	
2019	1	0.33	0.144	0.144	0.022	0.0192308	0.1247692	0.9	0.4	1	0.0449169	4400	0.15	295.32571	59677.361	0	59677.361	
2020	1	0.33	0.144	0.144	0.022	0.0192308	0.1247692	0.9	0.45	1	0.0505315	4400	0.15	339.62457	77419.571	0	77419.571	
3021	1	0.33	0.144	0.144	0.022	0.0192308	0.1247692	0.9	0.5	1	0.0561462	4400	0.15	390.56826	99195.876	0	99195.876	
2022	1	0.33	0.144	0.144	0.022	0.0192308	0.1247692	0.9	0.5	1	0.0561462	4400	0.15	449.1535	114075.26	0	114075.26	
2023	1	0.33	0.144	0.144	0.022	0.0192308	0.1247692	0.9	0.5	1	0.0561462	4400	0.15	516.52652	131186.55	0	131186.55	
2024	1	0.33	0.144	0.144	0.022	0.0192308	0.1247692	0.9	0.5	1	0.0561462	4400	0.15	594.0055	150864.53	0	150864.53	

Appendix F(7) Open Economy: Economic surplus results for mixed hay over single species hairy vetch without compost in Ohio

Ohio:No Compost application_Mix hay and hairy vetch																		
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
Year	ε	η	Max yld chg	Gross cost chg /ton	Input cost chg /ha	Input cost chg /ton	Net cost chg	Prob. of suc.	Adop rate	DF	Kt	Price	Exog. Otpt grth rate	Quan	ΔTS	Research cost	Net ben-efit	NPV
2010	1	0.33	0.88	0.88	0.008	0.00426	0.87574	0.9	0	1	0	4400	0.15	84	0	127401	-127401	$3,120,871
2011	1	0.33	0.88	0.88	0.008	0.00426	0.87574	0.9	0	1	0	4400	0.15	97	0	127401	-127401	
2012	1	0.33	0.88	0.88	0.008	0.00426	0.87574	0.9	0	1	0	4400	0.15	111	0	127401	-127401	
2013	1	0.33	0.88	0.88	0.008	0.00426	0.87574	0.9	0.1	1	0.07882	4400	0.15	128	46023	0	46022.816	
2014	1	0.33	0.88	0.88	0.008	0.00426	0.87574	0.9	0.15	1	0.11823	4400	0.15	147	80894	0	80894.355	
2015	1	0.33	0.88	0.88	0.008	0.00426	0.87574	0.9	0.2	1	0.15763	4400	0.15	169	126346	0	126345.68	
2016	1	0.33	0.88	0.88	0.008	0.00426	0.87574	0.9	0.25	1	0.19704	4400	0.15	194	184939	0	184939.18	
2017	1	0.33	0.88	0.88	0.008	0.00426	0.87574	0.9	0.3	1	0.23645	4400	0.15	223	259794	0	259793.89	
2018	1	0.33	0.88	0.88	0.008	0.00426	0.87574	0.9	0.35	1	0.27586	4400	0.15	257	354699	0	354698.73	
2019	1	0.33	0.88	0.88	0.008	0.00426	0.87574	0.9	0.4	1	0.31527	4400	0.15	295	474248	0	474247.71	
2020	1	0.33	0.88	0.88	0.008	0.00426	0.87574	0.9	0.45	1	0.35468	4400	0.15	340	624001	0	624001.43	
3021	1	0.33	0.88	0.88	0.008	0.00426	0.87574	0.9	0.5	1	0.39409	4400	0.15	391	810680	0	810679.58	
2022	1	0.33	0.88	0.88	0.008	0.00426	0.87574	0.9	0.5	1	0.39409	4400	0.15	449	932282	0	932281.51	
2023	1	0.33	0.88	0.88	0.008	0.00426	0.87574	0.9	0.5	1	0.39409	4400	0.15	517	1E+06	0	1072123.7	
2024	1	0.33	0.88	0.88	0.008	0.00426	0.87574	0.9	0.5	1	0.39409	4400	0.15	594	1E+06	0	1232942.3	

