Protocols for the Assessment of Economic and Environmental Effects of Integrated Pest Management Programs

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(ABSTRACT)

State Integrated Pest Management (IPM) programs are often called on to demonstrate their impacts. While many studies demonstrate techniques for assessing various economic and environmental effects of IPM, the literature provides little guidance on incorporating the techniques to perform complete assessments of IPM programs. This thesis begins with a discussion of relevant economic and environmental techniques for IPM impact assessment. Next, impact assessment techniques that are widely accepted and analytically feasible are identified. These techniques are incorporated into comprehensive impact assessment frameworks for use by individuals charged with the assessment of state level IPM programs. The study concludes with case studies which show how the assessment protocols were applied to estimate and describe the impacts of the Pennsylvania and Massachusetts sweet corn IPM programs.

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Chapter I: Introduction

I.1: Background

I.1.1: Pests

Organisms that interfere with the goals and activities of humans are considered 'pests.' As such, any type of organism might be considered a pest if its habits are antagonistic to the goals and objectives of humans (Flint and Bosch, 1981). In the context of agricultural production, a pest can be defined as an organism which negatively influences the production of food and fiber (Zalom, et al., 1993). It is important to note that a pest may be any type of organism. Although certain insects, weeds and nematodes are more often thought of as pests, some vertebrates, mollusks, and pathogenic microorganisms may also be pests in certain situations.

I.1.2: Pest Control

Man has always had to deal with the problems caused by pests (Dover, 1985). For example, controlling pest damage to crops has been a major objective of farmers since man first began cultivating (Zalom, et al., 1993). In agricultural production, humans must compete directly with pests for the use of resources. Thus, in order to meet food and fiber production goals, it is often necessary to mitigate the negative effects of pests through the use of various pest control practices.

The set of possible practices used to control pests is often delineated into 4 categories: chemical controls, cultural controls, biological controls and physical controls (CAST, 1982, EPA, 1995, Fernandez-Cornejo, et al., 1992, Rajotte, et al., 1987). Others use different categories, such as crop plant resistance, growth regulation (Araji, 1981) legal control (Rajotte, 1993), genetic controls (Rajotte, et al., 1987) and preventive controls (CAST, 1982). Nonetheless, it appears that most relevant control tactics can be grouped into one of the 4 categories.

Chemical pest controls include the use of chemicals to control antagonistic insects, weeds, plant diseases and nematodes. Chemical insect control includes not only the use of insecticides, but also the use of insect growth regulators, chemosterilants and pheromones. Chemical control of weeds, nematodes and diseases includes the use of herbicides, nematicides, bactericides and fungicides, respectively (CAST, 1982).

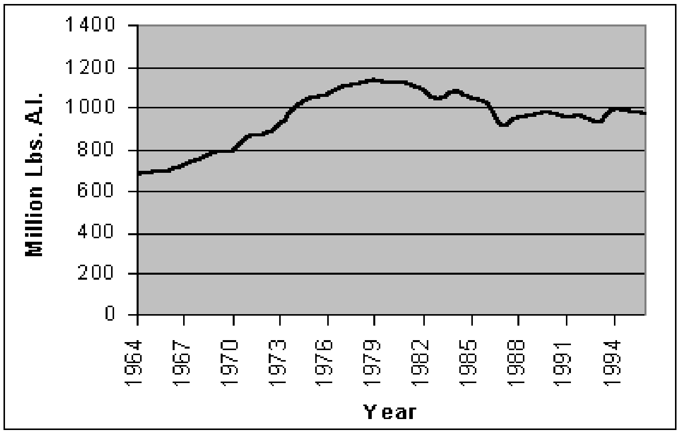
Production practices that make the environment less favorable to pests are called cultural controls. Cultural controls commonly include adjusting row spacing, crop rotations and the use of trap crops. Biological controls generally include the use of predators and disease causing organisms for the control of insect pests, the introduction of plant pathogens, insects and grazing animals for the control of weeds and the use of various microorganisms to control nematodes (CAST, 1982, Greene, et al., 1985, Napit, 1986). Finally, examples of physical controls include trapping pests, the use of pest barriers, and altering the time at which a crop is planted.

I.1.3: The Perceived Problem of Chemical Pesticides

The use of chemical controls to manage agricultural pests has steadily increased since the introduction of relatively efficacious chemical pesticides five decades ago. Over this time, chemical pesticides have become the most important pest control technique used by agricultural producers (Rajotte, et al., 1987). Chemical pesticides are often the first line of defense against insects, weeds, diseases and nematodes which hinder agricultural production. Assumably, this is because chemical controls are generally effective, resulting in an average of a $4 reduction in crop damages for each dollar spent (Pimentel, et al., 1992). In 1997, U.S. farmers spent $7.7 billion on chemical pesticides, further demonstrating that pesticides are perceived to be effective (USDA, 1997).

Between 1948 and 1996, use of pesticides by agricultural producers has increased at an average rate of 6% per year, making pesticides the fastest growing farm input category (USDA-ERS, 1998). Since the mid-1960's, use of pesticides by U.S. producers almost doubled, increasing from 540 million pounds of active ingredient to just over 1 billion pounds of active ingredient in 1993[1] (EPA, 1994). Such increases in the use of chemical pesticides have heightened concerns regarding the actual and potential negative effects of chemical pesticides (Wetzstein, et al., 1985). Some areas of concern related to pesticide use include: human health effects and worker safety, animal kills, effects on livestock and wildlife, the emergence of pest resistance, environmental contamination and the destruction of beneficial species (Greene, et al., 1985, Mullen, et al., 1997, Pimentel, et al., 1992, Rajotte, 1993, Wetzstein, et al., 1985 and others). With such concerns related to the perceived negative effects of excessive chemical pesticide use as an impetus, the concept of integrated pest management (IPM) emerged (Dent, 1991 p2).

Figure 1:U.S. Conventional Pesticide Use: 1964-1995. Data source: (Aspelin, 1997)



I.2: Integrated Pest Management

I.2.1: IPM Defined

Integrated Pest Management (IPM) is defined in various ways by different authors and organizations. Some of these definitions are presented in Table 1.

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[1] As will be discussed below, changes in total active ingredient (a.i.) usage is not

Nonetheless, nearly all IPM definitions emphasize some common points. First, most IPM definitions invoke some notion of reducing the health and environmental risks associated with pesticide use. Second, most definitions emphasize the use of multiple pest control techniques. Sometimes definitions also endow IPM with various economic and financial attributes such as increasing farmer profitability or reducing yield variability. IPM definitions will be discussed in more detail in section II.2 in the context of IPM adoption.

Table 1: Some Definitions of IPM

Organization	Definition Given
Office of Technology Assessment (OTA) as quoted by Fernandez-Cornejo (1992)	"…the optimization of pest control in an economically and ecologically sound manner, accomplished by the coordinated use of multiple tactics to assure stable crop production and to maintain pest damage below the economic injury level while minimizing hazards to humans, plants and the environment."
the Food Quality Protection Act of 1996 § 303 H.R. 1627	"…a sustainable approach to managing pests by combining biological, cultural, physical and chemical tools in a way that minimizes economic, health and environmental risks."
U.S. Dept. of Agriculture, Agricultural Research Service (USDA-ARS) (USDA, 1993)	"… a management approach that encourages natural control of pest populations by anticipating pest problems and preventing pests from reaching economically damaging levels."
National Coalition on IPM as quoted by Czapar et. al. (1995)	"…a system that controls pests and contributes to long-term sustainability by combining the judicious use of biological, cultural, physical, and chemical tools in a way that minimizes the risks of pesticides to human health and the environment."
Council for Agricultural Science and Technology (CAST) (CAST, 1982)	"… the use of a variety of tactics to control pests in the efficient production of food and fiber while holding to a minimum the overall unfavorable effects of the various practices."

I.2.3: IPM Programs

In 1993, the Clinton Administration declared that decreasing pesticide use and the associated risks was a high priority (EPA, 1997). In response this announcement, the U.S. Department of Agriculture, the U.S. Environmental Protection Agency and the Food and Drug Administration agreed to cooperate in reducing pesticide use in order to diminish the associated health and environmental effects (Fernandez-Cornejo and Jans, 1996). The result of this agreement was the joint announcement of a national goal of

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necessarily indicative of changes in the level of environmental and health risks.

implementing IPM methods on at least seventy-five percent of U.S. cropland by the year 2000 (Hollingsworth, et al., 1997). In endeavoring to meet this goal, various governmental agencies sponsor and fund IPM programs.

The main goal of IPM programs is to manage pests in such a way as to preserve producer profitability while minimizing environmental damage resulting from pest control techniques (McNamara, et al., 1991, Wetzstein, et al., 1985). IPM programs involve research and education activities in the development and promotion of integrated pest management. Allen and Bath (1980) described pest management programs as consisting of seven components. Included are scientific research, the development of pest control techniques and management systems, and the delivery of information to potential users. (See Table 2) The components demonstrate that "knowledge and information form the base of an IPM program." (Rajotte, et al., 1987) However, as noted by Rajotte (1993), the goals of IPM programs increasingly include economic and environmental objectives.

Table 2: Components of Pest Management Programs. Adapted from discussion in Rajotte (1987)

Component	*Description*
Basic Research	Investigates the biology, ecology, and taxonomy of pests.
Control Components Research	Develop as many pest control techniques as possible.
IPM Systems Research Level 1	Develops management systems that integrate tow or more control techniques to manage one or more species of the same type, such as insects.
IPM Systems Research Level 2	Integrates research from two or more management systems for two or more pest groupings, such as plant pathogens and insects.
Extension Level 1	Delivers information for managing pests of one type, such as insects or weeds, in one or more commodities.
Extension Level 2	Delivers information for managing pests belonging to two or more groupings, such as disease and insects, in one or more commodities.
Higher Education	Develops curricula and courses to provide interdisciplinary training.

State IPM programs receiving federal funds are required by congressional mandate to "reduce pesticide use, minimize environmental contamination, and reduce pesticide exposure to farmworkers."(Greene and Cuperus, 1991) Thus, while IPM does not imply a prohibition on the use of chemical pesticides, a major focus of programs is on reducing pesticide use. Traditionally, the emphasis of IPM programs has been on the encouragement of or assistance with pest scouting and monitoring. Scouting and monitoring of pests supposedly reduces the application of pesticides (Greene and Cuperus, 1991), thus integrating the traditional IPM program goals with the federal mandate to reduce pesticide application.

However, Allen and Bath's (1980) description indicates that IPM programs are somewhat more broad-based than the above descriptions might imply. Over time, the focus of programs has evolved to include more non-chemical pest management tactics in the set of acceptable practices (for example, see Greene and Cuperus (1991)). Modern programs also employ other means to encourage the use of IPM. For example, New York and Massachusetts IPM programs offer a method by which growers who use IPM practices can be 'certified'. With certification, growers gain the right to use an IPM label on their products thus differentiating them in the market (for example, see Cowles (1997)).

IPM programs have also extended past the farm-gate. For example, there are many IPM programs specifically designed to address off-farm pest control. Such programs are often referred to as 'urban IPM' programs. Urban IPM programs generally address three categories of non-farm pest control needs: structural, landscape and home lawn (e.g., see (Koehler and Short, 1995)). Landscape and home lawn programs encourage the use of scouting and other IPM techniques in parks, golf courses, home lawns, etc. Structural programs address pest control issues within buildings, particularly school buildings. At least two states, Florida and North Carolina, mandate the use of IPM practices in public buildings and schools via compulsory applicator certification programs.

IPM programs are carried out in differing social, economic and biological climates and with various goals and objectives. Each program is specifically tailored to address pest control issues relevant to production or maintenance of specific biological outputs. Different outputs are susceptible to different pests and, as such, separate IPM programs for each output are generally necessary. Further, many outputs are grown in more than one geographic area, necessitating the adaptation of IPM programs to address the unique pest control requirements of each area. Thus, IPM programs are not only crop-specific, but are also specific to a certain geographic area (Fernandez-Cornejo and Jans, 1996).

IPM programs are implemented with varying objectives. These objectives address issues at both the user level and at the societal level. Generally, user level objectives include improving profitability, decreasing variability of returns, and improving the health and safety of workers. The more aggregate societal objectives often address environmental and health concerns related to chemical pest control.

The geographical, cultural, environmental and economic circumstances to which each program is relevant implies a unique set of possible costs and benefits that may result from implementation of the program. The set of costs and benefits considered when assessing a given program is dependent upon the objectives of the program in question. Such costs and benefits may be directly attributable to certain individuals or may be widely dispersed. Costs and benefits of an IPM program might include: the direct cost of the program to the funding agency, costs and benefits associated with the direct and indirect market effects of the program, costs of implementation and adoption by program participants, environmental and health effects of changes in production techniques and changes in production costs associated with IPM adoption. Further, IPM users may experience benefits and costs related to changes in yield variability as a result of adopting IPM practices.

I.3: Problem and Objectives

I.3.1: General Problem

In response to the national IPM goal, various federal and state agencies have become increasingly interested in funding IPM programs. However, funding decisions cannot be made haphazardly. First, it is required that government entities demonstrate that publicly funded projects are beneficial. Examples of such requirements are included in the Government Performance Review Act of 1993 (Antle and Capalbo, 1996) and the Food and Agriculture Act (PL 95-113) (Rajotte, et al., 1987). Further, public agencies have limited funds for the support of projects. As such, it is necessary for these agencies to carefully choose which programs to support in order to maximize the benefit obtained from scarce funds. In general, this requires some comparison of actual and potential programs on which expenditures may take place. Further, it is necessary to consider the goals and objectives of the agency when undertaking such analysis and to rank results accordingly.

Comparison of investments in any potential or actual IPM program with a competing use for funds requires that some analysis of user level and societal costs and benefits of each potential use of the funds be undertaken. Because of the wide variation in IPM programs, each program requires individual consideration. Further, differing goals and objectives of funding agencies necessitates consideration of varying attributes of programs. Such attributes may include environmental, health and economic effects of the programs at varying degrees of aggregation. As such, numerous techniques may be employed in the analysis of a program as appropriate to the particular case.

I.3.2: Specific Problem

There have been several evaluations of the impacts of IPM programs. Most commonly, the user level effects on profitability and risk have been assessed. Other studies have evaluated the health and environmental benefits of IPM programs and economic costs and benefits at varying levels of aggregation. However, most studies have been applied to particular IPM programs or practices. Given the wide variation in IPM programs, it is difficult to draw on the procedures used in such studies to assess other programs. Thus, in order to provide for consistent and effective evaluation of programs and for comparison across programs, a uniform set of techniques for IPM program appraisal is needed. Such techniques should address the necessity of evaluating IPM programs individually based on both the attributes of the program and on the goals and objectives of the funding agency.

I.3.3: General and Specific Objectives

In response to the specific problem identified above, the general objective of this study is to present a consistent and broadly applicable set of techniques for the analysis of IPM programs by funding agencies. This general objective shall be accomplished by fulfilling and synthesizing the following specific objectives:

1. Identify the various techniques and procedures of economic impact assessment that are generally applicable and appropriate for use in evaluating IPM programs. The set of techniques identified must be sufficient to address the diverse environmental and economic impacts of IPM programs at both the societal and user levels while not recommending techniques and procedures that are not appropriate for practical analyses.

2. Provide a recommended procedure for analyzing typical cases that can serve as a benchmark for other analyses.

3. Apply the procedure to actual IPM programs by conducting case studies.

Chapter II: Assessment of IPM Programs

Appraisal of IPM programs draws on a variety of techniques and ideas. Each appraisal is different, having been tailored for the attributes of the program under assessment and to meet particular goals and objectives. Previous appraisal studies have concentrated on assessing a variety of program attributes, including the environmental and health effects of programs, the effect of programs on consumers and producers, the characteristics of program participants and the cost of programs. Further, studies have been done at different levels of detail ranging from quick estimations to in-depth assessments. The resulting heterogeneity of previous studies provides a rich set of theory and techniques from which the current study can draw.

This chapter will accomplish two objectives. While previous studies differ greatly in both scope and focus, many common themes can be identified. The first objective of the following section is to identify the techniques and ideas that are common to many studies and to introduce them as they relate to IPM program appraisal. The second objective of this section is to develop and justify a set of methods for use in evaluating IPM programs. The chapter begins with a short discussion of economic thresholds and the economic injury level which, although not particularly useful in assessing IPM programs, provide valuable insights into the economics of IPM. Next, there is a discussion of producer adoption of IPM, some analysis of which is found in almost every IPM appraisal study. The chapter continues with a discussion of techniques for economic appraisal of IPM programs at the user and societal levels. Finally, techniques for environmental appraisal of the effects of IPM programs are reviewed.

II.1: The Economic Injury Level

The economic foundation of IPM is the economic injury level introduced by

Stern, Smith, Van Den Bosch and Hagen in 1959. Stern et al. (1959) noted that chemical controls should only be used when the cost of using the controls is justified. Their basic argument was that if one considers the only important variable to be pest populations, then there is some pest population capable of inflicting enough damage on crops to justify the use of chemical pesticides. The pest population at which the cost of control equals the cost of damage is called the economic injury level (EIL). Stern et. al. note that the EIL may vary from "area to area, season to season, or with man's changing scale of economic values."

In Stern's treatment, pest populations are continually varying about a general equilibrium position. If pest populations are increasing such that the EIL will be reached, chemical controls must be applied at some point before reaching the EIL to avoid unnecessary economic damage. The point at which controls must be applied is called the economic threshold. Since the economic threshold occurs before reaching the EIL, the economic threshold is always lower than the EIL.

Headley (1972) developed a theoretical definition of the economic threshold. First, a damage function is specified relating crop damage to the pest population in some previous period. Next, yield (and revenue) is specified as a function of pest population. Assuming that control costs increase with pest kills (that is, it costs increasingly more to maintain increasingly smaller pest populations), a cost function can be specified. Headley then makes the expected conclusion: that the optimal level of pest control occurs when the marginal cost of pest control is equal to marginal revenue. The economic threshold is the pest population associated with the optimal level of control.

Pedigo et al. (1986) provides a tractable method of calculating the EIL. By modifying a model presented by Norton (1976), the authors define the EIL as:

$$EIL = \frac{C}{(V*I*D)} \qquad \textbf{(Equation 1)}$$

Where:

- EIL = the number of injury equivalents per production unit (e.g. insects/ac, all of which live to attain their full injury potential)
- C = cost of the management activity per unit of production (e.g. \$/ac)
- V = market value (utility) per unit of the produce (e.g. \$/lb)
- I = injury units per insect per production unit (e.g. proportion defoliated/(insect/ac)
- D = damage per unit injury, for example:

$$\frac{\text{lb reduction per acre}}{\text{(proportion defoliated)* (crop response to pest injury)}} \qquad \textbf{(Equation 2)}$$

Thus, Pedigo's EIL can be interpreted as being equal to the cost per unit value of damage caused by each individual pest. Since the EIL is defined in terms of pest populations, the cost of control must be equal to the total value of damage caused by pests. Thus, Pedigo's EIL does not conflict with Stern's definition.

The concept of the EIL is more valuable as a theoretical construct than as an empirical tool. In practice, it is often difficult or impossible to properly specify and estimate the damage function, rendering EIL calculations empirically intractable. However, the notion of the EIL aids in the conceptualization of pest control economics insofar as it provides a bridge between the biophysical aspects of pest control and economics.

II.2: Adoption

There is generally no direct output of IPM programs. Instead, the benefits of IPM research and extension are often realized only after producers adopt the technologies advocated by IPM programs. In other words, IPM benefits are manifested via changes in the techniques employed by producers. As such, IPM program appraisals are often assessments of the impact of producer adoption of IPM techniques and technologies. The first steps in most impact assessments will therefore be to specify exactly what is meant by ‘adoption’ and to determine the level of adoption.

II.2.1: Review of Adoption indicators

If a technology is discreetly applied, there is generally little or no difficulty in determining whether or not the technology has been adopted by a given firm. However, since IPM represents a set of control practices, it is often difficult to determine whether a producer has 'adopted' IPM. This is because producers rarely adopt IPM in its entirety, but adopt specific components of IPM. That is, farmers adopt techniques, not IPM (McDonald and Glynn, 1994). Thus, most farmers use IPM practices in combination with conventional practices. The implication is that IPM adoption is rarely dichotomous and therefore that some indication of the level of IPM adoption must be made.

Nevertheless, many studies have assumed that IPM adoption is an either-or situation. Such studies often include IPM adoption as a binary dependent variable in a regression model. For example, Fernandez-Cornejo (1992) included IPM adoption as a binary dependent variable in logit regressions directed at analyzing differences in the demographic and economic characteristics of adopters and non-adopters. Other examples of studies using adoption analysis with binary dependent variables include Harper (1990), McNamara (1991) and Thomas et al. (1990). However, Thomas used a binary adoption indicator for three practices then combined the variables to produce an adoption scale from zero to three.

More commonly, researchers distinguish between different levels of IPM adoption over some range from non-adopters to high-adopters. For example, in studies evaluating several IPM programs, Napit et al. (1988) and Vandeman et al. (1994) delineated producers into three IPM adoption categories: non-users, low-users and high-users. In the Napit study, producers were categorized based on their reported use of pest control practices, particularly scouting. Vandeman et al. developed crop specific IPM definitions, generally considering scouting and use of economic thresholds as “low-level IPM”, use of one or two additional practices as “medium-level IPM” and use of three or more additional practices as “high-level IPM.” Similarly, Kovach and Tette (1988) classified apple producers as either non, low or high adopters based on their use of monitoring devices, scouts and special spray methods.

In some cases, it may be possible to consider the use of a single technique as an indicator of IPM adoption. Such a treatment may be justified if the relevant IPM program is dominated by a single technique and/or the researcher is only concerned with the effect of a single technique. For example, McNamara (1991) first notes that scouting is the major component of the Georgia peanut IPM program, then uses producers' adoption of scouting as a proxy for IPM adoption. Specifically, McNamara determined that if a producer used scouting on 25% of his acres, he had adopted IPM. Another example is provided by Harper (1990) who was concerned only with the adoption of a single technology, insect sweep nets, by producers in the Texas rice belt. In this case, a producer's use of a sweep net was an absolute indicator of that producer's adoption of the technology.

More recently, continuous scales of IPM adoption have been developed. Continuous scales take one of two forms: point systems and weighting algorithms. Point systems are sometimes used by state IPM programs to certify growers as adopters. In these paradigms, various production practices are assigned points based on their compatibility with IPM. For example, Petzoldt (1998) provides a point system used for the certification of New York sweet corn growers, called “Elements of Sweet Corn IPM” (presented in the appendix). The point system includes 19 practices grouped into five categories: site preparation, planting, pest monitoring and forecasting, pest management, and post harvest. Each of the 19 practices was assigned a point value based on its importance and growers receiving 80% of the possible points were considered IPM adopters. Similar point systems have been developed for growers in Massachusetts (see Hollingsworth, et al., 1996) and for other crops in New York (Petzoldt, et al., 1998).

Mullen (1995) developed an "algorithm that transcends crops and locations but takes into account the proportion of available practices employed by producers and the importance of each class of pests" (Mullen, et al., 1997). First, a specific crop and growing region is identified. Next, the classes of pests that pose an "economic threat" to the producers of the crop are identified and assigned an indicator of the importance from 0 to 3. Finally, the numbers of alternative pest control practices that are cost effective for controlling each pest type are identified. Using this information, a degree of integration (DOI) is calculated as:

$$DOI = \frac{\sum_{C=1}^{n} \left(\frac{\text{employ}_C}{\text{available}_C} * \text{importance}_C \right)}{\sum \text{importance}_C} \quad \textbf{(Equation 3)}$$

Where:

- n = the number of relevant pest classes
- importance = importance of controlling each class (0,1,2 or 3)
- available_c = number of IPM practices available to control class c
- employ_c = number of IPM practices producer uses to employ c

Indicators of adoption will be somewhat arbitrary insofar as the researcher must determine which practices to consider, how use of practices will be measured and how individual measures will be aggregated into an adoption indicator. As noted by McDonald and Glynn (1994) , if an indicator of adoption is a single number, the indicator will either place value judgements on individual practices or will "collapse all individual variability" such that all practices receive the same weight. Point systems are subject to the problem of placing value judgments on individual practices since the weightings given to each practice must be determined and valued in some way. One might argue that other than the requirement that economically viable pest control techniques be identified, the DOI system does not require value judgments. However, weighting all practices equally implicitly places value judgments on the practices – the judgment that all practices are equally valuable. Further, the DOI system does value each control technique equally, thus "collapsing all individual variability. "

It may be appropriate to use an output-oriented definition of IPM when developing an indicator of adoption. As described by Swinton and Williams (1998), output-oriented definitions focus on the results of IPM rather than on the process(es) by which the results are achieved. For example, if an IPM program was designed to reduce environmental harm resulting from pesticide use (which is often the case), one might consider using an indicator of environmental impact to determine whether or not a producer is achieving the goals of IPM. One possible output-oriented IPM adoption indicator is the environmental injury quotient (EIQ), which purports to indicate the level of environmental and health risks posed by a producer's use of pesticides (see section II.5). Perhaps a location and crop specific definition could be derived that specifies ranges of EIQ values consistent with various levels of IPM adoption.

Predicting Adoption

Adoption should be predicted for future years if the level of adoption is expected to change significantly and if future benefits are to be assessed. For example, if a program is relatively new, the level of adoption may not have reached its peak. Also, there may be cases in which adoption is expected to decrease. In either case, program benefits will not be properly represented by the economic or environmental assessments unless adoption is predicted.

There is no preferred method for predicting adoption into the future. Studies that predict adoption generally are not clear about the methods used to derive adoption figures for future periods. However, expert opinion, analysis of historical trends and surveying techniques seem to be appropriate methods for the prediction of adoption.

If no data on historical adoption levels are available for the program, expert opinion might be useful. IPM program administrators and other industry representatives should be able to provide estimates of adoption levels into the near future. In order to provide results that are reasonably free of strategic bias, experts from various stakeholder groups might be consulted before estimating adoption levels.

Alston et. al.(1995) suggest a method for predicting adoption using expert opinion that may be applicable to new programs. First, adoption is specified as a logistic curve:

$$\mathbf{A_t = \frac{A^{MAX}}{1 + e^{-(\alpha + \beta t)}}} \qquad \text{(Equation 4)}$$

where:

- A_t = the actual adoption of a technology t years after it is released
- A^{MAX} = the maximum adoption rate (percent)
- α and β are parameters that define the shape of the curve.

The curve can be generated by defining three points on the curve. Alston et. al. (1995) suggest choosing three points that are easy to guess. For example, experts may be able to reasonably estimate the ceiling level of adoption (A^{max}) and the level of adoption in the initial period after the release of a technology (A_0). To guess the third point, experts might be asked to estimate adoption a few years into the future or to estimate how long it will take to reach a certain percentage of full adoption. Obviously, a similar procedure could be used for other functional forms if the analyst does not feel that a logistic curve is representative of adoption in the program in question.

A second option is to add questions that address future adoption to an adoption survey. Administrators of the IPM program should be able to predict changes in the program that are expected in the near future. After identifying the changes that will occur, questions on the adoption survey should be posed to address the future changes. For example, an IPM program may be evaluating a new pest resistant variety. Respondents would then be asked how likely they would be to adopt the technology given its expected cost, resource requirements and impact on profitability. A series of such questions that address future changes in the program could then provide a rough estimate of future adoption.

II.2.2: Discussion of Adoption Indicators

The above discussion suggests that it is usually appropriate to develop an adoption measure that does not consider adoption to be an either-or situation. In the literature review, several examples of adoption indicators that meet this criterion were provided from previous studies. These include point systems (e.g.Hollingsworth, et al., 1996, Petzoldt, et al., 1998), the definition of levels of adoption (e.g.Kovach and Tette, 1988, Napit, et al., 1988, Vandeman, et al., 1994) and the degree of integration (Mullen, 1995). Of these, point systems and the DOI appear particularly attractive since they provide continuous scales of adoption and thus allow for a more mathematically rich analysis.

However, there are drawbacks to continuous adoption scales. First, continuous scales are quite costly to set up. In the case of point systems, every technique must be identified and weighted according to its impact. This requires not only a workable definition of ‘impact’ but also a weighting for each technique. Further, if point systems were to be used in all IPM program appraisals, a point system would have to be set up for all but the few programs that already have developed them. Second, it is unlikely that a point system would be used in much of the economic and environmental appraisal of a program. In order to determine the environmental and economic effects of a program, researchers often model the effects of adoption at each of several predetermined levels.

Even when there is a continuous scale of adoption, researchers sometimes revert to the use of levels when performing the analysis. For example, Mullen (1995) first develops a continuous scale of adoption (the DOI) then categorizes producers as non-adopters, low-adopters, mid-level adopters and high-adopters based on their DOI scores.

If adoption is described in levels rather than as a binary indicator or continuous scale, it must be determined how each level will be defined. As discussed above, adoption indicators must be tailored to meet the needs of the IPM program. That is, definitions must be program specific. Ideally, levels of adoption would be based on how well adopters are meeting the goals of the IPM program. For example, high adopters should be meeting nearly all goals of an IPM program, while low adopters meet almost none of a program's goals. Such a delineation is necessarily somewhat arbitrary, although one can reduce the possibility that the delineation will be erroneous through careful consultation with experts familiar with the program in question.

Often the practices used in the assessment of adoption have an environmental or economic impact, but this is not necessarily the case. For example, some state IPM programs include sprayer calibration as a requisite to IPM adoption, but sprayer calibration has no discernable impact on pesticide use. Thus, sprayer calibration cannot be used in an environmental or economic impact analysis. It therefore seems appropriate to work with experts on a given program to develop adoption indicators that include practices with direct and discernable economic and/or environmental impacts.

In summary, one can think of adoption indicators as coming from two distinct categories: those based on ‘output’ oriented measures such as indicators of environmental and/or economic impact and those based on practices used, with the underlying assumption that the practices imply benefits. In either case, impact assessment will necessitate the formalization of the adoption indicator into an indicator of adoption. The above discussion suggests that this indicator be specified as a discrete polychotomous scale or a dichotomous indicator of adoption as appropriate to the case at hand. It was also noted that if a continuous adoption scale already exists, it might be appropriate to convert the continuous scale into levels of adoption.

II.3: User Level Economic Effects

The first step of an economic appraisal is usually to determine the effect of the IPM program on the net revenue of users. Such an analysis asks the simple question: how much does adoption of IPM at various levels affect the costs and returns of producers? Often, this question is answered by budgeting out changes in net revenue at each level of adoption. Sometimes, however, econometric or mathematical programming techniques are used to assess changes in net revenue or costs. The following sections will discuss some budgeting and econometric techniques for assessing the user level impacts of IPM adoption.

II.3.1: Review of Budgeting Analysis

The most commonly used technique for economic assessment of new crop production systems is budgeting analysis (Masud and Lacewell, 1985). Generally, budgeting is used to estimate net changes in revenues and costs resulting from (or associated with) changes in production practices. Two types of budgeting analysis are commonly used in assessing IPM: enterprise budgets and partial budgets. Enterprise budgets include estimates of all income and expenses associated with a single enterprise (e.g. a single commodity). By comparing enterprise budgets for an enterprise that has adopted a technology with one that has not, the effect of the technology on profitability can be assessed.

More commonly, *partial budgets* are used to analyze differences in net returns attributable to a practice. The difference between enterprise budgets and partial budgets is that enterprise budgets consider all cost and revenue changes for a single enterprise while partial budgets consider only cost and revenue items that are expected to change significantly. As such, when acreage is not expected to change, the partial budgeting "approach reduces to computing the change in per-acre profitability of the affected crops. If, however, the acreage of one or more crops are expected to change, one must make allowances for these changes" (Masud and Lacewell, 1985). Further, if aggregate production is expected to change significantly, changes in commodity prices must also be considered (Lacewell and Taylor, 1980).

Lacewell and Taylor (1980) note that the partial budgeting technique is "technically reasonable" as long as an economic surplus framework is used. However, the authors also note several problems associated with partial budgeting. The main "pitfall" of the approach is that one must subjectively specify how much acreages, production, price and other factors will change. Such subjective specifications are a drawback only because it is not always made clear how the estimates were obtained.

Since partial budgeting relates changes in management practices to changes in revenues and costs, the technique can be used to "impute net benefits [of] particular practices as they are added or removed from the budget." Specifically, partial budgeting can provide five types of information that are important at the producer level: "(1) how much … practices will increase costs; (2) how much benefits can be expected to increase; (3) if unit costs are influenced by the size of the operation; (4) how benefits and costs behave for varying levels of pest damage; and (5) how price received for the crop affects the feasibility of the recommended practices." (Headley, 1983) Further, partial budgeting can be used in an economic surplus framework to provide rough estimates of aggregate impacts (Lacewell and Taylor, 1980).

II.3.2: Discussion of Budgeting Analysis

Assessment of changes in farm-level income requires that the costs and revenues of farms at each level of adoption be modeled. The partial budgeting framework is particularly amenable to this task. By developing budgets for each level of adoption, changes in net revenue can be associated with the level of adoption itself. Finally, by assuming that adoption beyond a certain level is attributable to the IPM program, changes in net revenue can be associated with program participation.

The first step in the budgeting process is the development of partial budget forms. Often, budgets specifying all costs and revenues associated with growing a crop in a particular area can be obtained. Using expert opinion, the researcher needs to determine which cost and revenue items may differ as a result of participation in the IPM program. These items are included in the partial budgeting form.

Next, the partial budgeting forms need to be completed for each level of adoption. This will require data on inputs, outputs, prices, costs and perhaps demographic characteristics for each level of adoption. Such data can be obtained by adding questions to an adoption survey. Further, there may be secondary sources of data such as completed budgets from previous studies.

If a survey is not administered and there are not secondary sources of data, it may be possible to derive estimates of necessary data from field trials administered by the IPM program. It is likely that there are detailed data for the practices that have been tested by the program prior to release. If the practices used by farmers at different levels of adoption are known, field trial data may be associated with different levels of adoption for the budgets. However, the analyst must be aware that the costs incurred by actual farmers are likely to be lower than the costs suggested by field trials since farmers will be choosing a set techniques and practices with the goal of maximizing profits rather than assessing individual practices.

Finally, the budgeting forms can be filled out. If the only difference in farms is the level of IPM participation, net revenue figures obtained from this process can be interpreted as changes in net revenue due to IPM adoption. If it is suspected that there are significant systemic differences in farms at different levels of adoption, regression analysis may be used to correct for such differences.

After correcting for pest severity, farm size and other relevant variables, producers can be classified into adoption categories. Next, revenues and returns obtained from model farms, a producer survey or expert opinion can be used to complete the budgeting forms. Finally, differences in net revenue figures between adoption levels can be compared.

One should assure that net revenue differences are statistically significant before attempting to interpret the differences. Norton and Mullen (1994) suggest that t-statistics or ANOVA be used when enterprise or partial budgets are "used to compare [differences in] yields, costs, or profitability of alternative pest management practices." Norton and Mullen (1994), Napit (1986) and others recommend that the t-statistic to test for significant differences in means be specified as:

$$t = \frac{(\bar{x}_1 - \bar{x}_2)}{\sqrt{s^2(\frac{1}{n_1} + \frac{1}{n_2})}} \qquad \textbf{(Equation 5)}$$

where s^2 is the pooled variance:

$$s^2 = \frac{\left[(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2\right]}{(n_1 + n_2 - 2)} \qquad \textbf{(Equation 6)}$$

where:

s_1^2 and s_2^2 are the sample variances.

To test for significant differences in sample variances, Norton and Mullen (1994) and Napit (1986) suggest using a two-tailed test of the folded F-statistic (F'):

$$F' = \frac{(\text{larger of } s_1^2, s_2^2)}{(\text{smaller of } s_1^2, s_2^2)} \qquad \textbf{(Equation 7)}$$

Further, it is noted that *if sample variances are assumed to be different*, the t-statistic should be calculated as:

$$t = \frac{(\bar{x}_1 - \bar{x}_2)}{\sqrt{(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2})}} \qquad \textbf{(Equation 8)}$$

In summary, budgeting analysis begins by specifying a set of costs and revenue items that may differ by IPM adoption level. The data necessary to estimate each cost and revenue item for individual producers in a sample is collected and net revenue (NR) is derived for each producer[2]. The producers are then grouped according to their adoption levels and the expected net revenue for each level is derived. The change net revenue associated with adoption of IPM is calculated as $\Delta NR_j = NR_j - NR_{non}$ where ΔNR_j is the average change in net revenue attributed to adoption at level j instead of not adopting at all.

To determine the total farm level net revenue effect of the IPM program, the changes in net revenue from the sample are projected onto the entire population:

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[2] Note that NR only considers cost and revenue items that may change with adoption level and therefore does not represent actual net revenue

$$\sum_{j=1}^{m} \Delta NR_j * p_j * N \qquad \text{(Equation 9)}$$

where: p_j is the proportion of growers in category j. **(Equation 10)**

The total farm level net revenue change might be thought of as the short-run change in farm income due to the program. That is, the total farm level net revenue change does not consider changes in prices resulting from output changes and therefore may not represent an actual benefit. As discussed above, economic surplus analysis will be used to solve this problem.

II.4: Aggregate Economic Effects

Calculation of net revenue changes resulting from program participation can be useful. The exercise is intuitive and transparent, and results are readily interpretable. However, from the standpoint of project appraisal, the calculation is not as useful for several reasons. First, the assumptions that prices do not change and that supply does not shift may be unrealistic. Second, a change in net revenue may not accurately represent the net benefit to producers. This is especially true when the constant price assumption does not hold. Finally, changes in farm technology may affect the welfare of consumers, which is outside the scope of the budgeting framework.

II.4.1: Review of Economic Surplus Analysis

In this section, a method for addressing the shortcomings of partial budgeting will be suggested. This will be accomplished by modeling producer and consumer wellbeing using economic surplus analysis (ESA). Rather than assuming that changes in farm net revenue are the only effect of IPM programs, this method recognizes that changes in technology may be exhibited as changes in the cost of producing and that there are resulting changes in prices and quantities. The ESA method is used to assess changes in consumer and producer welfare resulting from such price and quantity changes.

The Concept of Consumer and Producer Surplus

An individual consumer's demand for a single commodity is defined as function of the market price. Since the demand curve results from the consumer's maximization of utility subject to a budget constraint, the consumer's demand curve can be thought of as a monetary measure of the benefit a consumer obtains from consuming a good. That is, the demand curve equates the quantity of a good consumed to the benefit obtained from the good and is therefore the consumer's marginal benefit curve.

For any given price, P, the consumer will demand a certain amount of the good, say Q. Recalling that the demand curve is downward sloping, for each unit of the good less than Q the consumer pays less than his/her marginal benefit of consuming the good. If this marginal benefit is totaled for each unit of the good consumed, the resulting figure will be the total consumer benefit from consuming the good. However, the total amount paid for the good (P*Q) will be less than the total benefit. The difference between the total benefit and the total amount paid is called the ‘consumer surplus.’ This is very similar to the definition provided by Mishan (1976) (following Marshall 1925) – “the maximum sum of money a consumer would be willing to pay for a given amount of the good, less the amount he actually pays.” More specifically, for an inverse consumer demand function p=f(q) - price as a function of quantity demand, the consumer surplus for any given equilibrium price (p) and quantity (Q) is defined as:

$$CS = \int_0^{Q'} P(Q)dQ - p * Q \qquad \textbf{(Equation 11)}$$

This definition of consumer surplus only holds if the consumer's utility function is quasilinear (linear in at least one good - see Varian (1992)).

Before discussing the producer surplus, it is useful to consider the concept of rents. Mishan (1976) defines rents as "the difference between what the factors, or productive services, of a resource owner earn in their current occupation and the minimum sum he is willing to accept to keep [them] there." Rents are therefore the obvious supply side counterpart to consumer surplus. The industry supply curve (assuming perfect competition) is equilivent to the industry marginal cost curve. Thus, the inverse supply curve, p = *f*(q), gives the minimum price (p) that a producer will accept in order to supply a certain level of output (q).

If the price of a good is above the supply curve at a certain quanitity, producers receive more for the good than the minimum acceptable price. This difference in price results in positive returns to the fixed (or quasi-fixed) factors of production and such returns are in fact rents accruing to fixed factors. Considering an equilibrium situation, the price of the good will just equal the *marginal* cost of producing it. However, recalling that supply curves generally slope upward, it can be seen that the marginal cost of producing any given unit less than the equilibrium quantity (Q) will be less than the price received for that unit. In equilibrium, fixed factors will accrue rents equal to the the sum of the difference in the price and the marginal cost of producing each unit of output. This value can be interpreted as the producer surplus and is equilivent to the area above the supply curve and below the price line:

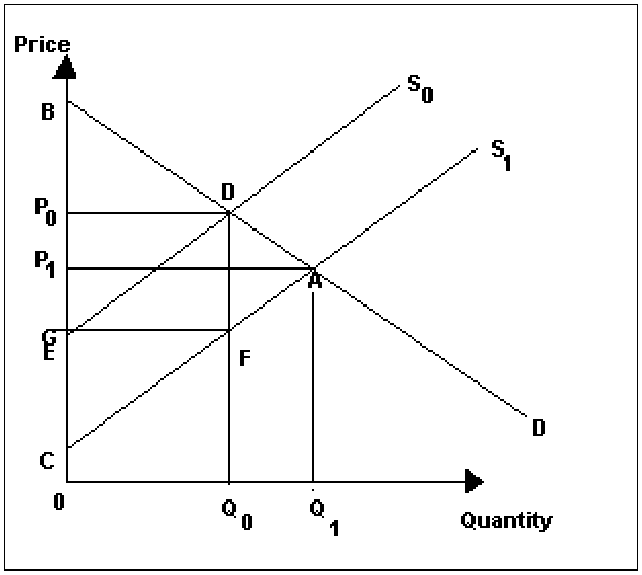
$$PS = PQ - \int_0^Q P(Q)\,\partial \mathrm{Q}$$ **(Equation 12)**

where: P(Q) represents the inverse supply function, P = *f*(Q).

It is useful to create a simplified case for graphical analysis. Consider a market with linear supply and demand curves that have positive price intercepts. This is represented in Figure 2 by the curves S_0, D and the associated price (P_0) and quantity (Q_0). In this case, the consumer surplus is P_0DB and the producer surplus is P_0DE.

Now consider some change in the economy that results in an increased supply of the good for any given price - perhaps a cost reducing production technology. The increased supply is denoted by a outward shift in the supply curve. In figure 1, this is represented by a shift from S_0 to S_1 and the resulting price and quantity changes. After the shift, consumer surplus becomes P_1AB and producer surplus becomes P_1AC.

Figure 2 : Consumer and Producer Surplus



Often, changes in consumer and producer surplus are of interest. In this case, the cost reducing technology changed consumer surplus by P_1AB - P_0DB. By refering to the diagram, it is obvious that this is equal to P_1ADP_0 which is definitely greater than 0. The producer surplus was changed by P_1AC - P_0DE. It is not readily apparent whether or not producers gain. However, some manipulation reveals that the net gain in producer surplus is P_1AFG. Any time a linear supply curve shifts in parallel, producers gain. However, producers loose if supply pivots about its price intercept and demand is inelastic (See Below).

When appraising a project, one is likely to be interested in the *net* change in consumer and producer surplus. If the change in both consumer and producer surplus is positive, which was unambiguously the case in the above example, the project is said to be Pareto safe - there are no 'loosers.' If, however, the change in either producer or consumer surplus is negative, the project is not Pareto safe even if the net change in consumer and producer surplus is positive (it is *potentially* Pareto safe). If this is the case, the project still has a positive net benefit, but some analysis of the distribution of that benefit might be in order.

II.4.2: Economic Surplus Analysis of IPM Programs

In the context of IPM program appraisal, the core assumption of economic surplus analysis (ESA) is that IPM adoption causes decreases in the cost of production. The subsequent downward shift of the supply curve results in a new market equilibrium in which prices are lower and quantities are higher. Thus, the consumer surplus unambiguously increases. Producer surplus may increase or decrease depending on the ESA specification used. The following sections will discuss two of the choices that must be made when performing ESA: the functional form of supply and demand and the type of supply shift.

Research Induced Supply Shifts

Linder and Jarrett (1978) describe three types of research induced supply shifts: divergent (pivotal or proportional), parallel or convergent. These are represented in Figure 3 where S_0 represents the initial supply curve, D represents the demand curve and S_1 represents the supply curve after innovation. The authors note that the level and distribution of benefits is affected by the nature of the shift. This can be seen in Figure 3, by observing the shaded areas, representing total benefits for each case.

Since the nature of the supply shift will affect the results obtained from an economic surplus model, choosing the correct type of supply shift is an important step in the modeling process. Further, the functional form of the supply curve will affect both the distribution and nature of benefits. Unfortunately, as noted by Alston, Norton and Pardey (1995), "economic theory is not informative about either the functional form of supply and demand or the functional form […] of the research induced supply shift." However, this does not mean that the choice must be made randomly. First, it is evident that specifying a divergent shift will tend to produce more conservative benefit estimates than a parallel shift and that a parallel shift will produce lower benefit estimates than a convergent shift (see Table 3).

Second, some insight may be obtained by considering the implications of a supply shift. A divergent shift (pivotal or proportionate) implies that the innovation reduces costs more for high-cost producers than for low cost producers while a parallel shift implies that the innovation reduces average costs by the same amount for all producers. Innovations that are likely to reduce the costs of marginal (high cost) producers while having a negligible effect on inframarginal (low cost) producers will therefore result in a divergent shift. By the same logic, innovations that result in equivalent cost reductions per unit output for all producers will then result in a parallel shift (Linder and Jarrett, 1978).

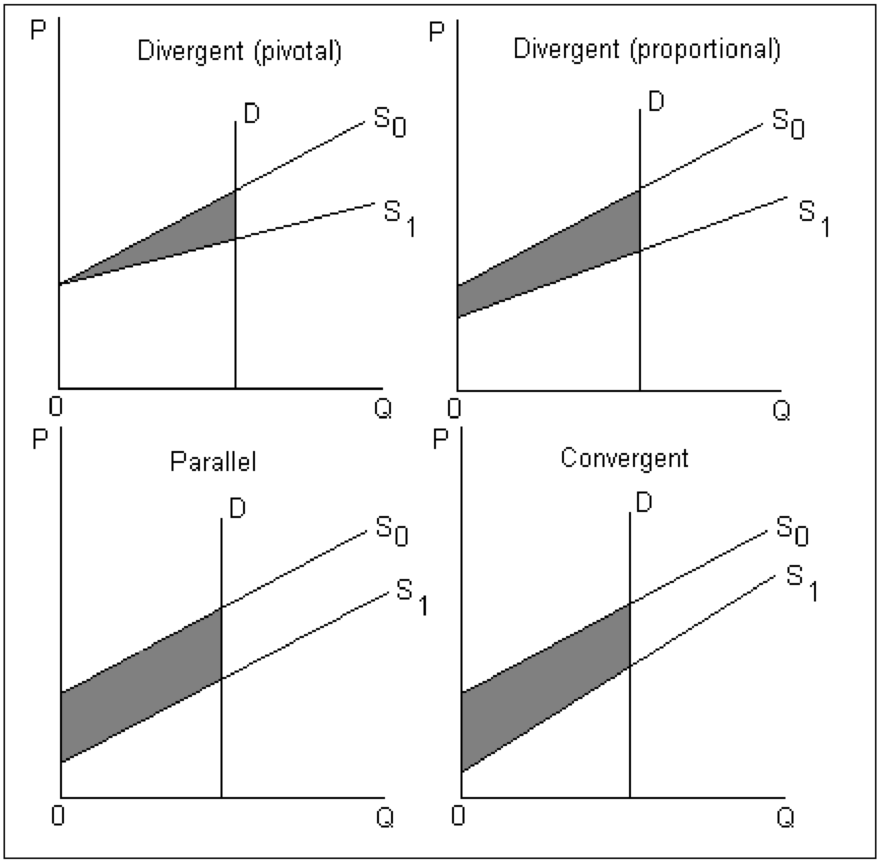


Figure 3: Types of Supply Shifts

A comparison of results derived using parallel and pivotal supply shifts is presented in Table 3. Results were derived with formulas presented by Alston, Norton and Pardey (1995). Two conclusions can be made by considering the table. First, parallel shifts produce positive producer surplus changes while pivotal shifts may produce negative producer surplus changes. Second, as stated above, total benefits are lower when calculated assuming a pivotal shift.

Table 3: Comparison of Benefit Estimates: Parallel vs. Pivotal Supply Shifts[3]

Elasticity		*PIVOTAL*			*PARALLEL*		
|η|	ε	TS	CS	PS	TS	CS	PS
0.01	0.01	0.0500	0.0500	0.0000	0.1000	0.0500	0.0500
0.01	0.5	0.0500	0.0981	(0.0481)	0.1001	0.0981	0.0020
0.01	1	0.0500	0.0991	(0.0491)	0.1001	0.0991	0.0010
0.01	2	0.0500	0.0996	(0.0496)	0.1001	0.0996	0.0005
0.25	0.01	0.0500	0.0038	0.0462	0.1000	0.0038	0.0962
0.25	0.5	0.0508	0.0672	(0.0164)	0.1008	0.0672	0.0336
0.25	1	0.0510	0.0808	(0.0298)	0.1010	0.0808	0.0202
0.25	2	0.0511	0.0899	(0.0388)	0.1011	0.0899	0.0112
1	0.01	0.0500	0.0010	0.0490	0.1001	0.0010	0.0991
1	0.5	0.0517	0.0339	0.0178	0.1017	0.0339	0.0678
1	1	0.0525	0.0513	0.0012	0.1026	0.0513	0.0513
1	2	0.0533	0.0689	(0.0156)	0.1033	0.0689	0.0344
20	0.01	0.0500	0.0000	0.0500	0.1000	0.0000	0.1000
20	0.5	0.0524	0.0025	0.0499	0.1024	0.0025	0.0999
20	1	0.0548	0.0050	0.0498	0.1048	0.0050	0.0998
20	2	0.0591	0.0099	0.0492	0.1091	0.0099	0.0992

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[3] Calculations assume that the proportionate downward vertical shift of the supply curve (κ) = 0.1 and the initial price and quantity are equal to unity (P_0=Q_0=1). ε and η refer to supply and demand elasticities at the initial equilibrium, respectively. Results assume linear supply and demand curves. (See below for more information)

The type of supply shift appropriate for use in the analysis of an IPM program must be determined for each analysis. The literature provides little guidance with this choice. One answer is provided by Lacewell and Taylor (1980) who state that: "[a] non-parallel shift will typically be the case because producers with low marginal costs (at the lower end of the supply curve…) will tend to be those without serious pest problems, while producers with high costs will tend to be those with pest problems and thus those that would be most benefited by new crop protection systems." Taken in context, it is clear that "non-parallel shift" refers to a pivotal-divergent shift rather than a convergent shift. Second, Linder and Jarrett (Linder and Jarrett, 1978) conclude their analysis of the subject with the statement: "*ceteris paribus* biological and chemical innovations are more likely to produce a divergent supply shift."

It is not immediately apparent that producers might suffer a loss with IPM. Since adoption is not mandatory, it does not seem likely that there would be any adoption if the result were a loss in producer surplus. With a pivotal shift, however, producers only gain if demand is elastic (or if $\varepsilon \leq 1$ and $\eta = 1$). For technologies that cause large decreases in cost, this may indeed be the case. This is because adoption decisions are made on an individual basis. As relatively innovative producers adopt, they experience excess profits. Faced with an inelastic demand curve, less innovative producers are forced to adopt as prices fall. The net result is that total revenue decreases when yield enhancing technologies are widely adopted and demand is inelastic[4]. For a given appraisal, the analyst must determine whether the IPM technologies are adopted widely enough and cause a large enough decrease in average cost for this to be realistic.

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[4] This is called the 'treadmill effect.' (Cochrane, 1979)

ESA Functional Forms

The functional form of the supply and demand functions must also be determined *a priori*. The most commonly used functional forms are linear and constant elasticity (CE). This does not imply that functional forms must be linear or CE – any valid specification could be used. However, it is very unlikely that the actual functional form will be known (e.g. see Rose 1980). As such, researchers often employ linear or CE supply and demand curves under the assumption that the specification is a sufficient (approximation) representation of the actual form. Before further discussion, methods for estimating surpluses using linear and CE frameworks will be presented.

ESA with Linear Supply and Demand

If the linear specification is used, the supply shift can be either pivotal or parallel. A parallel shift is represented in Figure 4 by a shift from S to S` and a pivotal shift is represented by a shift from S* to S'. Formulas for estimating benefit estimates with linear curves have been presented by Alston et. al (1995), Norton et. al {, 1987 #188, Rose (1980), Linder and Jarrett (1978), Voon and Edwards (1991) and others. Formulas developed by Alston et. al. (1995) will be presented below.