Appendix F (8): Open Economy: Economic surplus results for mixed hay over single species tillage radish without compost in Ohio

Ohio:No Compost application_Mix hay and tillage radish																		
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
Year	ε	η	Max yld chg	Gross cost chg /ton	Input cost chg /ha	Input cost chg /ton	Net cost chg	Prob. of suc	Adop rate	DF	Kt	Price	Exog. Otpt grth rate	Quan	ΔTS	Research cost	Net ben-efit	NPV
2010	1	0.33	0.36	0.36	0.077	0.05662	0.30338	0.9	0	1	0	4400	0.15	83.95	0	127401	-127401	$746,305
2011	1	0.33	0.36	0.36	0.077	0.05662	0.30338	0.9	0	1	0	4400	0.15	96.54	0	127401	-127401	
2012	1	0.33	0.36	0.36	0.077	0.05662	0.30338	0.9	0	1	0	4400	0.15	111	0	127401	-127401	
2013	1	0.33	0.36	0.36	0.077	0.05662	0.30338	0.9	0.1	1	0.0273	4400	0.15	127.7	15549	0	15548.5	
2014	1	0.33	0.36	0.36	0.077	0.05662	0.30338	0.9	0.15	1	0.041	4400	0.15	193.3	35546	0	35545.5	
2015	1	0.33	0.36	0.36	0.077	0.05662	0.30338	0.9	0.2	1	0.0546	4400	0.15	168.9	41680	0	41679.7	
2016	1	0.33	0.36	0.36	0.077	0.05662	0.30338	0.9	0.25	1	0.0683	4400	0.15	194.2	60313	0	60312.7	
2017	1	0.33	0.36	0.36	0.077	0.05662	0.30338	0.9	0.3	1	0.0819	4400	0.15	223.3	83781	0	83780.9	
2018	1	0.33	0.36	0.36	0.077	0.05662	0.30338	0.9	0.35	1	0.0956	4400	0.15	256.8	113143	0	113143	
2019	1	0.33	0.36	0.36	0.077	0.05662	0.30338	0.9	0.4	1	0.1092	4400	0.15	295.3	149671	0	149671	
2020	1	0.33	0.36	0.36	0.077	0.05662	0.30338	0.9	0.45	1	0.1229	4400	0.15	339.6	194890	0	194890	
2021	1	0.33	0.36	0.36	0.077	0.05662	0.30338	0.9	0.5	1	0.1365	4400	0.15	390.6	250628	0	250628	
2022	1	0.33	0.36	0.36	0.077	0.05662	0.30338	0.9	0.5	1	0.1365	4400	0.15	449.2	288222	0	288222	
3023	1	0.33	0.36	0.36	0.077	0.05662	0.30338	0.9	0.5	1	0.1365	4400	0.15	516.5	331456	0	331456	
2024	1	0.33	0.36	0.36	0.077	0.05662	0.30338	0.9	0.5	1	0.1365	4400	0.15	594	381174	0	381174	

Appendix F (9): Open Economy: Economic surplus results for mixed hay over single species rye without compost in Ohio

Ohio:No Compost application_Mix hay and rye																		
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
Year	ε	η	Max yld chg	Gross cost chg /ton	Input cost chg /ha	Input cost chg /ton	Net cost chg	Prob. of suc	Adop rate	DF	Kt	Price	Exog. Otpt grth rate	Quan	ΔTS	Research cost	Net ben-efit	NPV
2010	1	0.33	0.64	0.64	0.01	0.00835	0.6316	0.9	0	1	0	4400	0.15	83.95	0	127401	-127401	$2,066,591
2011	1	0.33	0.64	0.64	0.01	0.00835	0.6316	0.9	0	1	0	4400	0.15	96.5425	0	127401	-127401	
2012	1	0.33	0.64	0.64	0.01	0.00835	0.6316	0.9	0	1	0	4400	0.15	111.02388	0	127401	-127401	
2013	1	0.33	0.64	0.64	0.01	0.00835	0.6316	0.9	0.1	1	0.0568	4400	0.15	127.67746	32844	0	32844	
2014	1	0.33	0.64	0.64	0.01	0.00835	0.6316	0.9	0.2	1	0.0853	4400	0.15	193.28771	75613.2	0	75613	
2015	1	0.33	0.64	0.64	0.01	0.00835	0.6316	0.9	0.2	1	0.1137	4400	0.15	168.85344	89273.3	0	89273	
2016	1	0.33	0.64	0.64	0.01	0.00835	0.6316	0.9	0.3	1	0.1421	4400	0.15	194.18145	130056	0	130056	
2017	1	0.33	0.64	0.64	0.01	0.00835	0.6316	0.9	0.3	1	0.1705	4400	0.15	223.30867	181859	0	181859	
2018	1	0.33	0.64	0.64	0.01	0.00835	0.6316	0.9	0.4	1	0.199	4400	0.15	256.80497	247189	0	247189	
2019	1	0.33	0.64	0.64	0.01	0.00835	0.6316	0.9	0.4	1	0.2274	4400	0.15	295.32571	329077	0	329077	
2020	1	0.33	0.64	0.64	0.01	0.00835	0.6316	0.9	0.5	1	0.2558	4400	0.15	339.62457	431176	0	431176	
2021	1	0.33	0.64	0.64	0.01	0.00835	0.6316	0.9	0.5	1	0.2842	4400	0.15	390.56826	557889	0	557889	
2022	1	0.33	0.64	0.64	0.01	0.00835	0.6316	0.9	0.5	1	0.2842	4400	0.15	449.1535	641573	0	641573	
2023	1	0.33	0.64	0.64	0.01	0.00835	0.6316	0.9	0.5	1	0.2842	4400	0.15	516.52652	737809	0	737809	
2024	1	0.33	0.64	0.64	0.01	0.00835	0.6316	0.9	0.5	1	0.2842	4400	0.15	594.0055	848480	0	848480	

Appendix F (10): Closed Economy: Economic surplus results for mixed forage radish and hairy vetch over single species hairy vetch in Maryland

Maryland: Forage radish/HV vs hairy vetch																					
A	B	C	D	E	F	G	H	I	J	K	L	M	N		O	P	Q	R	S	T	U
Year	E	η	Max yld chg	Gross cost chg /ton	Input cost chg /ha	Input cost change /ton	Net cost cha-nge	Prob. of suc.	Ad op rat e	D F	Kt	Price	Zt		Quan	ΔTS	ΔCS	ΔPS	Researc h cost	Net ben-efit	NPV
2010	1	0.33	0.1	0.1	-0.0013	-0.0012	0.10	0.9	0	1	0	4400	0	0.15	449.7	0	0	0	127,401	-127,401	$1,494,322
2011	1	0.33	0.1	0.1	-0.0013	-0.0012	0.10	0.9	0	1	0	4400	0	0.15	517.1	0	0	0	127,401	-127,401	
2012	1	0.33	0.1	0.1	-0.0013	-0.0012	0.10	0.9	0	1	0	4400	0	0.15	594.7	0	0	0	127,401	-127,401	
2013	1	0.33	0.1	0.1	-0.0013	-0.0012	0.10	0.9	0.1	1	0.009106	4400	0.007	0.15	683.9	27432	20626	6806	0	27,432	
2014	1	0.33	0.1	0.1	-0.0013	-0.0012	0.10	0.9	0.2	1	0.01366	4400	0.01	0.15	786.4	47347	35599	11748	0	47,347	
2015	1	0.33	0.1	0.1	-0.0013	-0.0012	0.10	0.9	0.2	1	0.018213	4400	0.014	0.15	904.4	72639	54616	18023	0	72,639	
2016	1	0.33	0.1	0.1	-0.0013	-0.0012	0.10	0.9	0.3	1	0.022766	4400	0.017	0.15	1040	104478	78555	25923	0	104,478	
2017	1	0.33	0.1	0.1	-0.0013	-0.0012	0.10	0.9	0.3	1	0.027319	4400	0.021	0.15	1196	144261	108467	35794	0	144,261	
2018	1	0.33	0.1	0.1	-0.0013	-0.0012	0.10	0.9	0.4	1	0.031872	4400	0.024	0.15	1375	193659	145608	48051	0	193,659	
2019	1	0.33	0.1	0.1	-0.0013	-0.0012	0.10	0.9	0.4	1	0.036425	4400	0.027	0.15	1582	254666	191478	63188	0	254,666	
2020	1	0.33	0.1	0.1	-0.0013	-0.0012	0.10	0.9	0.5	1	0.040979	4400	0.031	0.15	1819	329659	247864	81795	0	329,659	
2021	1	0.33	0.1	0.1	-0.0013	-0.0012	0.10	0.9	0.5	1	0.045532	4400	0.034	0.15	2092	421468	316893	104575	0	421,468	
2022	1	0.33	0.1	0.1	-0.0013	-0.0012	0.10	0.9	0.5	1	0.045532	4400	0.034	0.15	2406	484688	364427	120261	0	484,688	
2023	1	0.33	0.1	0.1	-0.0013	-0.0012	0.10	0.9	0.5	1	0.045532	4400	0.034	0.15	2767	557392	419091	138300	0	557,392	
2024	1	0.33	0.1	0.1	-0.0013	-0.0012	0.10	0.9	0.5	1	0.045532	4400	0.034	0.15	3182	641000	481955	159045	0	641,000	