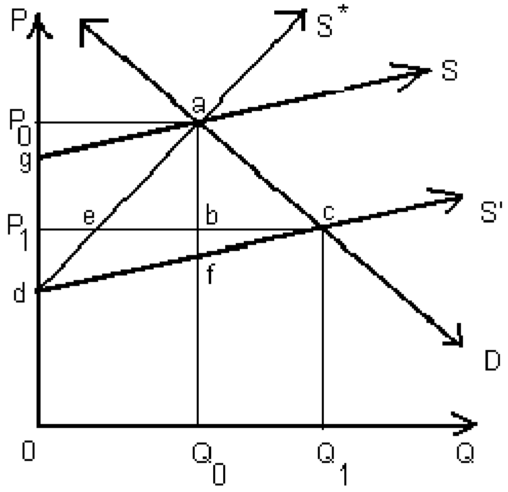

Figure 4:ESA With linear Curves

For a parallel shift, the change in consumer surplus (ΔCS) is represented by the area P_0acP_1, which is calculated as

$$P_0Q_0Z(1+0.5Z\eta) \qquad \textbf{(Equation 13)}$$

where:

- $Z = \dfrac{K\varepsilon}{\varepsilon + \eta}$
- ε is the equilibrium price elasticity of supply
- η is the equilibrium price elasticity of demand
- K is the proportionate downward shift in supply (the distance af/P_0 in the diagram)

The change in producer surplus ΔPS is represented by the area $dcP_1 - gaP_0$ and is numerically equivalent to $(K-Z)P_0Q_0(1+0.5Z\eta)$. The change in total surplus is calculated as $\Delta CS + \Delta PS$.

For the pivotal case, the change in total surplus (ΔTS) is represented by the area DAC and is calculated as $0.5KP_0Q_0(1+Z\eta)$. The change consumer surplus (ΔCS) is represented by the area P_0ACP_1, calculated as $ZP_0Q_0(1+0.5Z\eta)$. Finally, the change in producer surplus, represented by the area dec – P_0aeP_1, is calculated as $\Delta TS - \Delta CS$.

ESA with Constant Elasticity Supply and Demand

Now, the constant elasticity (CE) case will be developed. First, specify the inverse supply and demand curves as:

$$\textbf{demand: } P = \alpha Q^{-1/\eta} \qquad \textbf{(Equation 14)}$$

$$\textbf{supply: } P = \beta Q^{1/\varepsilon} \qquad \textbf{(Equation 15)}$$

The post-innovation supply curve, S’, will be:

$$P = (1-\kappa)\beta Q^{\varepsilon} \qquad \textbf{(Equation 16)}$$

The post-innovation equilibrium (Q_1, P_1) is found by solving S'(P) and D(P) simultaneously to obtain:

$$Q_1 = \left[\frac{\alpha}{(1-\kappa)\beta}\right]^{\left(\frac{1}{\frac{1}{\varepsilon}+\frac{1}{\eta}}\right)} \qquad \textbf{(Equation 17)}$$

Substituting this into D(P) results in:

$$P_1 = \alpha \left[\frac{(1-\kappa)\beta}{\alpha}\right]^{\left(\frac{1}{1+\frac{\eta}{\varepsilon}}\right)} \qquad \textbf{(Equation 18)}$$

The situation so far is represented in Figure 5.

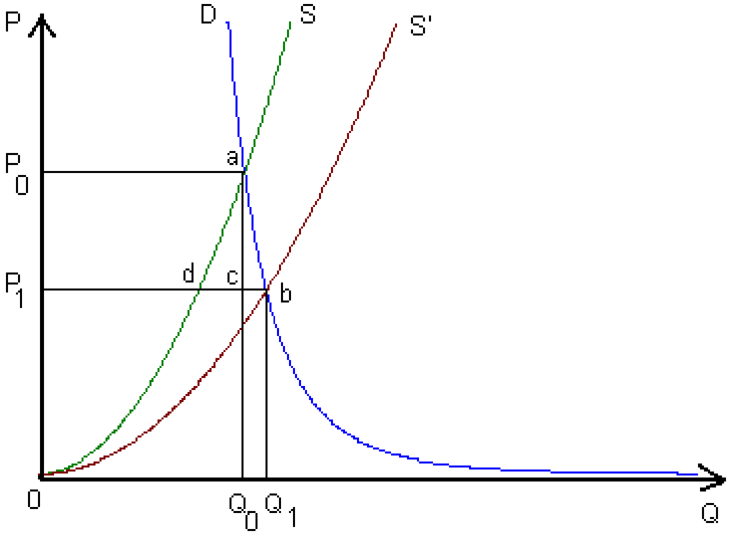

Figure 5: ESA with CE Curves

Now, the surplus areas can be calculated. The change in consumer surplus (ΔCS) will be the area P_0abP_1. The change in total surplus (ΔTS) will be the area 0ab. Again, the change in producer surplus will be caclulated as ΔTS - ΔCS.

Obtaining ΔCS is more straightforward when the demand curve is a function of P rather than Q. Solving D(Q) for P yields Q(P):

$$Q = \left(\frac{\alpha}{P}\right)^{\eta}$$

(Equation 19)

Integrating Q(P) over the range P_1 to P_0 will give the area P_0abP_1:

$$\Delta CS = \int_{P1}^{P0} Q\,dP = \int_{P1}^{P0} \left(\frac{\alpha}{P}\right)^{\eta} dP = \frac{\alpha^{\eta}}{1-\eta}\left(P0^{1-\eta} - P1^{1-\eta}\right)$$

(Equation 20)

The change in total surplus ΔTS is determined by integrating the inverse demand and supply curves:

$$\Delta \text{TS} = \int_{0}^{Q0} SdQ - \int_{0}^{Q0} SdQ + \int_{Q0}^{Q1} DdQ - \int_{Q0}^{Q1} SdQ$$

$$= \int_{0}^{Q0} SdQ - \int_{0}^{Q1} SdQ + \int_{Q0}^{Q1} DdQ$$

$$= \frac{\beta}{\frac{1}{\varepsilon}+1} Q_0^{1/\varepsilon+1} - \frac{(1-\kappa)\beta}{\frac{1}{\varepsilon}+1} Q_1^{(1/\varepsilon+1)} + \frac{\alpha}{1-\frac{1}{\eta}} \left(Q_1^{1-1/\eta} - Q_0^{1-1/\eta}\right) \qquad \textbf{(Equation 21)}$$

Linear vs. CE Functional Forms

Most economic surplus analyses of research benefits have used linear supply and demand curves because linearity simplifies the calculations necessary to calculate surplus changes (Alston, et al., 1995). The linear specification is generally considered adequate for the measurement of research benefits. However, the linear specification has been criticized. Such criticisms relate to the fact that the elasticity of supply (ε) is usually only known for a single point – the pre-innovation equilibrium. When extrapolating the rest of the supply curve, the slope of the curve is derived from this elasticity (as was done above). The result is that when ε is less than one (supply is inelastic) at the pre-innovation equilibrium, the price intercept of the estimated inverse supply curve will be below zero, implying that a positive quantity is supplied at a negative price. (Alston, et al., 1995)

In order to avoid the problem of a negative price intercept when supply is inelastic, Rose (1980) proposed that the supply curve be specified with a 'kink' at the initial equilibrium. Examples of calculations using kinked curves can be found in Rose (1980) for a parallel shift and Norton, Alston and Pardey (, 1987 #188} for a pivotal shift. Nonetheless, the surpluses calculated using kinked supply curves are the same as the calculated surplus without the kink (Alston, et al., 1995). Thus, there is little practical difference between analyses performed using kinked curves and those using linear curves although there is an important conceptual distinction.

Alston, Norton and Pardey (1995) also note that the constant elasticity specification is subject to similar criticisms. Since a constant elasticity inverse supply curve will always go through the origin, the minimum price at which the product will be supplied is zero. While not strictly a violation of economic theory, this is implausible in many applied cases. It is possible to use a variant of the constant elasticity specification that has a positive price intercept. An example of calculations using this specification is provided by Pachico, Lynam and Jones (1987). Alston and Wohlgenan(1990) note that this approach requires a non-linear algorithm to calculate benefits, and that the additional effort may not be justified (Alston, et al., 1995).

From the above discussion, there is no obvious conclusion regarding the choice between linear and CE supply and demand specifications. Some researchers, such as Voon and Edwards (1991) prefer the CE specification because it eliminates the possibility of a supply curve with a negative price intercept while the revealed preference of many others is obviously the linear specification. It does not appear that the use of the modified (positive intercept) CE form is warranted.

II.4.3: Discussion of Aggregate Economic Effects

Regardless of how the ESA model is specified, the analyst will need estimates for the pre-innovation elasticity of supply and demand (ε and η), the proportionate shift in the supply curve (κ) and the pre-innovation equilibrium quantity and price. Ideally, one would have estimated market supply and demand functions for the program area, rendering the determination of ε and η a trivial matter. Unfortunately, this approach is impractical in most cases and other techniques must be used to estimate κ. As will be seen, κ can be derived from a farm level budgeting analysis.

Under most conditions, ESA results will be relatively insensitive to changes in elasticity parameters and very sensitive to changes in the shift parameter. In an *ex post* study, an estimate of the shift parameter might be obtained from changes in costs or outputs as derived in the user level economic analysis. Estimating the shift parameter in an *ex ante* analysis may be more difficult since some knowledge of the technical production process and the effect of *potential* technological developments on that process will be required.

Before continuing, it should be noted that the shift parameter (κ) used in the above ESA models assumed a vertical supply shift. Other researchers specify a proportionate horizontal shift. The choice between a vertical or horizontal shift will not affect the benefit estimates derived (of course, the formulas used to calculate surplus estimates must be altered). Thus, the researcher should decide whether the program benefits are best characterized by a reduction in per unit costs or an increase average output. If the supply shift is measured as a supply increase, implying a horizontal shift, the proportional shift, ***J,*** can easily be converted to a κ-shift via:

$$\kappa = \frac{J}{\varepsilon} \qquad \textbf{(Equation 22)}$$

where ***J*** is the proportionate horizontal shift (Alston, et al., 1995, Napit, 1986).

In an *ex post* study, the κ value can be derived from the results of a user level economic analysis as the average decrease in per unit costs attributable to the program. Such a calculation implicitly requires that the researcher revert to a binary indicator of adoption. In most cases, the average per unit cost decrease weighted by the number of producers at each level of adoption will be appropriate (noting that the program has no effect on the production costs of non-adopters). In other cases, it may not be correct to assume that producers below a certain level of adoption benefit from the IPM program and the cost decreases of such producers should not be included in the weighted average.

If producer cost information is not available (e.g. if a user level economic appraisal was not conducted or in an ex ante study) it may still be possible to estimate κ. Alston et. al. (1995) describe several ways to obtain a κ estimate in such situations. The authors describe three sets of methods that may be useful in such situations: (1) econometric estimation of supply, profit, production or cost functions, (2) using experimental or industry data and (3) eliciting κ from scientists. In most cases, the data and time requirements of econometric estimations will be prohibitive and using experimental data or expert opinion will therefore be preferred.

The above discussion focused on deriving surplus measures for a single unit of time (usually 1 year). Often, it is desirable to calculate surplus measures over time to account for future and/or past impacts. Usually, the only variables that will be assumed to differ over time are the adoption rate and the cost of research.

The goal of a multi-year assessment will generally be to discount future benefits and costs in a way that recognizes alternative uses for funds (particularly foregone interest on funds invested in the program). This can be accomplished by calculating the net present value (NPV) of the project. NPV is defined as:

$$NPV = \sum_{t=1}^{T} \frac{R_t - C_t}{(1+i)^t}$$ **(Equation 23)**

where:

R_t = the return in year t = ΔTS
C_t = the cost in year t (the program costs)
i = the discount rate

The discount rate, *i*, ideally would be chosen such that it actually represents the opportunity cost of funds invested in IPM. In other words, it should equal the risk adjusted expected return on the next best alternative use for funds. However, it may not be appropriate to apply this approach to IPM investments. This is because government investments in IPM are made for the purpose of providing public goods and without valuation of all benefits (including environmental benefits) are therse investments are not comparable with traditional investments.

In summary, ESA is used to account for changes in prices resulting from an IPM induced change in output. IPM is usually assumed to reduce per-unit costs, resulting in a vertical supply shift. Given reasonable supply and demand elasticities, this will result in an increase in equilibrium output and corresponding changes in prices, consumer welfare and producer welfare.

II.5: Assessing Environmental Effects

IPM programs are not generally created with the goal of increasing producer profitability or consumer welfare. Rather, the programs are created and funded with the goal of providing non-market environmental benefits via reductions in pesticide use[5]. For example, as noted in the introduction, state IPM programs receiving federal funds are required by congressional mandate to "reduce pesticide use, minimize environmental contamination, and reduce pesticide exposure to farm workers"(Greene and Cuperus, 1991). Since environmental benefits are supposedly the primary dividend

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[5] It is important to note that farm level incentives such as increased profitability are the generally the impetus for farmer adoption of IPM. Thus, it is important to consider farm level economic benefits even if the primary goal of the IPM program is to provide environmental benefits.

of IPM programs, some indication of the level and nature of such benefits must be included in any complete program appraisal.

In this section, various methods and techniques for assessing the environmental impacts of IPM programs are reviewed. These methods include both economic and non-economic approaches to environmental assessment. The section begins with a discussion of various methods for describing environmental impacts in sections 5.1 and 5.2. After a brief digression on willingness to accept and willingness to pay, the economic valuation technique of contingent valuation is discussed. Next, costing methods such as the value of damages avoided are briefly described. The section concludes by specifying methods for environmental assessment of IPM programs.

II.5.1: Assessing the Environmental Risks of Pesticide Use

The environmental effects of pesticides depend on many complex factors. Further, it is difficult to quantify environmental effects. There are two reasons for this difficulty. First, the effects of pesticides on the environment and human health are not always well understood. More importantly, however, it is difficult to properly assign values to known or likely damages. The following section describes several algorithms that have been developed to assess the environmental and health effects of pesticide use.

A common indicator of the environmental and health impacts of pesticide use is the environmental impact quotient (EIQ) developed by Kovach et al (1992). The EIQ uses a discrete ranking scale in each of ten categories to arrive at a single rating for each pesticide active ingredient (AI). The categories include toxicity to non-target species (birds: 8 day LC_{50} and fish: 96 hr LC_{50} and bees), acute dermal toxicity (measured by rabbit or rat LD_{50}), long term health effects, residue half-life (soil and plant surface), toxicity to beneficials and groundwater/runoff potential. The EIQ formula groups the ten categories into three broad areas of pesticide action: farm worker risk, consumer exposure potential and ecological risk. The EIQ is then defined as the average impact of a pesticide AI over the three broad areas of action, generally reported as a single number.

The EIQ is defined for specific pesticide active ingredients. In order to make the EIQ meaningful in assessing the actual damage attributable to a farmer's use of pesticides, the EIQ must be converted into an *'EIQ field use rating*.' For a farmer applying only one pesticide to a field, this is accomplished by multiplying the pesticide's EIQ by the percent active ingredient then by the rate at which the pesticide was applied. For an applied example of EIQ calculations see Fernandez-Cornejo (1998).

Penrose et. al. (1994) proposed the Pesticide Index (PI) as an objective means of comparing the advantages and disadvantages of pesticide use. The PI is composed of two individual indices: the Potential for Residues Index (PRI) and the Value Index (VI). PRI calculations are based on the activity of the pesticide (A), the site of application (S), the timing of application (T) and the persistence of the AI (P). A, S, T and P are determined based on an integer scale from 1 to 5. For example, insecticide products receive a weight of 1 if they contain 10 or less grams of AI per liter.

The value index (VI) is an indicator of the "value or importance of the pesticide in any particular crop production system." It is based on the pesticide's efficacy (Ef), cost (Cs), environmental effects (En), mammalian toxicity (Tx), IPM compatibility (Cp) and the availability of alternatives. Each component of the VI is defined on a subjective integer scale from 1 to 5. PRI and VI are then calculated as the sum of the values given to their respective components. The pesticide index (PI) is then the sum of the value index and the Potential Residues Index. The PI recognizes that environmental damages (and benefits) from a given pesticide differ according to the environment in which the pesticide is used (e.g. location and time) and on the method of application. The authors conclude that the PI is an improvement on Kovach's EIQ since it allows for the consideration of the benefits of pesticide use in a given situation. However, the EIQ is only intended to measure damages, so the meaning of such a comparison is not clear. A more relevant comparison would contrast the PI with environmental EILs (see below).

Benbrook et. al. (1996) developed an indexing method to assess the aggregate risks of pesticide use to mammals. The index considered acute toxicity via LD_{50} values and developed a composite variable – the mammalian toxicity score (Mam Tox Score) to consider chronic effects. In most cases, the Mam Tox Score for a pesticide is composed of the pesticide's reference dose (RfD), cancer potency factor and an indicator of the pesticide's WHO classification (A, B or C).

Teague et. al. (1995) developed the Chemical Environmental Index (CINDEX) to describe the effect of pesticides on ground and surface water. CINDEX values are defined for individual pesticide use strategies. Calculations are based on the 96-hour fish LC_{50}, lifetime Health Advisory Level (HAL) value, the EPA Carcinogenic Risk Category and the runoff and percolation potential for each pesticide used in the strategy under consideration. The authors also present a second index, the Chemical Concentration Index (CONC). The CONC is based on the percolation and runoff potential of each pesticide AI in a given strategy, its LC_{50} and lifetime HAL values. The authors posit that the CINDEX and CONC are superior to the EIQ because they are calculated for individual production situations. As such, the index values will differ insofar as runoff and percolation levels are affected by localized factors such as soil type and irrigation systems.

There are many other indexing schemes. These include the Potential Environmental Hazard Index (Warner, 1985), the Environmental Harm Coefficient (Alt, 1976), Environmental Impact Points (Reus, 1998) and PERSIST (Barnard, et al., 1997).

Other types of pesticide indexing schemes are described by Levitan et al. (1995), (vanderWerf, 1996) and (Teague, et al., 1995).

It is important to note that using a relatively complex algorithm to assess the environmental effects of pesticides does not remove the subjectivity of the resulting indicators of risk. For example, both the CINDEX and CONC rating schemes rely on the relatively complex GLEAMS simulation model to derive site specific percolation and runoff potentials (chemical loadings). Nonetheless, the analyst must specify the relative importance of surface and groundwater (Teague et. al. weighted both equally). Thus, the resulting rating is not rendered value free.

Perhaps the most important distinction between the various weighting algorithms relates to their accuracy with respect to localized conditions such as soil type and irrigation systems. The environmental effects of pesticides differ according to such localized factors and a completely accurate assessment of pesticide risks therefore requires their consideration. Simulation based approaches (e.g. those derived from GLEAMS type models) are arguably more accurate because they are calculated based on local conditions. However, it is important to note that the data requirements of localized models greatly exceed those of non-localized models such as the EIQ. For example, in an environmental assessment, CINDEX calculations must be made for each field, incorporating information on soil, cropping systems and irrigation into the underlying simulation model. EIQ calculations only require knowledge of total pesticide a.i. changes. Quoting Teague (1995): "… an important shortcoming of EIQ, and similar indices which do not incorporate chemical loading estimates in the risk assessment, is that their value is strictly a function of the chemicals used in the production system. The index value is not influenced by other factors involving management decisions and natural conditions, such as soil type, irrigation system, and irrigation level." While this is indeed a shortcoming, it is also provides benefits in the form of decreased analytical requirements. Most types of analysis require that the researcher assess this tradeoff when choosing assessment techniques.

Indexing schemes provide methods for demonstrating the environmental and health benefits of reductions in pesticide use. For example, the environmental assessment of an IPM program might simply demonstrate that the field use EIQ has been lowered. Sometimes, researchers forgo indexing schemes altogether and simply report reductions in per acre a.i. applications because of IPM adoption, thus implying associated health and environmental benefits.

Each of the above indexing schemes is a member of a set of assessment and decision-making models known as *scoring models.* Scoring models attempt to account for and reconcile multiple decision criteria with less information than would otherwise be needed (Alston, et al., 1995). In addition to requiring less information, scoring methods are often less computationally and theoretically demanding than other assessment methods (e.g. statistical analysis or economic valuation).

Often, objections to the indexing schemes are actually objections to the use of simple scoring models in general. Alston et. al. (1995) list several reasons why one might object to the use of scoring models. Some objections are that scoring studies often have a weak conceptual framework, a limited methodological basis and appear to have "been conceived and executed in an *ad hoc* fashion." Thus, some objections are not related to scoring per se, but to the way in which *most* scoring models are constructed and implemented. However, the majority of objections to scoring models do not relate to their construction or implementation but to the subjectivity of weightings, and to their tendency to mathematically manipulate units of measurement that are not compatible. For example, the meaning of the EIQ is somewhat unclear because of the addition, subtraction and multiplication of such variables as toxicity, leaching potential and pesticide half-lives. Further, it is not clear whether or how the resulting figure can be properly aggregated. Often, the figures obtained from scoring models are not readily interpretable and may not be reconcilable with other decision criteria. For example, EIQ values calculated for an IPM project cannot be readily compared with financial indicators from other projects, causing difficulty when choosing between alternative investments.

The following sections will propose contingent valuation as a method for at least partially remedying the problems associated with scoring models. As will be seen, composite figures such as EIQ values will not be of much interest in the CV approach. However, the underlying assignment of risks to environmental categories (e.g. acute human toxicity) made when deriving composite figures will prove quite useful.

II.5.2: Contingent Valuation (CV)

Contingent valuation is a technique by which analysts attempt to elicit consumer valuations of non-market goods and services (Pearce, 1995). Either using a survey or experimental techniques, individuals are asked what they are willing to pay to receive a benefit (WTP) or what they would be willing to receive in compensation for a cost (WTA). The goal of such questions is to obtain bids for non-market goods and services that are close to those that would be revealed if a market actually existed (Pearce and Turner, 1990).

In the present context, the use of CV WTP/WTA estimates provides a solution to some of the problems associated with scoring models. This section will proceed in three steps. First, the ideas of WTP and WTA will be developed in the context of non-market goods and services. Next, CV will be described as a method for eliciting WTP and WTA estimates. Finally, methods for using CV elicited WTP and WTA estimates as weightings in pesticide indexing schemes will be presented.

WTP and WTA in CV

The goal of CV analysis is to derive WTP or WTA estimates for changes in non-market goods and to use such estimates as a proxy for changes in consumer welfare. As such, it is important to understand the relationship between WTP/WTA, environmental assets and utility. This sub-section, adapted from a discussion presented Diamond (1993) will clarify these relationships.

If a consumer's utility is defined as a function of commodities consumed and the status of an environmental asset, a standard preference problem can be defined as:

$$\max U(x,z) \text{ subject to: } px \leq I \qquad \textbf{(Equation 24)}$$

Where:

- x is a vector of commodities consumed
- z is an n-vector consisting of zeros and ones where a zero at position m indicates the status of the m^{th} environmental asset ($0 < m \leq n$)
- p is a vector of commodity prices.
- I is the consumer's income

Thus, the problem is to maximize utility subject to a budget constraint. The optimized level of utility with prices normalized will be a function of income (I) and the state of the environmental assets (z). Conversely, if a level of utility, say U_1, is first established, an expenditure function, $E(p,z,U_1)$, can be used to show the amount of income needed by the consumer to obtain U_1 when the environment is in the state indicated by z.

Further, the level of expenditure needed to obtain an optimized utility level, U_1, is equal to the income for which that level was achieved. Substituting U_1 into the expenditure function, this equality implies:

$$E(p,z,U_1(I,z)) = I. \qquad \textbf{(Equation 25)}$$

If the 4th environmental asset was not threatened, assuming that n - 4 were threatened, the z vector would be written as:

$z_1=[0,0,0,0,1,\ldots,1]$

and if the 4th asset was threatened, it would be written as:

$z_2=[0,0,0,1,1,\ldots,1]$.

Assuming that z is increasing in all elements, it is obvious that:

$U(x,z_1) > U(x,z_2)$

And therefore, for any level of utility U_1 (or income), WTP to preserve the 4th area is defined as:

$$\mathbf{WTP = E(p,z_2,U_1) - E(p,z_1,U_1)} \qquad \textbf{(Equation 26)}$$

That is, WTP gives the change in income that would be necessary to maintain U_1 given a change in the environment from z_2 to z_1.

If an additional environmental asset is to be exploited, a different z vector may be defined, say z_3. As was the case above, the environment is currently described by z_2. Thus, the environment is now going to be degraded. Consumers are therefore asked how much they would be willing to accept in compensation for this degradation. Implicitly, respondents are being asked to derive their WTA such that their utility remains constant at U_1. Thus, WTA can be defined as:

$$\mathbf{WTA = E(p,z_3|U_1) - E(p,z_2|U_1)} \ \ \textbf{(where } \mathbf{U_1} \textbf{ is associated with } \mathbf{z_2}\textbf{)} \qquad \textbf{(Equation 27)}$$

However, there is no need to assess WTP and WTA using the same starting point (z_2). It is useful to compare the WTA for a change from z_1 to z_2 with the WTP for a change from z_2 to z_1. Since the starting point is better (z_2 instead of z_3), the utility level to be maintained must also be higher, say U_2. Thus,

$$\mathbf{WTA = E(p,z_2|U_2) - E(p,z_1|U_2)} \qquad \textbf{(Equation 28)}$$

and, WTP for a change from z_2 to z_1 was:

$$\mathbf{WTP = E(p,z_2|U_1) - E(p,z_1,U_1)} \qquad \textbf{(Equation 29)}$$

Thus, the difference between WTA and WTP for this case results from the different utilities being maintained (U_2 and U_1) rather than from the environmental starting point. It is expected that the difference between WTA and WTP will equal the difference between:

a) the amount of income needed to raise utility from U_1 to U_2 when the environment is at z_1 and

b) the amount of income needed to raise utility from U_1 to U_2 when the environment is at z_2.

It is therefore accepted that WTA and WTP will significantly diverge for large changes in the environment. However, WTP and WTA should be approximately the same for smaller changes.

The important point is that WTP and WTA estimates provide a monetary valuation of changes in environmental assets. As was shown, WTP/WTA for an environmental change can be interpreted as a change in consumer income and is comparable with other changes in income.

Efficacy of CV in Eliciting WTP Estimates

Many scientists, including a subset of economists, argue that estimates of WTP and WTA derived using CV are unreliable. Given that there is generally not a market price for the commodity in question, it is not usually possible to validate WTP estimates by reference to known WTP values. Further, prices for market goods are not necessarily analogous to WTP estimates for an environmental asset as the latter include non-use values that have no counterpart in market prices.

Nonetheless, CV WTP estimates should meet certain criteria if they are to be considered reliable. Carson (1997) notes that CV opponents often contend that if CV is reliable, "willingness to pay and willingness to accept CV estimates should be fairly close, that income elasticities should generally be fairly large if most environmental amenities are luxury goods, that the value of the good should not change much with the order in which it is valued, and that different ways of eliciting CV responses should yield similar responses." Opponents often argue that CV estimates are not reliable since CV results often do not meet these criteria.

Carson's first criterion, that WTP and WTA estimates should be close, has been the focus of several studies. For example, Cummings et al. (1986) reported WTP and WTA estimates from several studies, each of which seem to diverge significantly (see Table 4). It is interesting to note that in every result reported by Cummings et al., WTA was higher than WTP even though the researchers' a priori expectations were that the values would be similar. One possible explanation is provided by Hanemann (1991) who notes that WTA measures are unbounded while WTP estimates are constrained by

Table 4: WTP vs. WTA Estimates {Cummings, 1986 #182}.

Study	*WTP*	*WTA*
Hammack and Brown (1974)	$247.00	$1,044.00
Banford et al. (1977)	43.00	120.00
	22.00	93.00
Sinclair (1976)	35.00	100.00
Bishop and Heberlein (1979)	21.00	101.00
Brookshire et al. (1980)	43.64	68.52
	54.07	142.60
	32.00	207.07
Rowe et al. (1980)	4.75	24.47
	6.54	71.44
	3.53	46.63
	6.85	113.68
Hovis et al. (1983)	2.50	9.50
	2.75	4.50
Knetsch and Sinden (1983)	1.28	5.18

income. Thus, at least for very large changes, WTA may indeed exceed WTP. Pearce and Turner (1990) provide an alternative explanation from psychological theory – that individuals value loosing something they already own more than they value gaining something new. [6] The implication is that since WTA implicitly values a loss while WTP values gains, WTP should be lower than WTA.

Carson's second criterion was that WTP income elasticities for environmental assets should be large. Assuming that environmental assets are indeed luxury goods, one would expect WTP income elasticity estimates to be at least unity. However, CV studies often derive income elasticities of WTP for environmental assets that are between 0.2 and 0.6 (Diamond, et al., 1993). One possible explanation is that a consumer's stated WTP may be derived from some combination of preferences *and* notions of political correctness (McFadden and Leonard, 1993). A second possibility is that some environmental assets may be perceived as being critical to achieving a tolerable existence (which would negate the assumption that environmental assets are luxury goods). Finally, Flores and Carson (1997) show that the income elasticity of WTP is not the same as the income elasticity of demand. Specifically, they show that "the income elasticity of WTP is equal to the product of income elasticity of demand, the matrix of substitution terms, and the ratio of disposable income to total virtual income (disposable income plus implicit value of available public goods)." Since the final term is always less than one, it is expected that the income elasticity of WTP will always be less than the income elasticity of demand (Carson, 1997).

Carson's final criterion was that "different ways of eliciting CV responses should yield similar responses." In other words, other things being equal, WTP responses should be approximately the same regardless of the type of question used to

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[6] It should be noted that maintenance of the status quo in this case may not compatible with the assumption that consumers maximize utility (Pearce and Turner, 1990).

elicit the response. However, most researchers do not believe that this is the case. For example, there “appears to be a widespread belief that discrete response (closed-ended) contingent valuation questions yield substantially larger estimates of the mean … WTP in comparison to estimates developed from open-ended (payment card) responses” (Huang and Smith, 1998). In any event, it seems to be generally recognized that the design of CV surveys does impact the answers obtained. Therefore, a great deal of attention must be paid to the wording and order of questions and to the method used to obtain answers (e.g. length and timing of interviews or questionnaires).

There are several other problems associated with contingent valuation. These problems are usually addressed in relation to several biases that contingent valuation is said to produce. In other words, the problems associated with contingent valuation are often said to result from the tendency of the technique to produce WTP and WTA estimates that are either not correct on average or are distributed differently from the actual WTP and WTA.

Pearce and Turner (1990) group the possible biases of CV into 4 broad categories: strategic bias, design bias, hypothetical bias and operational bias. Strategic bias results when respondents have an incentive to report a lower WTP than they actually feel is appropriate (McFadden and Leonard, 1993). Strategic bias may occur if respondents feel that the survey is not hypothetical, and the good in question is a public good or has the features of a public good. In such cases, the 'free rider' problem emerges and individuals determine that their optimal strategy is to under-report their demand for the good. While strategic bias is a potential problem, CV studies have found that strategic bias is not significant (Pearce and Turner, 1990).

The design biases are a result of the way a survey is administered or worded. The first source of design bias is starting point bias. If an interviewer suggests a starting bid in a bidding game, respondents may bid relative to the starting point rather than by determining their actual WTP. Further, respondents may agree "too readily with bids in the vicinity of the initial bid in order to keep the [bidding] game as short as possible" (Pearce and Turner, 1990) The second source of design bias is known as vehicle bias. Vehicle bias results from differences in respondents' WTP based on differences in the payment mechanism by which they will supposedly be required to pay. Finally, information bias is a result of the quantity and quality of information with which respondents are provided.

Since there is no [market] alternative to CV when measuring nonuse values, there is “no standard against which CV answers can be compared to detect bias.” However, there have been many attempts to compare CV WTP results to other non-market valuation techniques. Shabman and Stephenson (1996) reviewed several such studies. The results of the studies were inconclusive: some researchers found that CV generated similar results to other non-market valuation techniques while others found that the results of different techniques differed significantly.

The Case for Contingent Valuation

As stated above, contingent valuation techniques can be used to elicit values (WTP and/or WTA) for changes in the environment. In this capacity, contingent valuation has several benefits. First, the technique is very flexible. Since CV uses hypothetical questions to value a commodity, contingent valuation surveys can be used to obtain WTP data for any commodity (Mullen, 1995). Second, CV results are easily interpreted in an economic framework. Since CV surveys ask respondents to indicate how much they would accept in compensation for a certain cost or how much they would pay for a benefit, the survey data can be interpreted as an indicator of the respondent's perceived tradeoff between income and changes in the asset being valued. Thus, WTP and WTA data is directly interpretable as respondents' compensated Hicksian variation (Diamond and Hausman, 1993). Finally, contingent valuation is often the only technique available for benefit estimation when there are changes in non-market goods (Pearce and Turner, 1990).

Although contingent valuation is subject to various biases, there is considerable evidence that contingent valuation is capable of providing useful information about non-market values. For example, Schulze, d'Arge and Brookshire (1981) found that various methods of environmental valuation, including the travel cost method, the hedonic method and contingent valuation can give values within one order of magnitude of each other. Further, comparisons of the travel cost method with contingent valuation often show that the techniques yield similar results. "Therefore, the choice between techniques may be largely determined by the specific study being designed and the […] issues to be addressed" (Deloitte & Touche Consulting Group1996).

The use of CV was harshly criticized by the oil industry after the government used the procedure to value damages from the 1989 Exxon Valdez oil spill. In response to these criticisms, the National Oceanographic and Atmospheric Administration (NOAA) commissioned a “blue ribbon panel” (including Kenneth Arrow and Robert Solow) to evaluate CV as a method for damage assessment. The panel issued a circumscribed approval of the use of CV as a method for estimating non-use values. While rejecting many of the more extreme claims of CV opponents, the panel expressed concern over several issues and issued recommendations for minimizing some of the problems associated with CV (Carson, 1997). The panel’s conclusion was that “CV studies can produce estimates reliable enough to be the starting point for a judicial or administrative determination of natural resource damages – including passive use values.” More information on the NOAA panel findings, including the panel’s specific guidelines for CV surveys, can be found in Randall (1997).

Combining Pesticide Risk Rankings and Contingent Valuation

It was noted above that the major problems with pesticide indexing schemes result from the subjective nature of the weightings given to various criteria. The weighting problem results because there is no market mechanism through which the environmental and health effects of pesticides are realized by producers. As such, the full social cost of pesticide application is not accounted for by producers and the level of pesticide application is decided with the goal of attaining a private optimum. If all social costs of pesticide use were included in the private costs of producers, there would be little question that the level of use coincides with the socially optimal level of use. Thus, there would be no need to concoct weighting schemes to determine the effects of pesticides as these effects would be internalized in the decision-making process of producers.

Free market prices encapsulate a great deal of information about technologies, social and private costs and benefits, substitute technologies, preferences etc. Such information is obtained through the market interactions of many individuals. Thus, prices provide a natural weighting of the objectives of society at large.

Since the costs of pesticides and pesticide applications do not fully reflect the social costs of pesticide use, there is no way to interpret them as indicators of the environmental damage caused by pesticides. Two solutions to this inadequacy present themselves. First, tradable quotas or similar quasi-market mechanisms could be put in place to force producers to consider social costs when using pesticides. If these mechanisms were perfectly set up, market interactions would ensure that pesticides are used at socially optimal levels. In the case of tradable quotas, quota prices would reconcile the private benefits of pesticide use with the social costs. A second possibility is to determine WTP/WTA estimates for the environmental risks associated with pesticide use and to use these estimates in lieu of market 'prices' for environmental and health damage. Obviously, the former approach is only theoretically interesting. As such, the remainder of this section will discuss studies that have used the latter approach to determine the environmental and health costs of pesticide use.

Both Pedigo et al. (1986) and Winterstein & Higley (1990) suggest that including environmental risks in the EIL calculation will "improve IPM decision making." (Higley and Wintersteen, 1992) Higley and Winterstein (1992)suggest an EIL model that considers "risks to various environmental categories by specific pesticides" and assigns a cost to the risks. The suggested model is a slight modification of the EIL model presented by Pedigo et. al. (1986), and is presented as:

$$\mathbf{EIL = (EC+PC)/VIDK} \qquad \textbf{(Equation 30)}$$

Where:

- EC = environmental cost
- PC = pesticide and application costs (same as "C" in Pedigo's EIL model).

Of interest here is the addition of environmental costs to Pedigo's EIL. The analysis proceeded in several steps. First, levels of risk (high, medium and low) were assigned to each relevant pesticide in each of eight environmental categories[7] based on secondary data. Next, a survey was administered to determine the relative importance of each category to respondents and their willingness to pay (WTP) to avoid each level of risk from a pesticide per application per acre. Interestingly, Higley and Wintersteen distributed the CV survey only to crop producers. They reasoned that since their goal was to create environmental EILs, “it was most appropriate to survey those who would use environmental EILs.”

It seems that the Higley and Wintersteen’s goal in creating the environmental EIL was to internalize environmental costs. External costs are borne by society at large and a proper WTP estimate would therefore require a more diverse sample. However,

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[7] The categories were: surface water, ground water, aquatic organisms, birds, mammals, beneficial arthropods acute human toxicity and chronic human toxicity.

the approach should work well if the goal is to help farmers include their personal valuation of environmental assets in pesticide use decisions.

The survey elicited a rating of each category on a scale from one to ten. The relative importance of the i^{th} category was then calculated as the ratio of the importance of that category to the sum of the importance of all categories. The value of the environmental effect of a given pesticide was calculated as the product of the relative importance of the category and the per-acre WTP to avoid the pesticide's associated risk level in that category. Higley and Wintersteen's relative importance estimates are presented in Table 5. WTP estimates for low, moderate and high risk were $5.79, $8,76 and $12.54, respectively.

Table 5: Higley and Wintersteen's Relative Importance Estimates

	Importance	
Environmental Category	**Importance ± SD**	**Relative**
Surface Water	8.78 ± 1.69	0.1267
Ground Water	9.26 ± 1.43	0.1336
Aquatic Organisms	8.19 ± 2.04	0.1182
Birds	8.07 ± 2.09	0.1162
Mammals	7.83 ± 2.24	0.1130
Beneficial Insects	8.29 ± 1.94	0.1196
Humans - chronic	9.45 ± 1.36	0.1362
Humans – acute	9.44 ± 1.37	0.1362

Mullen (1997) uses an environmental risk valuation approach similar to Higley and Wintersteen's (1992). First, secondary data is used to classify each relevant pesticide as high, moderate or low risk based on the pesticide's effect on groundwater, surface water, acute and chronic human health, aquatic species, avian and mammalian species and non-target arthropods. Thus, each pesticide is classified by its effects in each of 8 categories and the level of its effect (low, moderate and high), resulting in "24 risk/environmental classes for pesticides." Next, the effect of the IPM program on pesticide use is estimated using regression analysis. Finally, the value of pesticide reduction is estimated using a contingent valuation survey (CVS) and combined with the estimated reduction in pesticide use attributable to the program to derive the value of the program's environmental benefit.

The CV survey was sent to 3,000 households across the nation. Of the surveys sent to usable addresses, 15.4% were returned and usable. In the CVS, respondents were asked their WTP to avoid each level of risk in each category (with appropriate explanation of risk levels and categories). Respondents were also asked to rate (from 0 to 6) the importance of avoiding each level of risk for each environmental category. Finally, the WTP for each level of risk in each category was calculated as the product of the proportionate importance of the category and the WTP for avoidance of the level of risk.

Program benefits were calculated by simultaneously considering the effect of the program on pesticide use, the calculated WTP and the calculated environmental risk for each pesticide. For a single pesticide, the value of the program ("savings in external costs") was calculated as the product of the proportionate reduction in pesticide use for each risk/category class, the WTP for reduction of risk in each risk/category class and the number of households in the relevant area (study area). WTP estimates for the avoidance of high, medium and low risks were \$35.50, \$22.77 and \$13.78 per month, respectively. Importance estimates were not presented but are easily disaggregated. The result of this disaggregation is presented in Table 6.

Mullen’s WTP estimates are for complete avoidance of risk from pesticide use. In the analysis, Mullen assumed (implicitly) that WTP is a linear function of the risk level and that the risk level is a linear function of the amount of pesticides applied. Thus, total WTP could directly expressed in terms of pesticide use and a given change in one will result in a proportional change in the other. However, a linear function may not properly characterize the relationship between environmental damage and pesticide use (Dushoff, et al., 1994). It is more likely that marginal will increase with increased pesticide use (at least in the relevant range).

Table 6: Mullen's Importance Estimates

	Risk Level		
Category	**High**	**Moderate**	**Low**
Acute Human	0.121	0.127	0.126
Chronic Human	0.129	0.138	0.137
Ground Water	0.128	0.135	0.135
Surface Water	0.124	0.129	0.128
Aquatic Species	0.123	0.126	0.127
Avian Species	0.117	0.119	0.118
Mammalian Species	0.116	0.119	0.120
Arthropods	0.106	0.109	0.109

Mullen's basic approach was to obtain WTP estimates based on the current state of the environment (with the program) and to predict WTP without the program by assuming a linear functional form for the damage function. If *marginal* environmental damage increases with pesticide use, the Mullen approach will underestimate WTP for a partial reduction in pesticide use (see Figure 6)[8]. Even if this is the case, it may be more appropriate to produce conservative results using a linear function, especially when there is insufficient data to properly specify a nonlinear damage function.

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[8] The same problem would occur in an ex-post study although the analyst would project WTP for a reduction from a lower point on the damage function to a higher point.

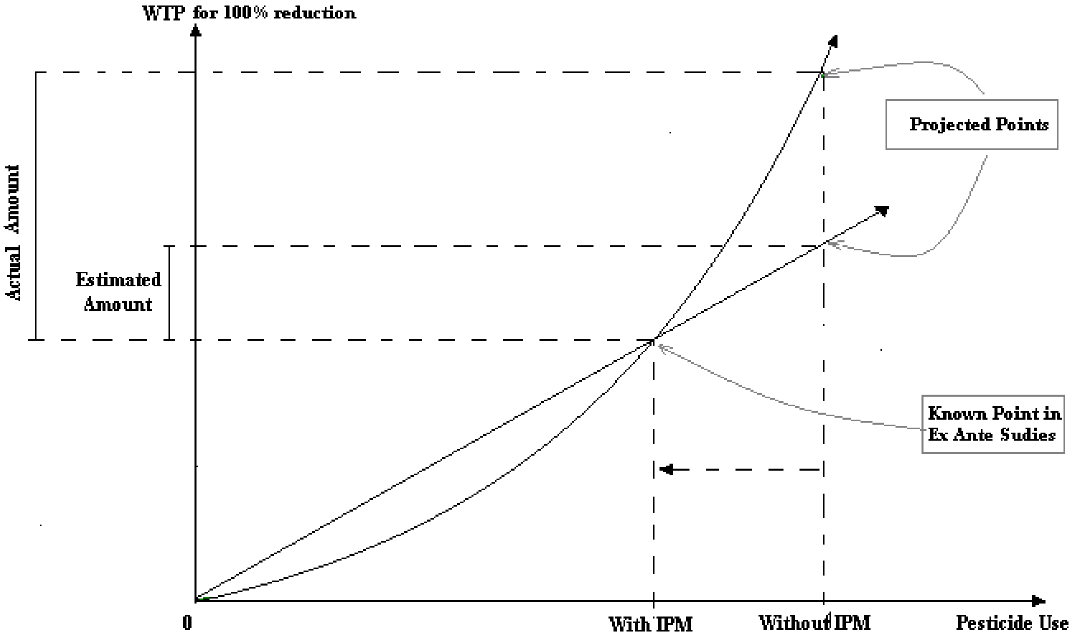

Figure 6: Concave vs. Linear Pesticide Damage Curves

II.5.3: Cost Approaches

Cost approaches attempt to value an environmental damage based on the actual or potential costs incurred because of the damage or the possibility of damage. This type of analysis uses such costs as changes in productivity, earnings losses, costs to repair or replace damaged assets, and costs such as insurance expenditures to hedge potential damages. The prices used to value physical costs are often market prices, such as the cost of healthcare to alleviate the symptoms of poisonings, foregone wages due to sickness and the cost of monitoring wells.

There have been a few IPM and pesticide studies using the cost approach. Pingali et. al. (1994) assessed the effects of IPM and other pest control strategies on the health costs of Philippine rice farmers. In a complementary study, Antle and Pingali (1994) measured the impact of pesticides on farmer health (and the effect of health on productivity) for a group of Phillipine rice farmers. Crissman et. al. (1994) calculated the costs of acute pesticide poisonings among a group of Ecuadorian potato farmers. Pimmentel and various colleagues have published several studies aimed at assessing the full impacts of U.S. pesticide use.

Pingali et al. (1994) used a cost of illness approach to value the negative health effects of applicator exposure to pesticides. The researchers monitored and collected data on input use, pest management practices and pesticide storage and handling practices from Filipino rice farming households over several crop seasons. Further, each household member received a detailed medical assessment from a medical doctor. Medical indicators of pesticide exposure were then developed and related to farmer characteristics using regression analysis. The sum of treatment and opportunity costs was defined as the farmer's health cost and used as the dependent variable with insecticide and herbicide doses and relevant demographic and behavioral indicators as independent variables.

The estimated coefficient for the herbicide dose was not significant. In the specification used, the coefficient for insecticide dose implied a 0.49% increase in health costs per percent increase in insecticide dose. The authors calculated pesticide related health costs and the value of pesticides as a productive input for several situations and concluded that natural control was the dominant pest control strategy for the farmers when health costs are explicitly calculated. This was the case regardless of the farmers' level of risk aversion.

Pimentel and various colleagues (Pimentel, et al., 1978) (Pimentel, et al., 1980) (Pimentel, et al., 1991) (Pimentel, et al., 1991) use a direct cost approach to value the environmental, health and economic costs of pesticide use. The analyses include costs associated with human health effects, animal poisonings, destruction of beneficial and natural species, pesticide resistance in pests, crop losses, fishery losses, wild birds, microorganisms and government expenditure to reduce pesticide use. The analysis appeared to consist of three basic steps. First, major effects of pesticides were identified in each category. Next, secondary sources were used to estimate the physical and economic magnitude of each effect. Finally, the economic costs in each category were totaled. An example of the calculations used in the 1992 study is provided in Table 7 for the 'Human health' category. After summing the costs in each category, the total cost of pesticide use was estimated to be $8.1 billion (see Table 8). Results of previous Pimmentel studies are (in millions): 1980-$839, 1991a-$955, 1991b-$2,155. Although the results are interesting, the number of assumptions that must be made in such an analysis could yield unconvincing results that are not likely to satisfy funding agencies and other stakeholders.

Table 7: Health calculations from Pimmentel et al. (1992)

Effect	Calculation	Cost ($ million/year)
Hospitalization after poisonings	2380 x 2.84 days @ $1000/day	6.759
Outpatient treatment after poisonings	27,000 x $630	17.01
Lost work due to poisoning	4680 workers x 4.7 days x $80/day	1.76
Treatment of pesticide induced cancers	<10,000 cases x $70,700/case	707
Accidental fatalities	27 accidental fatalities x $2 million	54
Total		786.529

Table 8: Total estimated environmental and social costs from pesticides in the United States. (Source: Pimentel et al., 1992)

Impact	Cost ($ million/year)
Public health impacts	787
Domestic animal deaths and contamination	30
Loss of natural enemies	520
Cost of pesticide resistance	1,400
Honeybee and pollination losses	320
Crop losses	942
Fishery losses	24
Bird losses	2,100
Groundwater contamination	1,800
Government regulation to prevent damage	200
Total	**8,123**

II.5.4: Discussion of Environmental Assessment

The primary environmental benefits of IPM programs result from the reduction in the use and risk of pesticides. Therefore, an environmental assessment must accomplish two goals. First, reductions in pesticide use and risk must be associated with the IPM program. Second, the environmental effects of the reduction in pesticide use and risk must be established and described. The final step in environmental assessment is to summarize the benefits of IPM related pesticide use and risk reductions.

Associating Changes in Pesticide Use with the IPM Program

The first step in the environmental analysis is to associate changes in pesticide with the IPM program. In fact, this step might be viewed as the only step that is mandatory. There are two reasons for this conclusion. First, IPM programs are not funded to provide farm level or aggregate economic benefits[9]. Second, analysts can simply show reductions in the level of pesticide use to provide evidence of environmental benefits.

Ideally, the effect of the adoption of IPM technologies on pesticide use would be known. Unfortunately, many confounding demographic and technological factors render such understanding unattainable. However, statistical models are often used to estimate the effect of adoption on pesticide use.

If production in the relevant area is more or less homogeneous, one can simply present differences in the level of pesticide use for each level of adoption, or for adopters and non-adopters. Before interpreting such results, a statistical test should be

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[9] This does not mean that such benefits do not influence the practices advocated by IPM programs or that they are not important.

used to ensure that differences in pesticide use are statistically significant. One such test is the same as the t-test for differences in means presented in the budgeting section.

If production is not homogeneous, a statistical technique must be used to associate adoption with a reduction in pesticide use (Mullen, et al., 1997). For example, if there are significant differences in pest severity, farm size or demographic characteristics across farms in the study area, it may be unclear whether differences in IPM adoption or in production and demographic characteristics are causing differences in pesticide use. The easiest way to associate differences in pesticide use with IPM adoption when other variables are hypothesized to affect pesticide use is to use regression analysis including IPM adoption levels as a set of binary variables and any other variables that are expected to affect pesticide use, particularly farm size and pest pressure. Slope parameter estimates for the IPM adoption variable(s) will indicate the level and direction of changes in pesticide use.

The dependent variable in such regressions is pesticide use. The simplest measure of pesticide use is total pounds of A.I. applied. However, it is not clear that adding pounds of A.I. from different types of pesticides produces a meaningful metric. This problem can be avoided by estimating a regression equation for each A.I. (or type of A.I.). For example, the following equation might be estimated for the k^{th} A.I.:

$$\mathbf{AI_k = \sum_{j=1}^{m} \alpha_{jk} ADOPT_j + \sum_{h=1}^{H} \beta_k X_h} \qquad \textbf{(Equation 31)}$$

Where:

- $ADOPT_j$ are binary variables indicating adoption at level j
- X includes all other variables.

The coefficients α_{jk} will therefore indicate the effect of each adoption category on the k^{th} active ingredient.

The variables to be included in X will depend on the characteristics of the program under analysis. However, there are two variables that should be included in most cases: pest severity and farm size. There is some evidence that farm size directly affects pest management decisions. For example, Fernandez-Cornejo (1992) found that farm size is significant in explaining IPM adoption decisions. Other studies, such as (Napit, 1986) and (McNamara, et al., 1991) have found that the proportion of farm income to the total income of the operator's family is significant. Since the ratio of farm income to total family income tends to rise with farm size {e.g. see Hoppe et. al.(1993), it might be assumed that farm size provides a proxy for farm income (at least within a single region and with a single crop). Second, although the effect of pest severity on IPM adoption has not been explicitly analyzed, it seems appropriate to account for it. Since pest control practices are often associated with pest severity, some indication of pest severity will allow correction for pest management differences that result from increased pest pressure.

If resources are limited, it may be prudent to use data from field trials of production practices. Many IPM programs and state universities use field trials to assess current and potential production strategies. Along with these trials, data on pesticide use is usually collected. Using this method, experimental data on the pesticide use for each practice can be used along with an adoption analysis to estimate the effect of the IPM program on pesticide use. Note that this does not differ from the statistical analysis presented above, except that the variables X_h are not included in the analysis and the sample size is equal to the number of field trial observations. Leaving off X_h reduces the analysis to determining conditional expectations:

$$\boldsymbol{\alpha_j = E(AI_{jk}|ADOPT_j=1).} \qquad \textbf{(Equation 32)}$$

The least resource intensive method is to use expert opinion to estimate pesticide use. An appropriate expert or panel of experts could be asked to estimate the pesticide use associated with each relevant practice. The effect of the IPM program on pesticide use can then be estimated using results from an adoption analysis. This technique will only provide useful results if production in the study area is reasonably homogeneous with respect to all factors that may affect pesticide use. Recall that when survey data is used and production is heterogeneous, regression analysis was recommended to separate the effect of the IPM program from other variables such as pest severity and farm size. In this case, pesticide use cannot be associated with any variables other than IPM adoption. Thus, the analyst must consider the ramifications of assuming homogeneity of production before using expert opinion or field trials to estimate pesticide use.

Assessing Environmental Effects of Pesticide Use Changes

There are four sets of methods for empirically assessing the effects of pesticide use on the environment. First, one can simply present the reduction in the use of pesticide a.i. that was associated with the IPM program. Second, one can use one or more of the indexing schemes, such as the EIQ or CINDEX and report the resulting figures. Third, the effects of reduced pesticide use can be valued using contingent valuation. Finally, a direct cost approach can be used to value the reduction in pesticide use and risk. Each of these methods will be briefly discussed below.