Appendix F (11): Closed Economy: Economic surplus results for rye and turnip over single species rye in New York

New York: Rye and Turnip vs Rye																					
A	B	C	D	E	F	G	H	I	J	K	L	M	N		O	P	Q	R	S	T	U
Year	ε	η	Max yld chg	Grs cost chg /ton	Input cost chg /ha	Input cost chg /ton	Net cost chg	Prob. of suc	Adop rate	DF	Kt	Price	Zt		Quan	ΔTS	ΔCS	ΔPS	Res cost	Net ben efit	NPV
2010	1	0.33	0.28	0.28	-0.0005	-0.00039	0.28039	0.9	0	1	0	4400	0	0.15	248.4	0	0	0	127401	-127401	$2,496,181
2011	1	0.33	0.28	0.28	-0.0005	-0.00039	0.28039	0.9	0	1	0	4400	0	0.15	285.66	0	0	0	127401	-127401	
2012	1	0.33	0.28	0.28	-0.0005	-0.00039	0.28039	0.9	0	1	0	4400	0	0.15	328.509	0	0	0	127401	-127401	
2013	1	0.33	0.28	0.28	-0.0005	-0.00039	0.28039	0.9	0.1	1	0.0252	4400	0.019	0.15	377.785	42079	31638	10441	0	42078.6	
2014	1	0.33	0.28	0.28	-0.0005	-0.00039	0.28039	0.9	0.15	1	0.0379	4400	0.028	0.15	434.453	72699	54661	18038	0	72698.9	
2015	1	0.33	0.28	0.28	-0.0005	-0.00039	0.28039	0.9	0.2	1	0.0505	4400	0.038	0.15	499.621	111645	83944	27701	0	111645	
2016	1	0.33	0.28	0.28	-0.0005	-0.00039	0.28039	0.9	0.25	1	0.0631	4400	0.047	0.15	574.564	160740	1E+05	39883	0	160740	
2017	1	0.33	0.28	0.28	-0.0005	-0.00039	0.28039	0.9	0.3	1	0.0757	4400	0.057	0.15	660.749	222165	2E+05	55124	0	222165	
2018	1	0.33	0.28	0.28	-0.0005	-0.00039	0.28039	0.9	0.35	1	0.0883	4400	0.066	0.15	759.861	298534	2E+05	74072	0	298534	
2019	1	0.33	0.28	0.28	-0.0005	-0.00039	0.28039	0.9	0.4	1	0.1009	4400	0.076	0.15	873.84	392967	3E+05	97503	0	392967	
2020	1	0.33	0.28	0.28	-0.0005	-0.00039	0.28039	0.9	0.45	1	0.1136	4400	0.085	0.15	1004.92	509186	4E+05	126339	0	509186	
2021	1	0.33	0.28	0.28	-0.0005	-0.00039	0.28039	0.9	0.5	1	0.1262	4400	0.095	0.15	1155.65	651631	5E+05	161683	0	651631	
2022	1	0.33	0.28	0.28	-0.0005	-0.00039	0.28039	0.9	0.5	1	0.1262	4400	0.095	0.15	1329	749376	6E+05	185935	0	749376	
2023	1	0.33	0.28	0.28	-0.0005	-0.00039	0.28039	0.9	0.5	1	0.1262	4400	0.095	0.15	1528.35	861783	6E+05	213826	0	861783	
2024	1	0.33	0.28	0.28	-0.0005	-0.00039	0.28039	0.9	0.5	1	0.1262	4400	0.095	0.15	1757.61	991050	7E+05	245900	0	991050	