The first option is to simply report reductions in the use of pesticide associated with the IPM program. The simplest way to accomplish this is to calculate the per acre reduction in pesticide a.i. associated with the program. Since different pesticides have different effects on human health and the environment, it is preferable to break down the reduction in a.i. either by specific active ingredients or by the type of active ingredient (e.g. organophosphates, carbamates, etc.). This method is less resource intensive than other methods and provides useful information on the effects of the program. However, while such methods may suggest some environmental benefit, they are not sufficient to provide evidence of an environmental impact.

The second option is to use an indexing scheme or simulation model to assess environmental effects. The choice of the specific model or scheme will depend on the preferences of the analyst, the type of analysis being done and the data available. Some models will require detailed data such as soil types and the timing of applications (e.g. CINDEX based models) while others only require information on the characteristics of pesticide a.i.'s (e.g. the EIQ). The analyst will need to assess the tradeoff between the resources needed to use a certain algorithm and the accuracy that is needed.

Usually, indexing schemes will require only data on use of individual pesticide A.I.'s. If this is the case, the analysis will proceed by estimating:

$$f(\mathbf{AI}) = \sum_{j=2}^{m} \alpha_j \mathbf{ADOPT}_j + \sum_{h=1}^{H} \beta \mathbf{X}_h \qquad \textbf{(Equation 33)}$$

where *f*() represents the indexing algorithm.

The estimated α_j parameters will then represent the per-acre effect of adoption at level j in terms of the indexing scheme, ***f***. The total effect of adoption at level j will then be $\alpha_j n_j$.

The third option is to use CV to assess the value of environmental impacts. This is the preferred method for the reasons described above. After determining the reduction in pesticide use attributable to the program (α_j), there are three steps to using CV to determine the value to reduction in external costs.

First, the environmental risk of each relevant pesticide must be assessed. This can be accomplished either by using a weighting scheme and associating certain ranges of index values with risk levels such as high, medium and low or by using secondary data to determine risk levels for each pesticide in several environmental categories. Either method is acceptable, but using the second method avoids the use of weighting algorithms altogether and therefore produces more transparent results.

In either case, the second step is to obtain WTP and relative importance estimates for each risk level. WTP estimates can be obtained from previous studies or by administering a survey. It should be noted that there is little benefit from administering a CV survey if valid WTP estimates are available from secondary sources.

The analyst must determine from whom the WTP estimates should be obtained. If the program is funded mostly by federal agencies, it may be appropriate to use WTP estimates from a nationwide survey. If the program is funded mostly by state sources, WTP estimates from nationwide surveys might not be appropriate. Further, one might consider using WTP estimates from farmers and consumers in addition to WTP estimates from the general population to show how different stakeholder groups value environmental benefits.

The final step in the CV analysis is to calculate the program benefits. This task is relatively straightforward since the weights are determined by the survey respondents. One method is to calculate the proportionate reduction in pesticide use for each environmental category and multiply it by the corresponding WTP and relative importance. This calculation allocates household WTP among environmental assets in proportion to the importance of each asset. For example, consider the hypothetical survey results in Table 9. For this example, assume there is only one relevant pesticide that poses a high risk to groundwater and a low risk to surface water. Using this method, the environmental benefits would be calculated as:

$$\textbf{(Percent Reduction in Use)} * [(\mathbf{WTP_{high}}) * \mathbf{0.8} + (\mathbf{WTP_{low}})*\mathbf{0.2}]$$

Table 9: Example CV Calculation

WTP		*Category*	*Importance*
High Risk	$\$WTP_{high}$	Ground Water	0.8
Low Risk	$\$WTP_{low}$	Surface Water	0.2

The final option for environmental analysis is to use a cost approach. Although it has not been done for IPM programs, one could follow Pimentel and estimate the external costs of pesticide use in the program area. If the costs increase linearly, the percent reduction in pesticide use in the program area would then be multiplied by the total external cost of pesticide use in the area to obtain the program benefits. Another approach would be to estimate the external costs in each of several environmental categories for the program area and estimate the proportionate reduction in the external cost for each category to obtain the program benefits. Either approach would be very costly and it does not appear that the approach would produce results that are on par with contingent valuation results. The cost approach may be more useful when applied to specific environmental assets instead of to overall environmental damage so that meaningful and relevant cost estimates can be developed.

Chapter III: A Framework for IPM Impact Assessment

The above discussion suggests a four-pronged approach to impact assessment that should be applicable to most programs. In this paradigm, a clear distinction is made between (1) adoption assessment, (2) assessment of user level economic effects, (3) assessment of market level economic effects and (4) the environmental assessment. In all cases, some type of adoption assessment will be necessary insofar as it is required for the economic and environmental analyses. Otherwise, the economic and environmental assessments are independent and can be considered separately.

III.1: Assessment Methods and Procedures

The general goal is to assess the relationship between producer adoption and various potential impacts. Impact assessment requires that potential impacts be viewed as a function of some measure of producer adoption. Thus, IPM impact assessment involves three tasks: measurement of impacts, measurement of adoption and evaluation of the relationship between them. It is interesting to note that the impacts of IPM programs are not directly assessed. Rather, the relationship between IPM *adoption* and impacts is assessed, with the implicit assumption that adoption derives from the IPM program. IPM program benefits are therefore assessed indirectly (see Figure 7)[10].

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[10] IPM benefits are likely to be overestimated by assuming all adoption derives from the program.

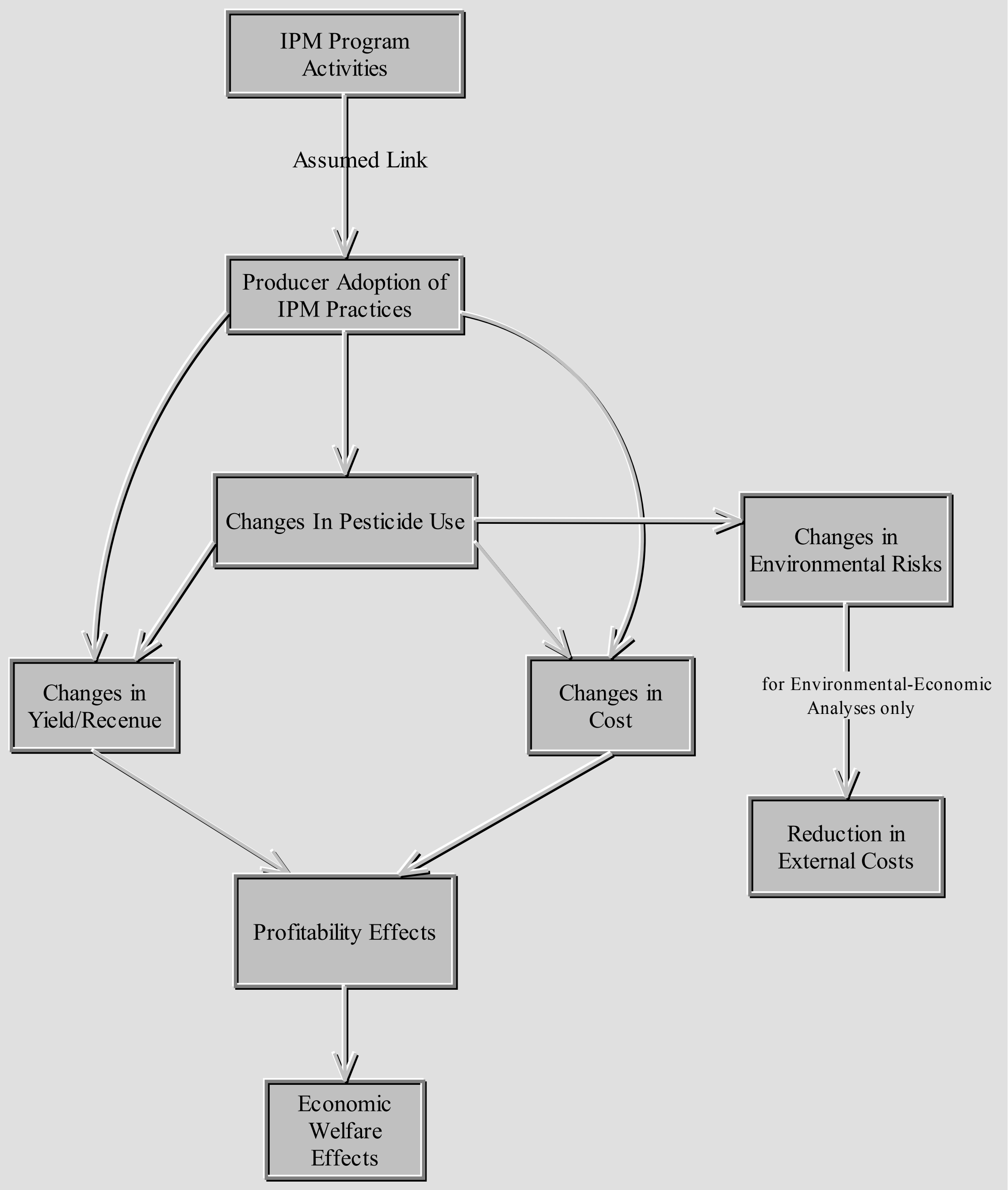

Figure 7:Assumed Flow of Impacts from IPM Programs

Measurement of Adoption

Since impacts are driven by adoption, most program assessments will begin with an adoption assessment. Whether or not a producer has adopted IPM depends on how one defines IPM and the definition of IPM depends on the program under assessment. Thus, the first step in an adoption assessment is to define the IPM program and to create a relevant IPM definition. In some assessments, the IPM definition will most appropriately be specified in terms of outputs while in others, the most appropriate specification will be in terms of inputs (e.g. production practices). The definition of IPM can then be used to create a specific measure of IPM adoption.

Generally, IPM is specified in terms of production practices (inputs). In such cases, it is important to determine which practices are IPM practices based on the program under assessment. Since the overall goal is to associate adoption of IPM practices with environmental or economic impacts, only practices that are expected to have such impacts should be included in the definition of IPM. Only a small subset of production practices meets this requirement (see Figure 8). While all practices might be expected to have some environmental or economic impact, all practices do not have predictable impacts. For example, sprayer calibration is often considered an IPM practice because calibrating sprayers helps farmers to apply the proper amount of pesticide. However, sprayer calibration will not have predictable impacts – in some cases calibration will cause a grower to use more chemicals and in other cases, it will cause growers to use less. Thus, it would be very difficult to statistically associate sprayer calibration with changes pesticide use and the resulting economic and environmental impacts.

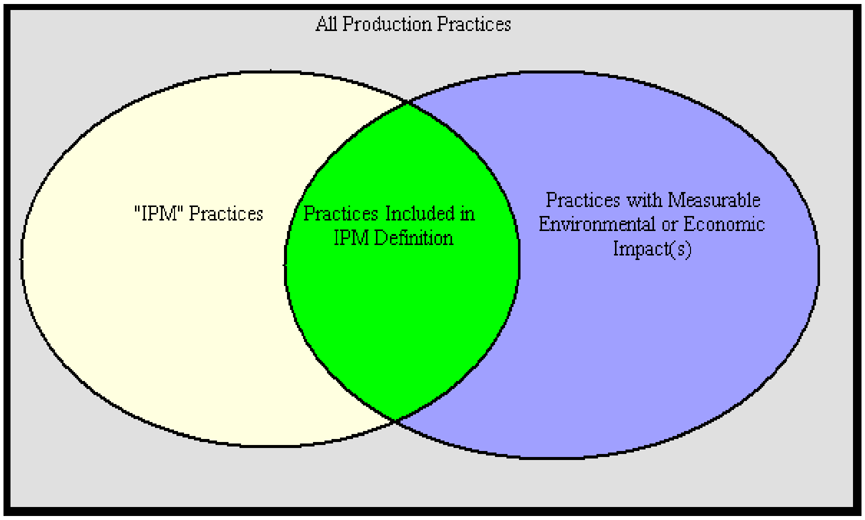

Figure 8: Practices Included in the Definition of IPM

After determining which practices form the definition of IPM, it is necessary to create an adoption metric. The adoption metric summarizes producer adoption data into a single indicator by weighting the practices in the adoption definition. The indicator can be continuous or discrete. For continuous indicators, expert opinion is used to assign a numerical coefficient to each IPM practice in proportion to the perceived importance of the practice to the program's objectives. Discrete indicators usually define levels of adoption (such as "low", "medium" and "high") in terms of the practices used at each level.

In some cases, it is necessary to predict adoption in future periods. For example, prediction is needed if the level of adoption is expected to change significantly or if the assessment is *ex ante*. Such predictions require the use of expert opinion. Adoption is generally predicted by estimating adoption at various points in time and fitting a curve to the points using a functional form assumed *a priori*. Chapter 2 provides a more thorough discussion of techniques for predicting adoption.

After creating a specific measure of adoption, the analyst can gather adoption data using a number of techniques, including producer surveys, expert opinion, secondary data analysis or some combination thereof. The technique(s) used depend on the accuracy needed, the availability of secondary data, resource availability and whether the study is *ex-post* or *ex-ante*. The procedures needed to gather adoption data are summarized in Figure 9.

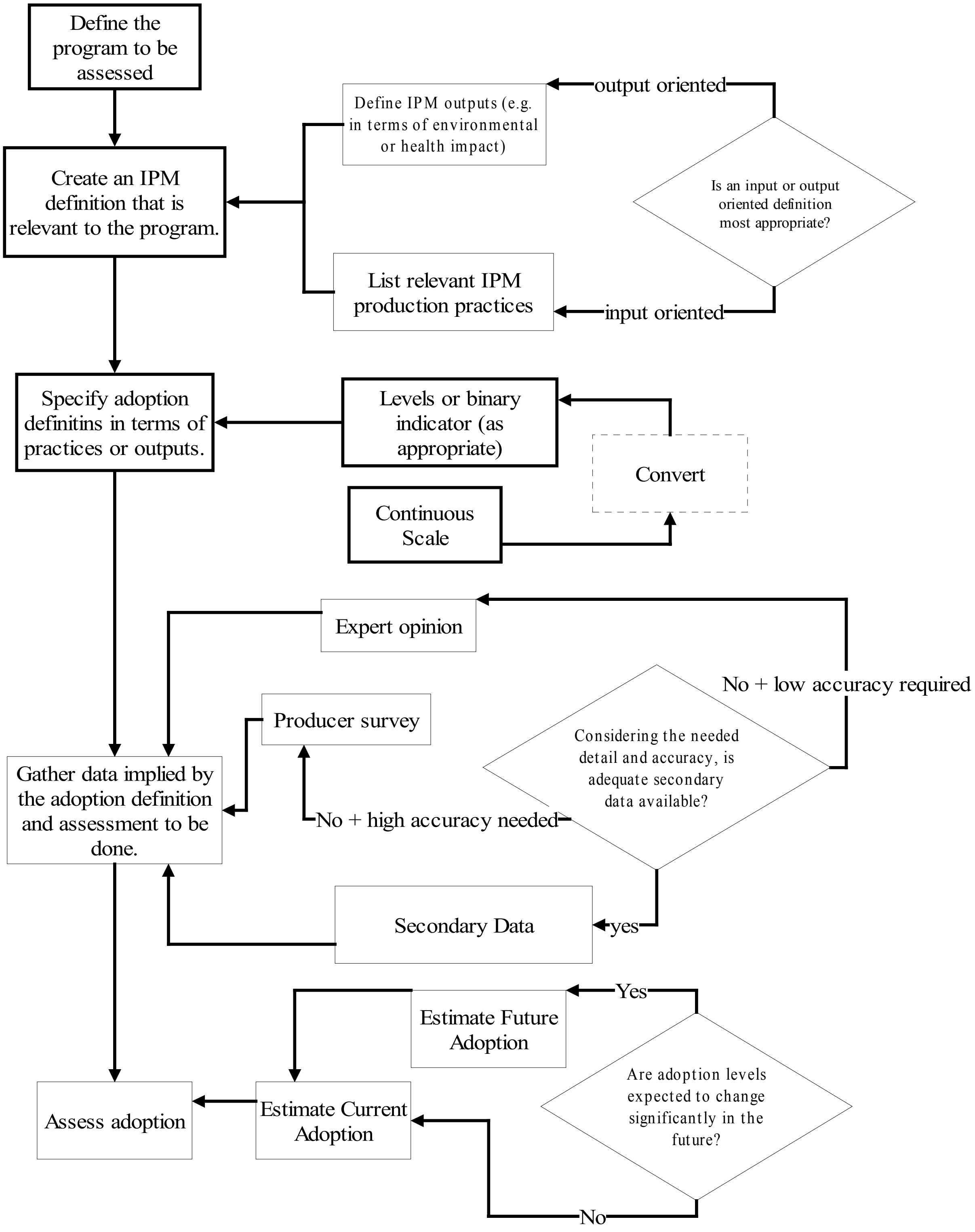

Figure 9: Summary of Adoption Assessment

Farm Level Economic Impacts

There is little variability in farm level economic assessments. All studies that consider farm level economic effects share the goal of deriving changes in net revenue resulting from IPM adoption. While some analysts rely on relatively complicated production economics techniques to address profitability impacts, most practical analyses rely on partial budgeting. Partial budgets are created by estimating the change in costs and revenue attributable to IPM adoption.

The simplest method for performing a farm level economic assessment is to compile budgets for each adoption level. The adoption indicator can be used to determine which production practices are relevant to the analysis. Revenue is usually estimated by applying an average per-unit price to the expected yield for each adoption level. By definition, the cost items can be considered a function of IPM adoption. However, there is no reason to assume that yields (revenue) are solely a function of adoption. Therefore, it may be appropriate to use regression analysis to correct for factors other than IPM adoption.

The typical budgeting process is shown in Figure 10. The process begins by estimating the per-acre costs of each IPM production practice. These estimates are then used to derive the change in cost associated with IPM adoption. When resources are scarce, the analyst might simply specify the production practices used by a hypothetical IPM adopter and non-adopter. Next, the change in net revenue is derived by considering the difference in yield and price between adopters and non-adopters. The farm level impact of adoption is then the change in revenue less the change in cost.

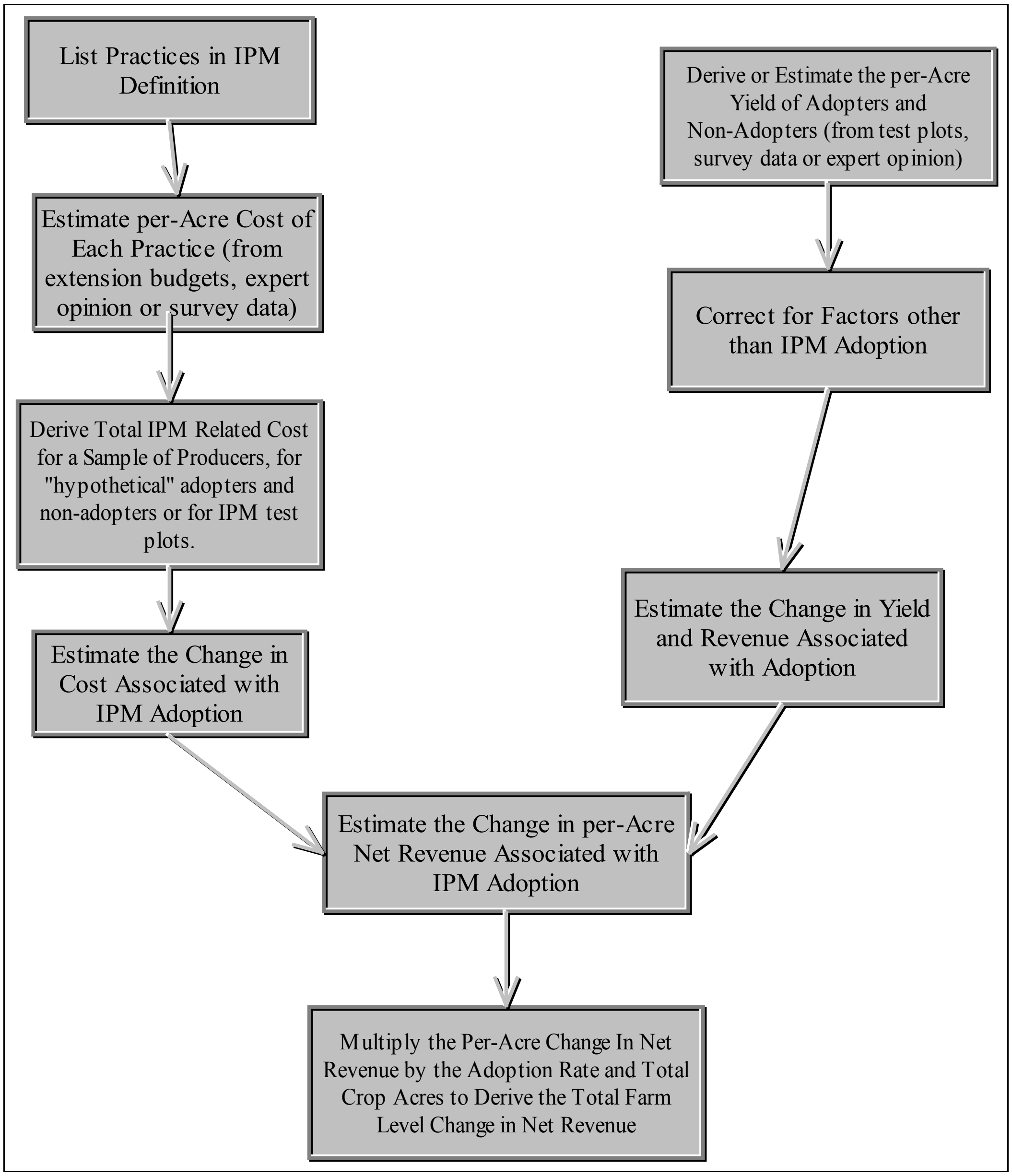

Figure 10: A Typical Budgeting Process

Societal Economic Impacts

Studies are relatively homogeneous with respect to societal economic assessments, with most studies employing economic surplus analysis to derive market level economic benefits. Economic surplus analyses differ with respect to the assumptions of the analysis, such as the functional form used. There are several options to consider when performing an economic surplus analysis. First, one must choose a functional form for the demand and supply curves. Usually, analysts use linear or constant elasticity specifications, although any functional form could be used. Second, one must specify the type of supply shift induced by IPM (if necessary given the specification). Most commonly, researchers use a parallel shift, although pivotal shifts might also be used. Third, supply and demand elasticities must be specified.

Various assumptions can be used to derive supply and demand elasticities to simplify the analysis. For example, demand is sometimes assumed to be perfectly elastic ($\eta = \infty$), particularly for easily transported commodities. As in all other types of assessment, one must also determine whether the analysis is multi-year or single year. If the program under assessment is not growing or declining significantly, a single year "snapshot" of the impacts is probably sufficient to characterize is benefits. However, in *ex-ante* assessments or when adoption rates are changing, a multi-year analysis will generally be necessary.

Most of the information required to perform a simple surplus analysis can be generated using the same data required for the adoption analysis and the farm level economic assessment. Table 10 shows the types of data required for a simple surplus analysis and the typical source of the data. Expert opinion can generally be substituted for the normal data source when time or resources are limited.

Table 10: Typical Data Sources for ESA

Item	Usual Data Source
demand and supply elasticities	secondary sources: various publications or assumed based on nature of the crop/program.
per-acre yield in the study area without adoption	Derived from survey data by correcting for factors other than adoption.
total cost of Production without adoption	Extension budgets
the change in production cost due to adoption	Derived from survey data by correcting for factors other than adoption.
yield without adoption	Derived from survey data by correcting for factors other than adoption.
Adoption rates	Current adoption rate from survey data, future adoption rates based on expert opinion.
Commodity price	USDA price reports or survey data.

Environmental Assessment

Substantially more variability appears in environmental assessments. By reviewing the literature, however, practical environmental assessments can be classified along a continuum from simple to complex. Note that there are three tasks in an environmental assessment: (1) to determine how pesticide use changes with IPM adoption, (2) to determine how changes in pesticide use are related to environmental impacts and (3) to weight or summarize environmental impacts. The complexity of environmental assessments differs with respect to each of these three steps (see Table 11).

The simplest environmental assessments show that adoption decreases (increases) some measure of pesticide use, thus implying positive (negative) environmental effects. This is shown either statistically or by using expert opinion on the effect of adoption. The next level of complexity addresses differences in pesticide active ingredients by assessing the effect of adoption on different active ingredients or types of active ingredient. More complex assessments actually attempt to estimate the effect of adoption on environmental endpoints. These types of assessments use a pesticide impact model, such as the EIQ, to assess the effects of adoption. At this level, assessments have a distinct methodological advantage since they address the program's impacts rather than the effect of the program on inputs (pesticide use) (see Table 11).

While pesticide impact models represent an improvement over simply reporting changes in A.I., they are still have several shortcomings. The major problem associated with pesticide impact models relates to the apparently *ad hoc* weightings attached to environmental endpoints (see section II.5). Environmental economic impact assessments attempt to correct this problem by providing more theoretically justified weightings. Thus, environmental economic impact assessment is very similar to the use of pesticide impact models, although an additional step is taken to derive weightings for environmental endpoints.

Table 11: Various Environmental Assessment Procedures

Data and Analytical Requirements	Method used to show change in pesticide use	Method used to link change in pesticide use to environmental impacts.	Method used to weight environmental impacts.
Least Demanding	Simulated or experimental changes in pesticide use.	None	None
	overall change in AI.	None	None
↓	changes by A.I. or class of A.I.	Subjective comparison of toxicity by A.I. or class of A.I.	None
	changes by A.I.	Scoring Model	Analyst or other experts provide weights (encapsulated in the scoring model).
Most Demanding	changes by A.I.	Environmental-Economic	Monetary – society provides weights.

Regardless of the complexity of the analysis, environmental impact assessment will require information on pesticide use. Again, expert opinion or data from IPM test plots might substitute for survey data. The data requirements of more complex analyses do not differ substantially from the requirements of simple assessments. Such assessments are based on the characteristics of pesticide active ingredients, which are readily available from secondary sources. Environmental-economic assessments also require monetary weightings (such as WTP estimates), which can also be obtained from secondary sources.

Many types of environmental assessment are not included in this section. For example, there is a large set of more complex environmental impact models such as “location specific“ models that consider factors such as soil type and the slope of land. Further, subjective discussions of the effects of pesticide use changes on important environmental assets may be appropriate in some circumstances. However, this section attempted to describe a set of environmental impact techniques that are appropriate for use in a variety of circumstances and that do not have excessive computational or data requirements.