Appendix F (12): Closed Economy: Economic surplus results for mixed hay over single species hairy vetch without compost in Ohio

Ohio: NoCompost_Mix hay vs Hairy vetch																					
A	B	C	D	E	F	G	H	I	J	K	L	M	N		O	P	Q	R	S	T	U
Year	ε	η	Max yld chg	Gross cost chg /ton	Input cost chg /ha	Input cost chg /ton	Net cost chg	Prob. of suc	Adop rate	DF	Kt	Price	Zt	EX grth	Qua	ΔTS	ΔCS	ΔPS	Res. cost	Net ben-efit	NPV
2010	1	0.33	0.88	0.88	-0.008	-0.0043	0.884	0.9	0	1	0	4400	0	0.15	84	0	0	0	127401	-127401	$2,770,897
2011	1	0.33	0.88	0.88	-0.008	-0.0043	0.884	0.9	0	1	0	4400	0	0.15	97	0	0	0	127401	-127401	
2012	1	0.33	0.88	0.88	-0.008	-0.0043	0.884	0.9	0	1	0	4400	0	0.15	111	0	0	0	127401	-127401	
2013	1	0.33	0.88	0.88	-0.008	-0.0043	0.884	0.9	0.1	1	0.080	4400	0.06	0.15	128	45150	33947	11203	0	45149.6	
2014	1	0.33	0.88	0.88	-0.008	-0.0043	0.884	0.9	0.15	1	0.119	4400	0.09	0.15	147	78264	58845	19419	0	78263.77	
2015	1	0.33	0.88	0.88	-0.008	-0.0043	0.884	0.9	0.2	1	0.159	4400	0.12	0.15	169	120588	90668	29920	0	120588.2	
2016	1	0.33	0.88	0.88	-0.008	-0.0043	0.884	0.9	0.25	1	0.199	4400	0.15	0.15	194	174185	130966	43219	0	174184.7	
2017	1	0.33	0.88	0.88	-0.008	-0.0043	0.884	0.9	0.3	1	0.239	4400	0.18	0.15	223	241533	181604	59929	0	241532.9	
2018	1	0.33	0.88	0.88	-0.008	-0.0043	0.884	0.9	0.35	1	0.279	4400	0.209	0.15	257	325610	244820	80791	0	325610.4	
2019	1	0.33	0.88	0.88	-0.008	-0.0043	0.884	0.9	0.4	1	0.318	4400	0.239	0.15	295	429987	323299	1E+05	0	429987.1	
2020	1	0.33	0.88	0.88	-0.008	-0.0043	0.884	0.9	0.45	1	0.358	4400	0.269	0.15	340	558938	420254	1E+05	0	558937.6	
2021	1	0.33	0.88	0.88	-0.008	-0.0043	0.884	0.9	0.5	1	0.398	4400	0.299	0.15	391	717574	539529	2E+05	0	717573.8	
2022	1	0.33	0.88	0.88	-0.008	-0.0043	0.884	0.9	0.5	1	0.398	4400	0.299	0.15	449	825210	620459	2E+05	0	825209.8	
2023	1	0.33	0.88	0.88	-0.008	-0.0043	0.884	0.9	0.5	1	0.398	4400	0.299	0.15	517	948991	713527	2E+05	0	948991.3	
2024	1	0.33	0.88	0.88	-0.008	-0.0043	0.884	0.9	0.5	1	0.398	4400	0.299	0.15	594	1E+06	820556	3E+05	0	1091340	