III.2: The Assessment Process

The previous sections describe methods and procedures that are commonly used in IPM impact assessment. The goal of this section is to bridge the gap between methods and performing an actual assessment. Rather than discussing specific techniques, the following paragraphs provide general suggestions for planning and conducting an IPM impact assessment.

Assessments are generally performed to provide information to stakeholders. Thus, it is very important to consider the attributes of these stakeholders before choosing techniques and procedures. The stakeholders will determine what types of information are appropriate and necessary; and various stakeholder groups may respond differently to certain assessment techniques. For example, some groups will be skeptical of contingent valuation results while others will reject the output of scoring models.

Sometimes it is beneficial to choose more than one set of methods and procedures to assess a given type of impact[11]. For example, one might use both the EIQ and contingent valuation to assess environmental impacts. There are several benefits to this. First, the techniques may have overlapping analytical and data requirements such that there is little additional cost associated with calculating additional measures. Second, differences and similarities in results from different methods may provide additional insight into the nature of the impacts. Finally, more stakeholder groups are likely to be satisfied when more than one method is used to calculate impacts (if any apparent differences in the results are explained).

The appropriateness of a method or procedure in a given analysis is determined by the objectives of the analysis, which are derived from the needs of stakeholders. The point is that methods and procedures are only valuable insofar as they provide output and that output is only valuable insofar as it is relevant to stakeholders. Questions such as those presented in Figure 11 may be helpful in determining which methods and procedures are appropriate in a given assessment.

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[11] Using more than one paradigm to assess a given type of impact is known as *triangulation.* For more information, see Van De Vall (1999).

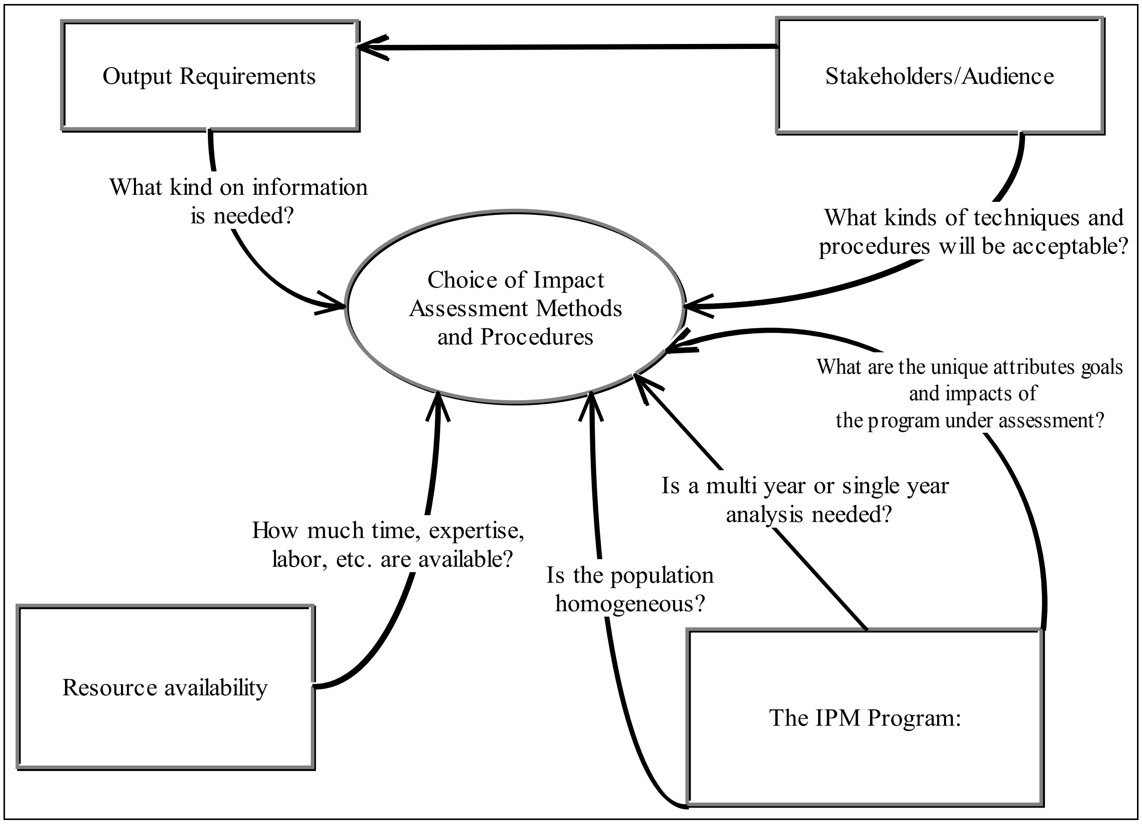

Figure 11: Choosing Methods and Procedures

Chapter IV: Case Studies

Impact assessments of IPM adoption in Massachusetts and Pennsylvania were performed to demonstrate how one might apply the basic and in-depth protocols. Both analyses begin with a basic assessment that estimates adoption within the program and the associated farm-level economic benefits. The basic assessments also attempt to link IPM with environmental benefits by using a simple scoring model (the EIQ) and by deriving the change in active ingredient usage associated with the program. In-depth assessments expand on the results from the basic assessments by estimating market level economic benefits and by conducting a more in-depth environmental assessment using contingent valuation. The state reports are somewhat redundant since they are written as “stand alone” documents.

IV.1: Pennsylvania Sweet Corn IPM Case Study

To demonstrate some of the assessment techniques, the impact of the Pennsylvania sweet corn IPM program during 1998 was assessed. Two analyses were performed. First, a “basic” assessment was performed using the less resource intensive techniques selected from those described above. A second “in-depth” analysis was performed using more demanding techniques such as economic surplus analysis and contingent valuation. Data was obtained from a grower survey and supplemented with secondary data. Impact assessment includes estimation of farm level and aggregate economic benefits (using partial budgeting and economic surplus analysis), and environmental benefits (using a scoring model and contingent valuation).

Background

A survey was distributed directly to sweet corn growers during the 1999 Pennsylvania Vegetable Growers Association meetings in late January. The survey was designed to collect data on the growers' use of selected production practices with an emphasis on pesticide use. Although sixty-four surveys were returned, only thirty-nine included complete and usable pesticide data. Since the benefits of IPM are primarily manifested via changes in pesticide use, surveys with incomplete or inconsistent pesticide use data were not considered. Surveys with non-Pennsylvania zip codes were also removed from the sample. Survey responses are summarized in the following sub-sections.

The survey instrument was reviewed by Darrel Bosch (Virginia Tech), Shelby Fleicher (Pennsylvania State), George Norton (Virginia Tech), Anja Preylowski (Cornell), Ed Rajotte (Pennsylvania State) and Susan Riha (Cornell). The Sky Bit whether forecasting service graciously provided a "door prize" as an incentive to fill out the survey and the Pennsylvania Vegetable Growers Association allotted valuable time during their meetings for us to explain and distribute the survey. In addition to reviewing the survey instrument, Dr. Rajotte also coordinated the survey with the Pennsylvania Vegetable Growers Association and arranged for the door prize.

General Grower and Farm Characteristics

The sample included both large and small farms, ranging in size from 2.5 to 2,500 acres. The average and median farm sizes in the sample were 246 and 105 acres, respectively. On average, 30% of the respondents' acreage was devoted to sweet corn. Large farms tended to devote proportionately less acreage to sweet corn, with the percentage of acres devoted to sweet corn decreasing by an average 2 percentage points for each 100 acre increase in size (α=.03). (See Table 12)

Table 12: Total and Sweet Corn Acreage

	Total Acreage (n=38)	*Sweet Corn Acreage (n=39)*	*%Devoted to Sweet Corn (n=38)*
Mean	246.11	34.96	29.54%
Median	105.00	15.00	22.11%
Std. Err.	428.66	48.17	25.32%

Respondents reported selling most of their sweet corn in the fresh market, with an average of 31% sold in the wholesale market and 66% in the retail market. The remaining 3% was sold to processors. More than half of the respondents sold 95% or more of their sweet corn in the retail market. (See Table 13)

Table 13: Percentage of Sweet Corn Sold in Each Market (n=39)

	Fresh Market Wholesale	Fresh Market Retail	Processing
Mean	31.28 %	66.15 %	2.56 %
Median	5.00 %	95.00 %	0.00 %

Location of Respondents

Responses were received from growers located throughout Pennsylvania. Seven respondents chose not to indicate their zip code and it was assumed that they were located in Pennsylvania. Surveys indicating non-Pennsylvania zip codes were discarded. The thirty-two valid zip code responses are plotted in Figure 12.

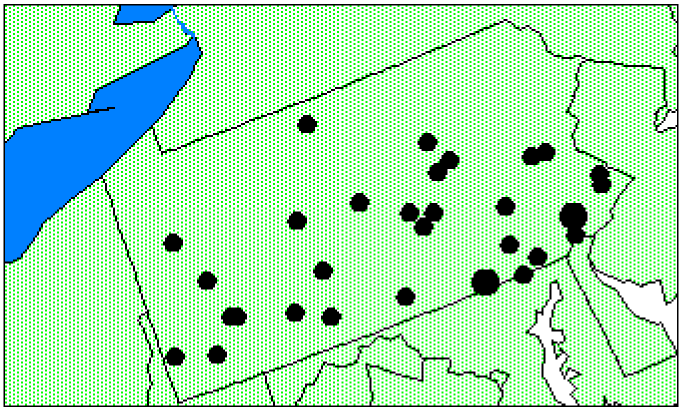

Figure 12: Location of Survey Respondents

Visual assessment seems to suggest that survey responses are somewhat biased towards growers located in the southern half of the state, and especially in the south-east quadrant of the state. It is possible that growers located in this area were more likely to be surveyed because the survey was distributed in Hershey, in the south-east quadrant of the state. However, as shown in Figure 13, most Pennsylvania sweet corn producers are located in the southern-half of the state, with a very high concentration in the south-east quadrant. A visual comparison of Figure 12 and Figure 13 seems to imply that survey responses may provide a geographically unbiased sample of growers. Unfortunately, it is difficult to statistically test such a hypothesis and the final determination is left to the reader.

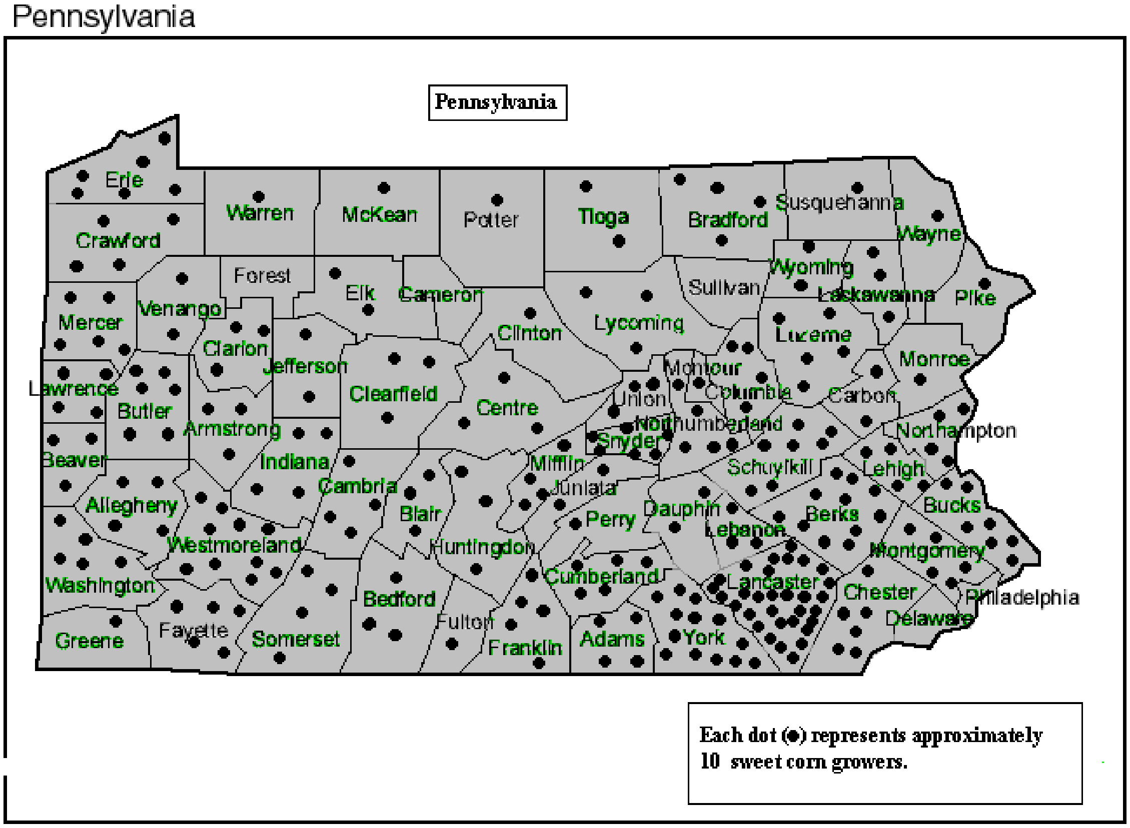

Figure 13: Location of Sweet Corn Growers

Sweet Corn Farming Experience

Survey respondents represented a wide range of sweet corn farming experience, ranging from 1 to 70 years. The average and median experience was 19 and 16 years, respectively. It appears that most growers were relatively experienced, with more than 75% indicating at least 11 years of experience. (See Table 14)

Table 14: Sweet Corn Farming Experience

	Years Farming Sweet Corn (n=39)
Mean	19.28
Median	16
Std. Error.	13.14

Perception of Pest Problems

Respondents were asked to indicate their perception of the severity of several insect, weed and disease pests on their farm relative to the severity on similar farms. There were two reasons for including this question. First, it is often difficult or impossible to obtain data on pest pressure, especially at the farm level. Since pesticide use decisions will be strongly influenced by pest populations and since pest pressures differ at the farm level, some indication of the pest pressure faced by each respondent is needed. Second, it might be argued that a farmer's perception of the pest pressure on his/her farm will influence pesticide applications and therefore, the relevant question will relate more to the respondent's perception of pest pressures rather than to the actual scope of the infestation.

Summary statistics for responses to the pest questions are presented in Table 15. Responses for each pest were given a value from 0 to 3, where:

0 - indicated the pest was completely absent
1 - indicated relatively low populations of the pest
2 - indicated moderate or average populations and
3 - indicated relatively high populations.

Most respondents perceived relatively mild pest problems, indicating less than average populations of most pests. However, all pests except rust were perceived to be at relatively high populations by at least one grower.

Table 15: Perception of Pest Severity

Pest	n	Median	Mean
Sap Beetles	34	1	1.2
Aphids	36	1	1.0
Fall Armyworm (FAW)	38	1.5	1.5
Corn Earworm (CEW)	38	2	2.0
Corn Rootworm (CRW)	33	1	1.4
European Corn Borer (ECB)	39	2	2.1
Unspecified Worms	13	1	0.8
Other Insects	5	0	0.6
Perennial Weeds	39	2	1.6
Annual Broadleaf Weeds	39	2	1.9
Annual Grasses	39	1	1.5
Stewart's Wilt	36	1	0.8
Smut	39	1	1.1
Rust	37	1	0.8

Pest Control

Crop Rotation

Most respondents (92%) reported rotating at least some of their sweet corn with other crops. The average proportion of acres rotated was 69% overall. Rotation appears to be a longstanding practice among growers as this practice has been used for an average 15 years (among those who rotate), which accounts for an average of 85% of the time spent farming sweet corn. Nearly all respondents plan to rotate their sweet corn in the future. (See Table 16)

Table 16: Crop Rotation

	n	Yes	No
Rotate Sweet Corn with Other Crops	39	92%	95%
Plan to Rotate over the Next 5 Years	37	95%	5%

Scouting

Most respondents scouted before deciding to apply insecticides (77%) and post-emergent herbicides (91%). However, less than a third of the growers in the sample reported scouting before deciding whether or not to apply soil insecticides. Only 2 of the 12 respondents who applied soil insecticides scouted before deciding whether or not to make the application (see Table 17). Further, many respondents (38%) used pheromone and/or light traps to aid in decisions regarding insecticide applications.

Table 17: Scouting

	Number who Scout	Average % acreage scouted for those who scouted	Average % scouted overall	Average Years Using Practice	Number who plan to scout over next 5 years
Before applying Soil Insecticides	11 (n=31)	n/a	n/a	n/a	n/a
Before applying Post-Emergent Herbicides	32 (n=35)	87.17% (n=29)	79% (n=32)	12.3 (n=29)	31 (n=32)
Before Applying Post-Emergent Insecticides	30 (n=39)	74.31 (n=29)	55.26 (n=39)	10.62 (n=29)	32 (n=35)

Cultivating for Weed Control

Over half of the respondents (61%) cultivated sweet corn fields to control weeds. When the practice was used, it was employed on an average 51% of sweet corn acreage. Overall, the practice was used on 26% of acreage. Cultivation appears to be a longstanding method of controlling weeds, in use for an average of 18 years among those currently using the practice. Based on the sample, it appears that cultivation will become more prevalent over the next few years as 72% of respondents plan to cultivate for weed control in the next 5 years.

Table 18:Cultivation for Weed Control

Number who Cultivate for Weed Control	Average % acreage cultivated for those who cultivated	Average % cultivated overall	Average Years Using Practice	Number who plan to cultivate over next 5 years
23 (n=38)	50.73% (n=15)	26.24% (n=29)	18.05 (n=22)	21 (n=29)

PENN-IPM

An important component of the Pennsylvania sweet corn IPM program is a telephone hotline (1-800-PENN-IPM) that provides statewide scouting information for important sweet corn insect pests. Exactly half of the respondents reported calling this hotline. Each user of the number made an average of 4.7 calls to the number over the growing season.

Disease Tolerant Varieties

Most respondents (>71%) planted tolerant or resistant varieties to help control common rust, smut, maize dwarf mosaic and/or Stewart's wilt. It appears that the use of tolerant varieties will increase over the next several years, with 83% of the respondents indicating that they plan to use the practice over the next 5 years and 9% indicating that they are undecided.

Table 19: Tolerant/Resistant Varieties

	n	Yes	No	Don't Know
Plant disease tolerant varieties	34	71%	24%	6%
Plan to plant disease tolerant varieties w/n 5 years	35	83%	9%	9%

Action Thresholds

Overall, 69% of the respondents used action thresholds when making decisions about insecticide applications. Of those growers who scouted for insects, most (83%) used action thresholds for insecticide decisions. Almost three quarters of the respondents plan to use action thresholds over the next 5 years and 84% of those who plan to scout over the period also plan to use action thresholds.

Table 20: Use of Action Thresholds

	n	Yes	No
Used insecticide action thresholds	39	69%	31%
Used insecticide action thresholds, among those who scouted	30	83%	17%
Plan to use action thresholds over next 5 years	39	74%	26%
Plan to use action thresholds over next 5 years, among those who plan to scout	32	84%	16%

Pennsylvania Basic Assessment

Adoption

The first step in a basic assessment is to create an adoption indicator for the program under analysis. Unfortunately, Pennsylvania has not developed an adoption scale for sweet corn. Therefore, a scale of adoption was created based on the New York Elements of Fresh Market Sweet Corn IPM (Petzoldt, et al., 1998). The New York elements were adapted to the Pennsylvania by removing practices with no quantifiable impact or with insufficient data. The scale assigns points to practices based on their relative importance (see Table 21). The sum of a grower's points is used as a measure of IPM adoption.

Table 21: IPM Adoption Scale

Practice	*Points*
Crop rotation	10
Plant tolerant varieties	5
Use insect traps	10
Scout for insects	10
Use action thresholds	10
Cultivate	5
Scout for post emergent weeds	10
Call PENNIPM	10
Scout before deciding on soil insecticides	10
Total possible points	80

The next task is to segment the adoption scale into levels of adoption. It was subjectively decided that high-adopters should obtain at least 65 points and that low-adopters should obtain at least 55. Non-adopters are those farmers who achieve less than 55 points (~70% of the possible points). It is important to note that the results of the assessment might be very sensitive to the values used to segment the adoption scale, particularly in small samples.

An adoption analysis was preformed for the growers in the sample. Adoption scores in the sample ranged from 5 to 80 and the average and median adoption scores were 50 and 55, respectively (see Table 22). Most growers in the sample were adopters, with 36% in the high adoption category and 15% in the low adoption category (see Table 23). High, low and non-adopters accounted for 34%, 35% and 31% of the sample acres, respectively.

Table 22: Adoption

	Adoption Score	Percent of Possible Points
Mean	50	62.5%
Median	55	68.8%
Std. Dev.	20.4	

Table 23: Adoption by Level

Adoption Level	Adoption Score	Percent of Sample Growers	Percent of Sample Acres
HIGH	≥ 65	36%	34%
LOW	[55,65)	15%	35%
NON	< 55	49%	31%

Farm Level Economic Effects of Adoption

The short run farm level economic effects of IPM adoption are manifested as changes in net revenue resulting from changes in both costs and yield. The adoption of IPM practices may result in cost increases or decreases. Most notably, IPM adoption is expected to decrease the cost of chemical pesticides as non-chemical controls are substituted for pesticides. However, implementation of IPM practices will increase some costs. IPM adoption may influence returns via price premiums or changes in yields. Partial budgets were created for each respondent to derive the effect of adoption on net income.

The change net revenue associated with adoption of IPM is calculated as:

$$\mathbf{E(\Delta NR_j) = E(NR_j) - E(NR_{non})}$$

where ΔNR_j is the change in net revenue attributed to adoption at level j instead of not adopting at all. To determine the total farm level net revenue effect of the IPM program, the changes in net revenue from the sample are projected onto the entire population:

$$\sum_{j=1}^{m} E(\Delta NR_j) * p_j * N$$

where: p_j is the proportion of acres in category j and N is the number of crop acres.

. Whether or not IPM growers generally receive a higher price than non-IPM growers is questionable. Survey data sometimes indicates that IPM growers receive a slightly higher price for their crops than non-IPM growers. However, there is rarely a market mechanism through which growers might receive such a premium. In such cases, it seems more likely that price differences result from factors other than IPM adoption. In Pennsylvania, one grocery chain (Wegmans) purchases sweet corn grown using IPM and differentiates the product by using 'IPM' labels. However, the stores do not pay a price premium for corn grown using IPM. As such, prices are assumed constant across adoption levels and revenues will change only because of changes in yield due to IPM adoption[12]. Although risk is not assessed in the present analysis, it is

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[12] IPM growers may have enhanced ability to sell output and therefore may sell a higher percentage of their marketable corn. This possibility is not addressed in this analysis.

interesting to note that the Wegmans program may decrease growers' financial risk. If the Wegmans program provides a more consistent market, farmers will experience less variability in their ability to sell output and, with constant prices, total revenue will also be less variable.

Cost decreases associated with IPM adoption are assumed to result only from decreases in chemical use and the associated application costs. The total chemical cost was calculated for each respondent using prices from the 1998 agricultural prices paid survey (USDA, NASS). When a chemical price was unavailable, Pennsylvania distributors were surveyed to determine a cost. The cost calculation was made by converting the price of each pesticide product to the corresponding price per unit of active ingredient and therefore assumes that the cost of active ingredients does not vary by formulation or manufacturer.

To account for changes in labor and machinery costs resulting from decreased pesticide use, it was assumed that each individual chemical formulation (not each A.I.) was applied separately. Various assumptions were also made regarding application methods and the equipment used to derive the machinery and labor cost per application. The calculated cost per chemical application was $3.26/acre.

Growers who implement scouting and trapping incur additional costs. Following Brumfield and Brennan (1999), insect scouting is assumed to cost $9 per acre. Since many growers do not scout all of their acreage, the per-acre charge for each grower was adjusted by the proportion of their acres that are scouted. Growers who indicated the use of traps were assumed to incur an additional $325 for their entire sweet corn acreage (converted to a per-acre charge).

Partial Budgeting Results

Assuming a constant price of $2.25 per dozen ears, per-acre total revenue for adopters in the sample was $279 greater than that of non-adopters. Further, adopters exhibited lower expenditure on chemicals and chemical applications and increased expenditure on scouting and trapping when compared with non-adopters. Overall, adopters in the sample spent $100 less than non-adopters per acre of sweet corn. The difference in net revenue between adopters and non-adopters was $295 (see Table 24).

It is important to note that factors other than IPM adoption affect net revenue. Since only IPM related costs were considered, it is reasonable to assume that the difference in cost derived from the budgets represents the cost associated with IPM adoption. However, it may not be reasonable to assume that the yield difference (and the difference in returns) is solely the result of IPM adoption. This issue is addressed in the in-depth assessment.

Table 24: Partial Budgeting Results

Item	Adopters	Non-Adopters	Difference
Returns			
Sweet Corn	$ 1,940.37	$ 1,660.71	$ 279.65
	Change in Revenue		$ 279.65
Costs			
Chemicals	$ 48.56	$ 80.08	$ (31.52)
Chemical Application	$ 18.91	$ 27.45	$ (8.54)
Scouting	$ 7.25	$ 3.23	$ 4.02
Trapping	$ 20.32	$ -	$ 20.32
	Change in Variable Costs		$ (15.72)
	Change in Net Revenue		**$ 295.38**

The change in net revenue is actually a difference in means. In the present case, the change in net revenue is the difference in average net revenue between adopters and non-adopters[13]. Thus, the analysis is considering a difference between means and it is prudent to determine whether this difference is statistically significant. Norton and Mullen (1994) suggest that t-statistics or ANOVA be used when enterprise or partial

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[13] Note that the net revenue figures used here actually represent returns net of specified costs and not an actual net revenue. However, given the assumptions of the analysis, the estimated change in net revenue represents an actual change in net revenue due to adoption.

budgets are "used to compare [differences in] yields, costs, or profitability of alternative pest management practices." Norton and Mullen (1994), Napit (1986) and others recommend that the t-statistic to test for significant differences in means be specified as:

$$t = \frac{(\bar{x}_1 - \bar{x}_2)}{\sqrt{(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2})}}$$

where s_1^2 and s_2^2 are the sample variances. Under the null hypothesis, the statistic is t-distributed with n_1+n_2-2 degrees of freedom. In the above example, the calculated t-value was 1.38, which implies that the difference in net revenue is significant at approximately the 0.09 level.

Aggregate Net Revenue Effect

There are approximately 22,400 sweet corn acres in Pennsylvania. Since 69% of the acres in the sample are farmed by adopters, it is expected that 15,500 acres are farmed by adopters (22,400*0.69). As such, the total farm level net revenue effect of the IPM program is estimated to be $4.58 Million ($295.38*15,500) assuming no price effect due to increased supply.

Basic Assessment: Environmental Effects of Adoption

In a basic environmental assessment, the major task is to associate IPM adoption with changes in pesticide use. If production in the relevant area is more or less homogeneous, one can simply present differences in the level of pesticide use for each level of adoption, or for adopters and non-adopters. Before interpreting such results, a statistical test should be used to ensure that the differences in pesticide use are statistically significant. One such test is the same as the t-test for differences in means presented in the budgeting section.

Assuming homogeneous production, the effect of adoption on pesticide use can be described by presenting the average use of AI at each adoption level. In the present case, the average grower in the sample applied slightly over 7 pounds of pesticide active ingredient per-acre. On average, adopters applied less active ingredient per-acre than non-adopters (see Table 25). Using the t-statistic discussed above, the difference in the per-acre quantity of AI applied was found to be significant for both high and low adopters ($p \leq 0.034$ and $p \leq 0.133$, respectively). EIQ ratings were also calculated for all of the survey respondents. The calculated values ranged from a minimum of 37 to a maximum of 942. The average EIQ field use rating for respondents was slightly under 199 per acre. T-statistics indicated that the differences in average EIQ values were significant for both low and high adopters ($p \leq 0.034$ and $p \leq 0.127$, respectively).

Table 25: AI and EIQ by Level of Adoption

Adoption Level	E(EIQ)	P-Value	E(AI)	P-Value
NON	254.04	N/A	9.00	N/A
LOW	121.68	0.034	4.29	0.034
HIGH	157.72	0.127	5.83	0.133

It is likely that pesticide use is dependent on factors other than IPM adoption. This possibility was explored by considering the effect of farmers' planting dates and farm size on the use of various types of active ingredients, total active ingredient usage and EIQ. Specifically, the following equations were estimated:

$$\mathbf{Y_i = \gamma_i + \alpha_{1i}\,LOW + \alpha_{2i}HIGH + \beta_{1i}PLANT + \beta_{2i}ACRES}$$

Where:

- The dependent variables (Y_i) are total pounds of active ingredient usage in various classes and overall, and EIQ field use ratings.
- γ is an intercept term
- LOW and HIGH are binary variables indicating low and high adoption, respectively
- PLANT is the first sweet corn planting date (days numbered sequentially from Jan 1, 1999)

- ACRES represents total sweet corn acreage

The results from these regressions are presented in Table 26. Results for active ingredient classes are difficult to interpret since a given increase or decrease in average usage may represent a substitution for other types of compounds. Generally, the adoption coefficients for individual active ingredient classes are insignificant at reasonable levels of certainty. As expected from the previous results, total active ingredient usage and EIQ values are lower for adopters than for non-adopters.

Table 26: Coefficient Estimates for AI Regressions

Dependent Variable[2]	Coefficient Estimates [1]					F-Value[3]
	INTERCEPT	ACRES	PLANT	LOW	HIGH	
All Active Ingredients (lbs)	25.20 (6.904)	0.0175 (0.0213)	-0.1606 (0.0658)	-3.32934 (3.0753)	-3.6211 2.0359	2.638 (p<0.051)
EIQ	709.6303 (203.2143)	0.775123 (0.62638)	-4.57533 (1.93744)	-109.047 (90.5214)	-112.337 (59.9258)	2.6981 (p<0.047)

1: Numbers in parentheses represent coeffieicent standard errors.

2: The data were insufficient to analyze organochlorines, phenoxy herbicides and Bt.

It appears that adopters use less pesticide active ingredient than non-adopters. However, the environmental effects of this decrease are dependent on the types of pesticide used as well as the total amount. This issue is addressed in the in-depth assessment. However, a simple comparison of usage by type of active ingredient reveals that approximately the same proportionate mix of pesticides is used by adopters and non-adopters. Thus, adopters have apparently scaled back all usage rather than focusing reductions on specific types of pesticides[14]. Average per-acre usage of active ingredient classes is presented in Table 27.

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[14] This provides a possible explanation for the high correlation between EIQ and AI usage.

Table 27: AI Application by Type

CLASS	Non-Adopters	Adopters
Amides	3.19 (35%)	2.19 (41%)
Dinitroaniline	0.6 (7%)	0.12 (2%)
Phenoxy Hormones	0.03 (0%)	0.07 (1%)
Triazines	2.79 (31%)	1.78 (33%)
Unclassified Herbicides	0.37 (4%)	0.11 (2%)
Total Herbicides	6.97 (77%)	4.27 (79%)
Benzoic acid	0.02 (0%)	0 (0%)
Carbamates	0.97 (11%)	0.52 (10%)
Organophosphates	0.81 (9%)	0.47 (9%)
Pyrethroids	0.2 (2%)	0.11 (2%)
Total Insecticides	2 (22%)	1.1 (21%)
Total Fungicides	0.02 (0%)	0 (0%)
Grand Total	9.00	5.37

Pennsylvania In-Depth Assessment

The in-depth assessment will extend the basic assessment by considering market level effects and by employing an environmental-economic model to interpret changes in pesticide use.

Market Level Economic Effects of Adoption

Aggregate net revenue effects derived using budgeting may not adequately characterize the economic effects of technology adoption when prices or output changes. In such cases, economic surplus analysis (ESA) can be used to account for the consumer and producer welfare effects of price and quantity changes.

It is likely that the Pennsylvania IPM program does not affect prices. This is because Pennsylvania represents a relatively small percentage of regional sweet corn production. In order words, consumers can substitute non-Pennsylvania sweet corn for Pennsylvania sweet corn. This implies that demand for Pennsylvania sweet corn is perfectly elastic ($\eta = \infty$). With perfectly elastic demand there is no consumer surplus and the change in total surplus will equal the change in producer surplus. Assuming perfectly elastic demand, linear supply and demand, and a parallel supply shift, the change in total surplus is:

$$\mathbf{\Delta PS = 0.5\, Q_0\, P_0\, K\, (2 + K\varepsilon)}$$

Where:

- ε is the equilibrium price elasticity of supply
- η is the equilibrium price elasticity of demand
- K is the proportionate downward shift in supply

The shift factor (K) was calculated via:

$$\mathbf{K = \left[\frac{O\rho}{\varepsilon} - - \frac{VC\rho}{(1+O\rho)}\right] * ADOPT}$$

Where:

- $O\rho$ = the proportionate change in output
- $VC\rho$ = the proportionate change in variable cost
- ADOPT = the adoption rate (percentage of acres)

$VC\rho$ was estimated from the budgets used in the basic assessment. The budgets indicated that the change in variable cost was approximately $100/acre. To calculate $VC\rho$, the total variable cost (TVC) is needed. However, TVC cannot be calculated from the data collected. TVC figures from Pennsylvania sweet corn budgets provided by the state cooperative extension service were used to estimate a baseline TVC value of $859.59/acre[15].

Factors other than IPM adoption affect output. As such, regression analysis was used to correct for various factors when calculating $O\rho$:

$$\mathbf{O_{ac} = \gamma + \alpha IPM + \beta_1 PLANT + \beta_2 ACRES + \beta_3 YRSFARM}$$

Where

- O_{ac} is output per acre
- IPM is a dummy variable equal to one if the farmer is a low or high adopter and zero otherwise
- YRSFARM is sweet corn farming experience in years

The proportionate change in output is calculated as:

$$\mathbf{O\rho = \frac{\alpha}{\gamma + \beta_1 * E(PLANT) + \beta_2 * E(ACRES) + \beta_3 * E(YRSFARM)}}$$

The only other value needed to calculate the change in economic surplus is the elasticity of supply, ε. Unfortunately, no recently derived supply elasticity is available for sweet corn. However, similar crops typically have short-run supply elasticities of around 0.3, which is the assumed value in the present case. The equation for ΔPS was solved for ε and plotted in Figure 14 to demonstrate the possible effect of this assumption. The assumed value for ε results in a change in total surplus of slightly more than \$6.7 million, all of which is assumed to accrue to producers.

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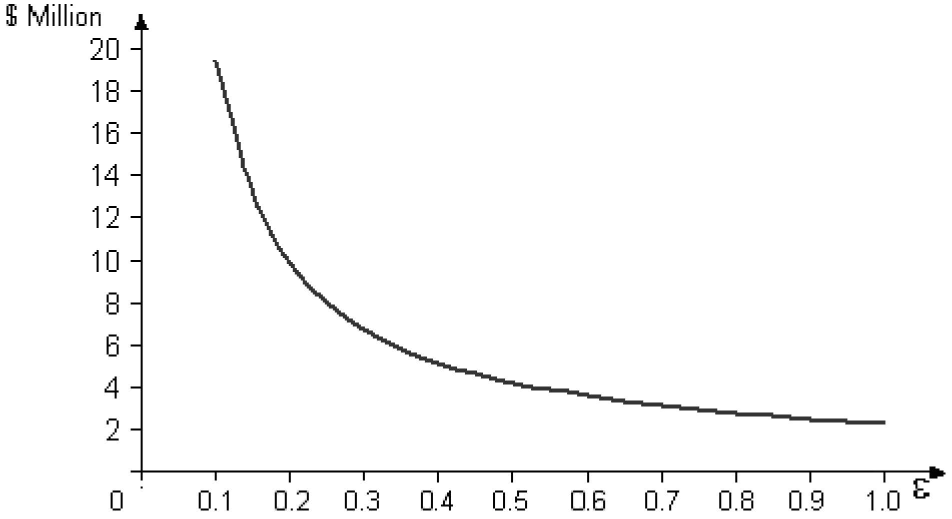
[15] This value is the average of early and late season sweet corn TVC from extension budgets.

Figure 14: Change in Total Surplus Vs. the Assumed Elasticity of Supply (ε)



Savings in External Costs

In the basic assessment, changes in pesticide use were used to imply environmental benefits and EIQ values were calculated. While the EIQ values strongly suggest that there are environmental benefits, the level of environmental benefits is still unclear. Contingent valuation is used to address this issue by valuing environmental benefits in terms of consumers' (taxpayers') willingness to pay. The approach used here is adapted from Mullen (1995).

There are three steps in the contingent valuation analysis. In general, pesticide use must be linked to environmental risks. Changes in pesticide use are then used to imply changes in environmental risks. Finally, changes in environmental risks are valued using WTP (or WTA) estimates derived from a contingent valuation survey. Thus, the approach only differs from scoring models in the last step where consumers'

WTP values are used as weightings instead of developing an arbitrary system to aggregate the results.

Mullen (1995) conducted a nationwide contingent valuation survey. Using survey results, he derived WTP estimates for avoidance of high, medium and low risks in eight environmental categories: acute human health effects, chronic health effects, groundwater, surface water, aquatic species, birds, mammals and insects. The WTP estimates that will be used in this analysis are presented in Table 27.

Table 28: WTP Estimates for Avoidance of Risks ($/month)[16]

	Risk Level		
Category	***High***	***Medium***	***Low***
Acute Human	$ 4.80	$ 3.24	$1.95
Chronic Human	5.15	3.52	2.12
Ground Water	5.11	3.45	2.09
Surface Water	4.93	3.29	1.97
Aquatic Species	4.90	3.23	1.96
Birds	4.65	3.05	1.83
Mammals	4.63	3.04	1.85
Insects	4.22	2.79	1.68

The proportionate change in pesticide use is needed for each AI. The change in use associated with adoption can be calculated from the survey data. However, to derive the proportionate change, the total use of each active ingredient is needed for the study area. Pesticide use data for Pennsylvania was obtained using the most recent version of the National Center for Food and Agricultural Policy (NCFAP) National Pesticide Use Database. Pesticide use data for twenty-eight crops was used in the analysis (see Table 28) and was assumed to represent overall pesticide use in Pennsylvania.

Table 29: PA Crops Included

Crop	Acres	Crop	Acres
Alfalfa	800,000	Oats	205,000
Apples	24,000	Onions	400
Barley	90,000	Pasture	2,593,000
Cabbage	2,000	Peaches	7,400
Cantaloupes	1,300	Pears	1,000
Carrots	196	Potatoes	19,000
Celery	129	Pumpkins	2,608
Cherries	1,700	Rye	20,000
Corn	1,360,000	Seed Crops	5,158
Cucumbers	422	Soybeans	285,000
Eggplant	86	Squash	870
Grapes	10,000	Strawberries	1,500
Green Beans	6,000	Sweet Corn	22,400
Green Peas	2,743	Sweet Peppers	1,047

For the crops under consideration, use of 110 individual pesticide active ingredients was reported. [17] In order to be conformable with the CV WTP estimates, each active ingredient was classified according to the level of risk it posed to each environmental category. Most of the pesticide active ingredients were previously classified by Mullen and previously unclassified active ingredients were classified using the same approach. A complete table of active ingredients and the level of risk posed to each environmental category is provided in the appendix..

To assess the impact of IPM adoption, the average amount of active ingredient applied in each environmental category for each risk level is derived for adopters and non-adopters. Since factors other than IPM adoption may affect pesticide use decisions, the averages were corrected for farm size, pest severity and sweet corn acreage using regression analysis by estimating the following equations:

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[16] Adjusted for inflation using CPI-U average for 1994 (148.2) and average for May 1999 (166.2)

$$\mathbf{LBS_{ij} = \beta_0 + \beta_{1*}Acreage + \beta_{2*}Plant + \beta_{4*}Adopt}$$

Where:

- LBS_{ij} = lbs. per acre of active ingredient posing risk level j to category i applied
- Acreage = respondent's sweet corn acreage
- Plant = first planting date (days numbered sequentially from Jan 1, 1999)
- Pests = average severity of pests (over all pest classes)
- Adopt = binary; equals 1 if adoption score is > 55; 0 otherwise

Thus, the estimated coefficient for β_4 will indicate the average effect of IPM adoption on LBS_{ij}. Based on t-values for β_4, the regression analysis revealed that IPM adoption significantly reduces mid level risks to surface water, chronic human health and acute human health and low-level risks to ground water ($p < 0.10$ in all cases). IPM adoption did not significantly affect other risk categories. Only those risk categories for which IPM adoption significantly affected the amount of AI applied will be considered in the contingent valuation analysis.

The proportionate reduction in risk to each environmental category is calculated as:

$$\mathbf{Reduction_{ij} = \frac{\Delta LBS_{ij} \text{ from Adoption}}{E(LBS_{ij} \text{ Without IPM})}}$$

The coefficient β_4 is interpreted as a per-acre reduction in LBS_{ij} attributable to IPM adoption. To derive the total (statewide) change in LBS_{ij} from adoption (ΔLBS_{ij}), this per-acre reduction is multiplied by the total number of sweet corn acres in the state and the adoption rate:

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[17] Plant growth regulators, antibacterial agents and Bt were not included in the analysis.

$$\Delta \mathbf{LBS_{ij}\ from\ Adoption} = \boldsymbol{\beta}_{ij}\mathbf{*(Acres*Adoption)}$$

where:

- β_{ij} = the coefficient on IPM adoption
- Acres = number of sweet corn acres
- Adoption = percent adoption

To derive the total use in each category without IPM, the total use for all other crops is added to the expected use in sweet corn without IPM using the expected rate for non-adopters:

$$\mathbf{E[LBS_{ij}\ Without\ IPM]} = \sum_{a=1}^{n-1} \mathbf{LBS_{ija}} + \mathbf{E[LBS_{ij}\ for\ non\text{-}adopters]*Acres}$$

Where:

- a = an index of individual crops
- n = the total number of crops, including sweet corn

The reduction in external costs for each category is calculated as the product of the total (statewide) WTP to avoid risks in that category and the proportionate reduction in risk for that category. Since WTP_{ij} is the average per-household WTP, it is converted to a total statewide WTP.

$$\mathbf{Savings_{ij} = WTP_{ij} * Households * Reduction_{ij}}$$

Total savings in external costs is calculated as the sum of the savings over all categories:

$$\mathbf{Total\ Savings_{ij}} = \sum_{i=1}^{8} \sum_{j=1}^{3} \mathbf{Savings_{ij}}$$

The total savings in external costs for the Pennsylvania sweet corn IPM program was about \$6.8 million. This implies that each Pennsylvania household would be willing to pay \$1.56 per year for environmental benefits of the program. However, recall that the estimated coefficient for the adoption variable (**β_4**) was used to determine whether the program had a statistically significant effect on each environmental risk category. If coefficient was not significant for a given risk category, it was assumed that the program had no impact on those risks. These results are very sensitive to the level of significance used to assess the parameter (see Table 29). For example, with $p < 0.05$, one would conclude that the program did not affect mid-level acute human health risks while with $p < 0.1$ one would conclude that there was an effect. Thus, it is useful to view the result in terms of its statistical significance and to recognize the tradeoff between the level of certainty and the resulting impact estimate. Table 30 provides a listing of coefficient estimates for each environmental category.

Table 30: Significance Level and Environmental Benefit

Significance Level	Estimated Savings in External Costs (\$)
0.05	0.9
0.10	6.8
0.15	17.7
0.20	19.3

Summary of Pennsylvania Case Study

The in depth assessment expanded on the basic assessment by using economic surplus analysis to derive the change in producer welfare and by using contingent valuation to value changes in environmental benefits. Both procedures produced useful but indeterminate results since both results were very sensitive to unknown parameters. The in depth assessment required considerably more time, but the data requirements were similar to the basic assessment. Using the relatively conservative assumptions discussed in the analysis, the Pennsylvania IPM appears to have produced economic benefits of about $6.7 million and environmental benefits valued at about $6.8 million during the study year. Although the precision of this figure is questionable, it is clear that IPM provides significant economic and environmental benefits to the state.

Table 31: Total Savings in External Costs

Environmental Category	Risk Level	Adoption Parameter			Change in External Cost (per year)	
		Coefficient Estimate	T-Value	P-Value	Potential (full adoption)	Actual
Surface Water	LOW	-0.09	-0.97	0.33	$ (227,591)	$ (157,569)
	MID	-2.60	-1.81	0.08	$ (2,425,782)	$ (1,679,456)
	HIGH	-0.90	-1.45	0.15	$ (2,411,320)	$ (1,669,443)
Aquatic Species	LOW	-0.35	-0.99	0.33	$ (516,269)	$ (357,431)
	MID	-2.34	-1.60	0.12	$ (2,127,208)	$ (1,472,742)
	HIGH	-0.90	-1.48	0.15	$ (3,300,398)	$ (2,284,984)
Birds	LOW	-2.78	-1.61	0.11	$ (1,050,691)	$ (727,431)
	MID	-0.73	-1.17	0.25	$ (2,312,465)	$ (1,601,003)
	HIGH	-0.08	-0.62	0.54	$ (924,616)	$ (640,145)
Chronic Human	LOW	-0.38	-1.22	0.23	$ (874,138)	$ (605,197)
	MID	-3.28	-1.83	0.07	$ (2,948,360)	$ (2,041,255)
	HIGH	0.06	-0.09	0.93	$ 259,896	$ 179,935
Mammals	LOW	-2.90	-1.63	0.11	$ (1,169,985)	$ (810,023)
	MID	-0.18	-0.03	0.81	$ (587,942)	$ (407,054)
	HIGH	-0.51	-1.01	0.32	$ (3,286,825)	$ (2,275,587)
Arthropods	LOW	-2.69	-1.53	0.13	$ (995,245)	$ (689,044)
	MID	0.10	-0.84	0.40	$ 668,091	$ 462,543
	HIGH	-0.96	-1.63	0.11	$ (3,300,911)	$ (2,285,339)
Ground Water	LOW	-1.45	-2.21	0.03	$ (1,319,489)	$ (913,529)
	MID	-0.95	-1.02	0.31	$ (1,414,512)	$ (979,317)
	HIGH	-1.19	-1.47	0.15	$ (3,782,292)	$ (2,618,616)
Acute Human	LOW	-0.86	-0.97	0.33	$ (794,006)	$ (549,719)
	MID	-2.73	-1.90	0.06	$ (3,073,971)	$ (2,128,220)
	HIGH	0.00	-0.01	0.99	$ 6,664	$ 4,614

IV.2: Massachusetts Sweet Corn IPM Case Study

The impacts of IPM adoption among Massachusetts sweet corn growers was assessed for the 1999 growing season. Data was gathered by surveying growers using the survey instrument presented in Appendix A. Surveys were mailed to 112 Massachusetts growers who were identified as possibly growing sweet corn. Of the 64 surveys returned, 52 were usable. The Massachusetts analysis employed both basic and in-depth analyses as described in the following sections.

The survey instrument was reviewed by Darrel Bosch (Virginia Tech), Ruth Hazard (University of Massachusetts), George Norton (Virginia Tech), Anja Preylowski (Cornell), and Susan Riha (Cornell). Ruth Hazard and Charles Thayer (University of Massachusetts) graciously provided a mailing list of Massachusetts growers. William Coli (University of Massachusetts) also provided many valuable suggestions.

Massachusetts Basic Assessment

The first step in the basic assessment s to develop a method for quantifying the growers' adoption levels. Massachusetts has already developed an adoption scale for classifying growers (Hollingsworth, et al., 1996) (Hazzard, et al., 1999). The adoption scale used in this study is based on the Massachusetts guidelines, although some practices have been removed (See Table 31). This scale assigns points to production practices based on their relative importance in meeting the goals of the IPM program. The sum of a grower's points is used as a measure of IPM adoption.

Table 32: Adoption Scale for Massachusetts

Practice	Points
Turn under of harrow corn stubble before planting.	3
Rotate sweet corn with other crops.	1
Use a winter cover crop.	2
Use a boom sprayer with drop nozzles when ear zone coverage is desirable.	3
When a mist blower is used, blocks are not more than 12 rows wide.	2
Records of planting and harvest dated of treated fields are maintained by block.	1
Pesticide coverage of target and non-target areas is checked with sensitive spray cards.	1

Practice	Points
CEW Populations monitored using pheromone traps.	4
ECB populations are monitored using pheromone traps.	2
FAW populations are monitored using pheromone traps.	2
Insecticide control of CEW populations corresponds to recommended thresholds.	3
Insecticide control of ECB and FAW populations corresponds to recommended thresholds.	3
Other insect pests are only treated after scouting.	2
Floating row covers are used in early corn through whorl to inhibit ECB.	2
Insects are kept below EIL using B.t.'s or beneficial insects on some acreage.	2
A weed map was created during the previous season.	2
Weeds are controlled by cultivation and no herbicide is applied.	4
Herbicide rates are reduced through banding of herbicides or cultivation. OR Herbicide rates are reduced through delayed application of reduced rates.	3
Weeds in alleys, fields and roadways are prevented from going to seed.	2
Tolerant or resistant varieties are used to control Stewart's wilt or MDMV.	1
Total possible points	45

The adoption scale was segmented into three adoption levels: "non", "low" and "high". The range of adoption scores associated with each adoption level was chosen to divide the sample approximately into thirds. Using this procedure, non-adopters are defined as respondents with 16 or less adoption points (~36% of possible points), low-adopters are those respondents with adoption scores greater than 16 and less than or equal to 25 (~56% of possible points) and high-adopters are those with scores greater than 25 (see Table 32). Adoption scores in the sample ranged from 3 to 33 and the average and median adoption scores were about 20 and 19.7 respectively (see Table 33). It is important to note that the results of the assessment might be very sensitive to the values used to segment the adoption scale, particularly in small samples.

Table 33: Adoption by Level

Adoption Level	Adoption Score	Percent of Sample Growers
HIGH	> 25	30.8%
LOW	(16,25]	34.6%
NON	≤ 16	34.6%

Table 34: Adoption

	Adoption Score	Percent of Possible Points
Mean	19.8	44.0
Median	19.0	42.2
Std. Dev.	7.1	N/A

In addition to indicating which practices they used, respondents were asked whether they considered themselves IPM growers. Most respondents indicated that they were IPM growers, regardless of their actual adoption level (see Table 34). Most notably, proportionately more non-adopters indicated that they were “IPM growers” than high or low adopters.

Table 35: Adoption Level vs. Perception of Adoption

Adoption Level	% Who Consider Themselves to be IPM Adopters
NON	77.8%
LOW	77.8%
HIGH	75.0%
All Growers	76.9%

It appears that growers are relying on a different definition of IPM than is implied by the adoption scale developed above. Several possibilities present themselves. First, growers may be defining IPM as the use of a particular practice rather than the use of several practices. Second, growers be defining IPM as some sort of general approach to pest management rather than in terms of practices. Finally, growers may be defining IPM in terms of outcomes (such as lowering pesticide use) instead of in terms of inputs. Each of these possibilities is explored below.

To determine whether growers are weighting certain practices heavily in their definition of IPM, a pair wise comparison of adoption of individual practices and the perception of adoption was performed. Pearson correlation coefficients revealed that none of the practices in the adoption scale is significantly linearly correlated with the perception of adoption (at $\alpha=0.05$). Further, there was little difference between the adoption scores of the two groups (see Table 35).

The second possibility was that growers define IPM as a methodology instead of as a set of inputs (practices). Several survey questions addressed this issue by inquiring about growers' reasons for selecting chemicals. In general, the growers who perceived themselves as IPM growers were more likely to rate environmental and safety considerations as "very important" than growers who did not consider themselves IPM growers (see Table 36). This provides some evidence that growers view IPM as a set of environmental objectives rather than as a set of practices. However, growers who consider themselves IPM adopters did not apply significantly less A.I. per acre nor did their EIQ scores differ (p = 0.93, 0.86, respectively). As will be seen, the input based IPM adoption scale described above is a much better predictor of environmental outcomes than producers' subjective perceptions.

Table 36: AI, EIQ and Adoption Score by Perception of Adoption

Grower's Perception:	**AI**	**EIQ**	**Adoption Score**
IPM Grower	9.71	253.25	19.85
Non-IPM Grower	9.89	277.69	19.58
P-Value	0.96	0.81	N/A

Table 37: Perception of Adoption and Importance of Various Pesticide Characteristics

Pesticide Characteristic		Percent of growers who consider themselves to be	
	Importance	"Non-IPM growers":	"IPM Growers:"
Effectiveness of the pesticide	Not Important	0	0
	Somewhat Important	33.3	4.9
	Very Important	66.7	95.1
Impact on ground and/or surface water	Not Important	0	0
	Somewhat Important	33.3	19.5
	Very Important	66.7	80.5
Cost	Not Important	8.3	17.1
	Somewhat Important	50.0	65.9
	Very Important	41.6	17.1
Availability of chemicals (e.g. leftover from other crops)	Not Important	33.3	27.8
	Somewhat Important	66.7	58.3
	Very Important	0	13.9
Safety of workers	Not Important	0.0	0
	Somewhat Important	25.0	4.9
	Very Important	75.0	95.1
Impact on beneficial insects	Not Important	25.0	0
	Somewhat Important	16.7	31.7
	Very Important	58.3	68.3
Impact on other non-target organisms (e.g. birds fish)	Not Important	25	0
	Somewhat Important	16.7	24.4
	Very Important	58.3	75.6

Farm Level Economic Effects of Adoption

The short run farm level economic effects of IPM adoption are manifested as changes in net revenue resulting from changes in both costs and yield. The adoption of IPM practices may result in cost increases or decreases. Most notably, IPM adoption is expected to decrease the cost of chemical pesticides as non-chemical controls are substituted for pesticides. However, implementation of IPM practices will increase some costs. IPM adoption may influence returns via price premiums and changes in yields. Partial budgets were created for each respondent to derive the effect of adoption on net income.