Appendix F (13): Closed Economy: Economic surplus results for mixed hay over single species rye without compost in Ohio

Ohio: NoCompost_Mix hay vs rye																					
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V
Year	ε	η	Max yld chg	Gross cost chg /ton	Input cost chg /ha	Input cost chg /ton	Net cost chg	Prob. of suc	Adop rate	D F	Kt	Price	Zt	Ex grth	Quan	ΔTS	ΔCS	ΔPS	Res. cost	Net ben-efit	NPV
2010	1	0.33	0.64	0.64	0.0137	0.0084	0.6316	0.9	0	1	0	4400	0	0.15	84	0	0	0	127401	-127401	$1,854,038
2011	1	0.33	0.64	0.64	0.0137	0.0084	0.6316	0.9	0	1	0	4400	0	0.15	97	0	0	0	127401	-127401	
2012	1	0.33	0.64	0.64	0.0137	0.0084	0.6316	0.9	0	1	0	4400	0	0.15	111	0	0	0	127401	-127401	
2013	1	0.33	0.64	0.64	0.0137	0.0084	0.6316	0.9	0.1	1	0.057	4400	0.043	0.15	128	32161	24181.5	7979.9072	0	32161	
2014	1	0.33	0.64	0.64	0.0137	0.0084	0.6316	0.9	0.15	1	0.085	4400	0.064	0.15	147	55673	41859.2	13813.541	0	55673	
2015	1	0.33	0.64	0.64	0.0137	0.0084	0.6316	0.9	0.2	1	0.114	4400	0.085	0.15	169	85663	64408.1	21254.67	0	85663	
2016	1	0.33	0.64	0.64	0.0137	0.0084	0.6316	0.9	0.25	1	0.142	4400	0.107	0.15	194	123568	92908.6	30659.831	0	123568	
2017	1	0.33	0.64	0.64	0.0137	0.0084	0.6316	0.9	0.3	1	0.171	4400	0.128	0.15	223	171115	128658	42457.181	0	171115	
2018	1	0.33	0.64	0.64	0.0137	0.0084	0.6316	0.9	0.35	1	0.199	4400	0.15	0.15	257	230372	173212	57160.093	0	230372	
2019	1	0.33	0.64	0.64	0.0137	0.0084	0.6316	0.9	0.4	1	0.227	4400	0.171	0.15	295	303817	228434	75383.224	0	303817	
2020	1	0.33	0.64	0.64	0.0137	0.0084	0.6316	0.9	0.45	1	0.256	4400	0.192	0.15	340	394412	296550	97861.519	0	394412	
2021	1	0.33	0.64	0.64	0.0137	0.0084	0.6316	0.9	0.5	1	0.284	4400	0.214	0.15	391	505693	380220	125472.66	0	505693	
2022	1	0.33	0.64	0.64	0.0137	0.0084	0.6316	0.9	0.5	1	0.284	4400	0.214	0.15	449	581547	437253	144293.56	0	581547	
2023	1	0.33	0.64	0.64	0.0137	0.0084	0.6316	0.9	0.5	1	0.284	4400	0.214	0.15	517	668779	502841	165937.59	0	668779	
2024	1	0.33	0.64	0.64	0.0137	0.0084	0.6316	0.9	0.5	1	0.284	4400	0.214	0.15	594	769096	578267	190828.23	0	769096	