The change in net revenue associated with adoption of IPM is calculated as:

$$\mathbf{E(\Delta NR_j) = E(NR_j) - E(NR_{non})}$$

where ΔNR_j is the change in net revenue attributed to adoption at level j instead of not adopting at all. To determine the total farm level net revenue effect of IPM adoption, the changes in net revenue from the sample are projected onto the entire population:

$$\mathbf{\sum_{j=1}^{m} E(\Delta NR_j) * p_j * N}$$

where: p_j is the proportion of acres in category j.

Whether or not IPM growers generally receive a higher price than non-IPM growers is questionable. Survey data sometimes indicates that IPM growers receive a slightly higher price for their crops than non-IPM growers. However, there is rarely a market mechanism through which growers might receive such a premium. In such cases, it seems more likely that price differences result from factors other than IPM adoption. As such, prices are assumed constant across adoption levels and revenues will change only because of changes in yield.

Cost decreases associated with IPM adoption are assumed to result only from decreases in chemical use and the associated application costs. The total chemical cost was calculated for each respondent using prices from the 1998 agricultural prices paid survey (USDA, NASS). The cost calculation was made by converting the price of each pesticide product to the corresponding price per unit of active ingredient and therefore assumes that the cost of active ingredients does not vary by formulation or manufacturer.

To account for changes in labor and machinery costs resulting from decreased pesticide use, it was assumed that each individual chemical formulation (not each A.I.) was applied separately. Various assumptions were also made regarding application methods and the equipment used to derive the machinery and labor cost per application. The calculated cost per chemical application was \$3.26/acre. Following Brumfield and Brennan (1999), insect scouting is assumed to cost \$9 per acre and growers who indicated the use of pheromone traps were assumed to incur an additional \$325 for their entire sweet corn acreage (converted to a per-acre charge). Based on budgets developed by Musser et. al. (1999), growers who plant a cover crop are assumed to incur an additional \$30 in per-acre costs. Finally, the creation of a weed map also assumed to cost \$9 per acre.

Partial Budgeting Results

Assuming a constant price of \$2.25 per dozen ears, per-acre total revenue for high adopters in the sample was \$171 greater than that of non-adopters. On average, the estimated difference in net revenue between low adopters and non-adopters was \$230 per acre. Partial budgeting revealed that the average grower in the sample spent less on chemicals than non-adopters, although only high adopters had lower application costs (see Table 37). High adopters had higher costs related to IPM practices. Surprisingly, low adopters had lower trapping and cover crop costs compared to non-adopters. This occurred because trapping is generally only employed by high adopters and because cover crops are used by both non-adopters and low-adopters.

Table 38: Partial Budgeting Results

Adoption Level	LOW	HIGH	Combined
Returns			
Sweet Corn	$216.57	$322.59	$266.46
(A) Change in Returns	**$216.57**	**$322.59**	**$266.46**
Costs			
Chemicals	($5.42)	($34.28)	($19.00)
Chemical Application	$14.31	($7.49)	$4.05
Scouting	$0.50	$2.75	$1.56
Trapping	$0.82	$15.72	$7.83
Cover Crop	($3.33)	$2.92	($0.39)
Weed Maps	$0.50	$3.44	$1.88
(B) Change in Variable Costs	**$7.38**	**($16.94)**	**($4.07)**
(A-B) Change in Total Revenue	**$209.19**	**$339.53**	**$270.53**
T-Value (p-Value)	**1.205 (0.237)**	**1.565 (0.127)**	**1.570 (0.126)**

IPM adoption may not be the only factor that influences producers' net revenue. However, the above analysis implicitly assumed that IPM adoption was the only important determinant in net revenue. One can be reasonably certain that the differences in variable costs are attributable to IPM adoption because the link between IPM adoption and adoption of the techniques is established by definition. It may not be reasonable to assume that the yield difference (and the difference in returns) is solely a function of IPM adoption. This issue is addressed in the in-depth assessment.

Aggregate Net Revenue Effect

There are approximately 9,500 sweet corn acres in Massachusetts. Assuming the sample is representative, 48% of these acres are farmed by high adopters and 30% are farmed by low adopters. High adopters farm an estimated 4,555 sweet corn acres in Massachusetts (9,500*0.48) and low adopters farm an estimated 2,847 acres. Multiplying the per-acre change in net revenue associated with each adoption level by these figures reveals that the total estimated net revenue effect of the Massachusetts

Sweet Corn IPM program is slightly less than $2.14 million.

Basic Assessment: Environmental Effects of Adoption

In a basic environmental assessment, the major task is to associate IPM adoption with changes in pesticide use. If production in the relevant area is more or less homogeneous, one can simply present differences in the level of pesticide use for each level of adoption, or for adopters and non-adopters. Before interpreting such results, a statistical test should be used to ensure that the differences in pesticide use are statistically significant.

Assuming homogeneous production, the effect of adoption on pesticide use can be described by presenting the average use of AI at each adoption level. In the present case, the average grower in the sample applied slightly over 9.75 pounds of pesticide active ingredient per-acre. On average, both high adopters and low adopters applied less active ingredient per-acre than non-adopters (see Table 38). However, the calculated t-statistics for these differences provided little evidence that the difference was statistically different from zero for low adopters.

EIQ ratings were also calculated for all of the survey respondents. The values ranged from 35 to 1130 and averaged 259. Both high and low adopters had lower EIQ ratings than non-adopters. The difference in EIQ was found to be significant for high adopters ($p \leq 0.052$). Although there was a notable difference in EIQ between non-adopters and low-adopters, the t-test revealed that the difference was not statistically significant. These results provide some evidence that the IPM program produces positive environmental benefits.

Table 39: AI and EIQ by Level of Adoption

Adoption Level	E[EIQ] (t-value)	E[AI] (t-value)
NON	318.08	11.30
LOW	270.86 1.02	10.89 0.76
HIGH	178.82 2.34	6.72 2.25
Combined	227.55 1.62	8.93 1.36

It is likely that pesticide use is dependent on factors other than IPM adoption. This possibility was explored by considering the effect of farmers' planting dates and farm size on the use of various types of active ingredients, total active ingredient usage and EIQ. Specifically, the following equations were estimated:

$$\mathbf{Y_i = \gamma_i + \alpha_{1i}\,LOW + \alpha_{2i}HIGH + \beta_{1i}PLANT + \beta_{2i}ACRES}$$

Where:

- The dependent variables (Y_i) are total pounds of active ingredient usage and EIQ field use ratings.
- γ is an intercept term
- LOW and HIGH are binary variables indicating low and high adoption, respectively
- PLANT is the last sweet corn planting date (days numbered sequentially from Jan 1, 1999)
- ACRES represents total acreage farmed

The results from these regressions are presented in Table 39. As expected from the previous results, total active ingredient usage and EIQ values are lower for adopters than for non-adopters. When corrected for planting date and acreage, high adopters reduced EIQ values by over 289 points and per-acre active ingredient usage by 7 pounds (about 54%). Correction for planting date and acreage lowered the expected reduction in AI and EIQ associated with low adoption. However, it should be noted that the coefficient estimates for low adoption had very high p-values (0.52 and 0.75 for EIQ and AI, respectively) and the regression analysis therefore provides little evidence that low adopters reduce either measure.

Table 40: Coefficient Estimates for EIQ and AI

Dependent Variable	Coefficient Estimates (std. Error)					Regression F-Value	
	Bo	High	Low	Plant	Acres	F-Value	Pr > F
EIQ	-274.13 (344.3)	-138.78 (91.96)	14.81 (92.17)	3.50 (1.95)	-0.89 (0.62)	1.69	0.169
AI (lbs)	-9.71 (12.97)	-4.74 (3.46)	1.56 (3.47)	0.12 (0.07)	-0.03 (0.02)	1.42	0.242

It appears that adopters use less pesticide active ingredient than non-adopters. However, the environmental effects of this decrease are dependent on the types of pesticide used as well as the total amount. This issue is addressed in the in-depth assessment. However, a simple comparison of usage by type of active ingredient reveals that approximately the same proportionate mix of pesticides is used by adopters and non-adopters. Thus, adopters have apparently scaled back all usage rather than focusing reductions on specific types of pesticides[18]. Average per-acre usage of active ingredient classes is presented in Table 27.

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[18] This provides a possible explanation for the high correlation between EIQ and AI usage.

Massachusetts In-Depth Assessment

The in-depth assessment will extend the basic assessment by considering market level effects and by employing an environmental-economic model to interpret changes in pesticide use.

Market Level Economic Effects of Adoption

Aggregate net revenue effects derived using budgeting may not adequately characterize the economic effects of technology adoption when prices or per-acre output changes. In such cases, economic surplus analysis (ESA) can be used to account for the consumer and producer welfare effects of price and quantity changes.

It is likely that the Massachusetts IPM program does not affect prices. This is because Massachusetts represents a relatively small percentage of regional sweet corn production. In order words, consumers can substitute non-Massachusetts sweet corn for Massachusetts sweet corn if Massachusetts prices increase. This implies that demand for Massachusetts sweet corn is perfectly elastic ($\eta = \infty$). With perfectly elastic demand there is no consumer surplus and the change in total surplus will equal the change in producer surplus. Assuming perfectly elastic demand, linear supply and demand, and a parallel supply shift, the change in total surplus is:

$$\mathbf{\Delta TS = 0.5\ Q_0\ P_0\ K\ (2 + K\varepsilon)}$$

Where:

- ε is the equilibrium price elasticity of supply
- η is the equilibrium price elasticity of demand
- K is the proportionate downward shift in supply

The shift factor (K) was calculated via:

$$\mathbf{K} = \left[\frac{\mathbf{O\rho}}{\boldsymbol{\varepsilon}} - \frac{\mathbf{VC\rho}}{\mathbf{(1+O\rho)}}\right] * \mathbf{ADOPT}$$

Where:

- $O\rho$ = the proportionate change in output
- $VC\rho$ = the proportionate change in variable cost
- ADOPT = the adoption rate (percentage of acres)

$VC\rho$ was estimated from the budgets used in the basic assessment. The budgets indicated that the change in variable cost was approximately $4.07/acre. To calculate $VC\rho$, the total variable cost (TVC) is needed. Unfortunately, TVC cannot be calculated from the data collected. TVC figures from Northeastern sweet corn budgets were used to estimate a baseline TVC value of $1457.78/acre[19].

Factors other than IPM adoption affect output. As such, regression analysis was used to correct for various factors when calculating $O\rho$:

$$\mathbf{O_{ac} = \gamma + \alpha IPM + \beta_1 PLANT + \beta_2 ACRES}$$

Where

- O_{ac} is output per acre in dozen ears.
- IPM is a dummy variable equal to one if the farmer is a low or high adopter and zero otherwise.

Coefficient estimates for this regression are provided in Table 41.

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[19] This value is the average of early and late season sweet corn TVC from extension budgets.

Table 41: Coefficient Estimates for Output Regression

Coefficient	*Coefficient Estimate*	*Std. Error*
γ	-323.79	493.35
Plant (β_1)	5.67	2.84
Acres (β_2)	-4.13	2.64
IPM (α)	155.79	114.59
Regression F: 1.99 (Pr > F = 0.13)		

The proportionate change in output is calculated as:

$$\mathbf{O\rho = \frac{\alpha}{\gamma + \beta_{1*}E(PLANT) + \beta_{2*}E(ACRES)})}$$

The only other value needed to calculate the change in economic surplus is the elasticity of supply, ε. Unfortunately, no recently derived supply elasticity is available for sweet corn. However, similar crops typically have short-run supply elasticities of around 0.3, which is the assumed value in the present case. The equation for ΔTS was solved for ε and plotted in Figure 15 to demonstrate the possible effect of this assumption[20]. Note that choosing a slightly higher value for ε results in a significantly lower estimate of total surplus. The assumed value for ε results in a change in total surplus of slightly less than $11.2 million, all of which is assumed to accrue to producers.

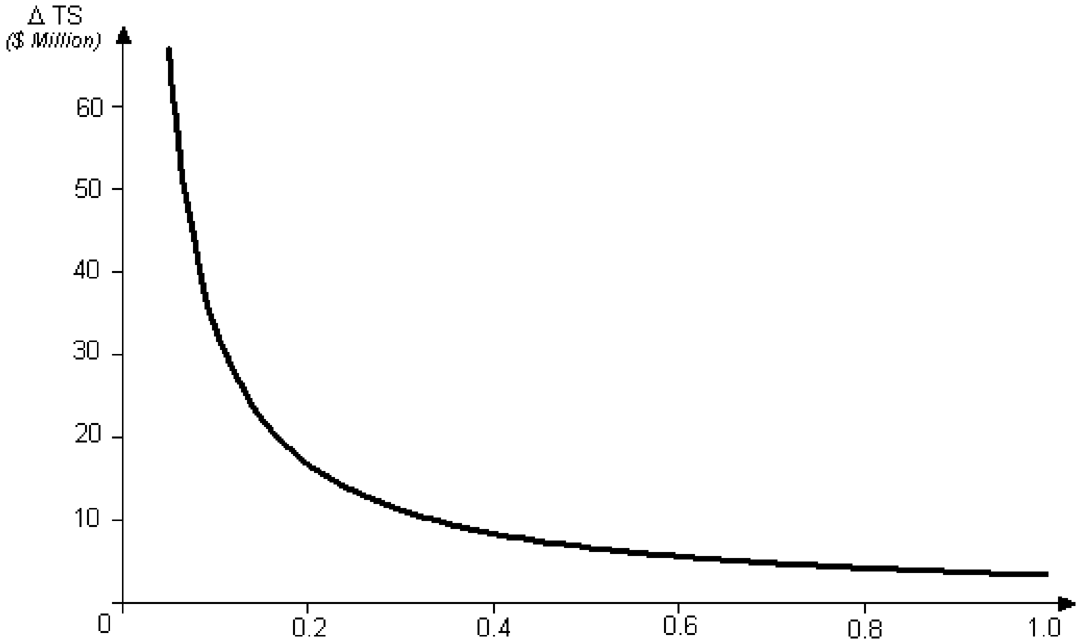

Figure 15: Change in Total Surplus Vs. the Assumed Elasticity of Supply (ε)

Savings in External Costs

In the basic assessment, changes in pesticide use were used to imply environmental benefits. Further, EIQ values were calculated. While the EIQ values strongly suggest that there are environmental benefits, the level of environmental benefits is still unclear. Contingent valuation is used to address this issue by valuing environmental benefits in terms of consumers' (taxpayers') willingness to pay. The approach used here is adapted from Mullen (1995).

There are three steps in the contingent valuation analysis. In general, pesticide use must be linked to environmental risks. Changes in pesticide use are then used to imply changes in environmental risks. Finally, changes in environmental risks are

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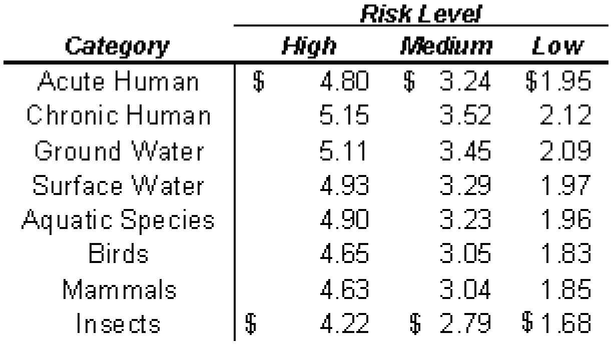
[20] Note that it is very likely that supply is price inelastic.

valued using WTP (or WTA) estimates derived from a contingent valuation survey. Thus, the approach only differs from scoring models in the last step where consumers' WTP values are used as weightings instead of developing an arbitrary system to aggregate the results.

Mullen (1995) conducted a nationwide contingent valuation survey. Using survey results, he derived WTP estimates for avoidance of high, medium and low risks in eight environmental categories: acute human health effects, chronic health effects, groundwater, surface water, aquatic species, birds, mammals and insects. The WTP estimates that will be used in this analysis are based on Mullen's results (see Table 41).

Table 42: WTP Estimates for Avoidance of Risks ($/month)[21]



	Risk Level		
Category	***High***	***Medium***	***Low***
Acute Human	$ 4.80	$ 3.24	$1.95
Chronic Human	5.15	3.52	2.12
Ground Water	5.11	3.45	2.09
Surface Water	4.93	3.29	1.97
Aquatic Species	4.90	3.23	1.96
Birds	4.65	3.05	1.83
Mammals	4.63	3.04	1.85
Insects	$ 4.22	$ 2.79	$1.68

The proportionate change in pesticide use is needed for each AI. The change in use associated with adoption can be calculated from the survey data. However, to derive the proportionate change, the total use of each active ingredient is needed for the study area. Pesticide use data for Massachusetts was obtained using the most recent version of the National Center for Food and Agricultural Policy (NCFAP) National Pesticide Use Database. Pesticide use data for eighteen crops was used in the analysis (see Table 42).

Table 43: MA Crops Included

Crop	
Alfalfa	Pasture
Apples	Potatoes
Cabbage	Pumpkins
Carrots	Squash
Corn	Strawberries
Cranberries	Sweet Corn
Cucumbers	Sweet Peppers
Green Beans	Tobacco
Onions	Tomatoes

For the crops under consideration, use of 52 individual pesticide active ingredients was reported.[22] In order to be conformable with the CV WTP estimates, each active ingredient was classified according to the level of risk it posed to each environmental category. Most of the pesticide active ingredients were previously classified by Mullen and previously unclassified active ingredients were classified using the same approach.

To assess the impact of IPM adoption, the average amount of active ingredient applied in each environmental category for each risk level is derived for adopters and non-adopters. Since factors other than IPM adoption may affect pesticide use decisions, the averages were corrected for farm size, pest severity and sweet corn acreage using regression analysis by estimating the following equations:

$$\mathbf{LBS_{ij} = \beta_0 + \beta_1 * Acreage + \beta_2 * Plant + \beta_4 * Adopt}$$

Where:

- LBS_{ij} = lbs. per acre of active ingredient posing risk level j to category i applied

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[21] Adjusted for inflation using CPI-U average for 1994 and the value for May 1999

[22] Plant growth regulators, antibacterial agents and Bt were not included in the analysis.

- Acreage = respondent's sweet corn acreage
- Plant = first planting date (days numbered sequentially from Jan 1, 1999)
- Adopt = binary; equals 1 for low and high adopters.

Thus, the estimated coefficient for β_4 will indicate the average effect of IPM adoption on LBS_{ij}. Based on t-values for β_4, the regression analysis revealed that IPM adoption significantly reduces mid level risks to surface water, aquatic species, chronic human health and acute human health. Low level risks to birds, mammals, arthropods and ground water and high level risks to aquatic species were also reduced ($p < 0.15$ in all cases). IPM adoption did not significantly affect other risk categories. Only those risk categories for which IPM adoption significantly affected the amount of AI applied will be considered in the contingent valuation analysis.

The proportionate reduction in risk to each environmental category is calculated as:

$$\mathbf{Reduction_{ij} = \frac{\Delta LBS_{ij}\ from\ Adoption}{E(LBS_{ij}\ Without\ IPM)}}$$

The coefficient β_4 is interpreted as a per-acre reduction in LBS_{ij} attributable to IPM adoption. To derive the total (statewide) change in LBS_{ij} from adoption (ΔLBS_{ij}), this per-acre reduction is multiplied by the total number of sweet corn acres in the state and the adoption rate:

$$\mathbf{\Delta LBS_{ij}\ from\ Adoption = \beta_{ij} * (Acres * Adoption)}$$

where:

- β_{ij} = the coefficient on IPM adoption
- Acres = number of sweet corn acres
- Adoption = percent adoption

To derive the total use in each category without IPM, the total use for all other crops is added to the expected use in sweet corn without IPM using the expected rate for non-adopters:

$$\mathbf{E[LBS_{ij}\ Without\ IPM] = \sum_{a=1}^{n-1} LBS_{ija} + E[LBS_{ij}\ for\ non\text{-}adopters]*Acres}$$

Where:

- a = an index of individual crops
- n = the total number of crops, including sweet corn

The reduction in external costs for each category is calculated as the product of the total (statewide) WTP to avoid risks in that category and the proportionate reduction in risk for that category. Since WTP_{ij} is the average monthly per-household WTP, it is converted to a total statewide monthly WTP.

$$\mathbf{Savings_{ij} = WTP_{ij} * Households * Reduction_{ij}}$$

Total savings in external costs is calculated as the sum of the savings over all categories:

$$\mathbf{Total\ Savings_{ij} = \sum_{i=1}^{8} \sum_{j=1}^{3} Savings_{ij}}$$

The estimated savings in external costs is very sensitive to the significance level chosen to determine if β_4 is statistically significant. If a relatively conservative significance level of 0.05 is chosen as a cutoff, the estimated savings in external costs is approximately \$5.73 Million. This implies that each Massachusetts household would be willing to pay \$2.55 per year for environmental benefits of the program[23].

Table 44: Actual and Potential Savings in External Costs

Environmental Category	Risk Level	Adoption Parameter			Change in External Cost (per year)	
		Coefficient Estimate	T-Value	P-Value	Potential (full adoption)	Actual
Surface Water	High	-0.481	-0.7427	0.461	(1,925,553)	(1,259,016)
	Low	-0.130	-1.2606	0.213	(853,735)	(558,211)
	Mid	0.482	-0.178	0.860	1,627,950	1,064,429
Aquatic Species	High	0.874	-0.849	0.400	3,997,226	2,613,571
	Low	0.248	-0.462	0.646	904,300	591,273
	Mid	-1.252	-0.5744	0.568	(4,519,959)	(2,955,358)
Birds	High	-0.129	-1.2112	0.231	(3,155,805)	(2,063,411)
	Low	0.602	-0.213	0.833	592,535	387,427
	Mid	-0.603	-0.6644	0.509	(4,627,065)	(3,025,389)
Chronic Human	High	-0.445	-0.3519	0.726	(2,781,794)	(1,818,866)
	Low	0.294	-0.277	0.783	1,767,969	1,155,980
	Mid	-0.019	-0.0077	0.994	(54,855)	(35,867)
Mammals	High	-0.820	-1.8199	0.075	(10,789,554)	(7,054,708)
	Low	-0.078	-0.0338	0.973	(83,533)	(54,618)
	Mid	0.769	-0.461	0.647	5,557,009	3,633,429
Arthropods	High	-1.898	-2.5905	0.012	(8,767,387)	(5,732,522)
	Low	0.310	-0.115	0.909	352,761	230,651
	Mid	0.468	-0.926	0.359	12,703,690	8,306,259
Ground Water	High	0.482	-0.269	0.789	6,675,312	4,364,627
	Low	-1.042	-1.1143	0.270	(1,470,494)	(961,477)
	Mid	0.431	-0.295	0.769	2,260,191	1,477,817
Acute Human	High	0.336	-0.645	0.522	2,004,997	1,310,960
	Low	0.988	-0.801	0.427	2,071,275	1,354,295
	Mid	-1.453	-0.644	0.522	(6,110,143)	(3,995,094)

Summary of Massachusetts Case Study

Both the in-depth and basic assessments provided evidence that IPM adoption among Massachusetts sweet corn growers produced economic and environmental benefits in 1999. In the basic assessment, the budgeting analysis revealed that IPM adoption is associated with increased yield and decreased variable costs. Further, EIQ and per-acre active ingredient usage implied that IPM adoption produced environmental benefits. In the in-depth assessment, the budgeting results from the basic assessment were used to derive market level producer welfare effects. Finally, environmental benefits were estimated using a contingent valuation analysis. As was shown, both the surplus and contingent valuation results are very sensitive to the analyst's choice of various parameters. However, using the relatively conservative estimates described above, the analysis implied economic benefits of about $11.2 million and environmental benefits valued at about $ 5.73 million.

Chapter V: Conclusions

This thesis developed a broadly applicable approach to IPM impact assessment. The assessment framework was tested in case studies of IPM in Pennsylvania and Massachusetts sweet corn. The next sections describe some of the lessons learned from application and implementation of the IPM assessment framework. This is followed by a brief discussion of economic risk, which was not considered in the assessment framework and may therefore limit its applicability. The section concludes with a discussion of the contributions of this study.

V.1: Lessons from Pilot Studies

The following sections discuss some of the lessons learned from using the impact assessment framework.

Survey Instruments

The Pennsylvania survey instrument was informally evaluated by speaking with several respondents as they turned in their forms. Many respondents in the Pennsylvania study indicated that the survey form was too long and was tedious to fill out, which may explain the tendency of respondents to partially fill out the survey form. Many objections regarded the pesticide application sections, which some respondents felt were confusing, intrusive or unnecessary. The form was eight pages long, including an explanatory cover sheet and an attachment. The quality and quantity of responses would have been improved if (1) fewer questions were asked and (2) more attention was devoted to the presentation of questions. These improvements were incorporated into the Massachusetts survey instrument by asking fewer questions and by presenting questions in a tabular format, which appears less intimidating to respondents. Further, the Massachusetts cover letter better explained why the information was needed and that is was confidential.

Calculating the Environmental Injury Quotient

Given pesticide application data, calculating EIQ values for farmers is not difficult. No additional data is required except for EIQ tables provided by Kovach (1992). However, the process is somewhat tedious and time consuming and it is not clear that it provides any additional insight. In both case studies, the calculated EIQ values were highly correlated with total A.I. application (〈 = 0.96 for PA and 〈 = 0.98 for MA). Given that EIQ and overall A.I. application were highly linearly correlated, the EIQ did not provide much additional information. In light of this and the controversial nature of the EIQ (see section II.5.2), one should carefully consider whether it is worth calculating.

Insights from use of the Impact Assessment Framework

The impact assessment framework presented in chapter 3 provided a relatively well-structured impact assessment procedure. The framework is intended to help the analyst choose appropriate impact assessment techniques and not to provide specific guidance or a “cookbook” approach. Nonetheless, relatively few techniques were identified as widely accepted, broadly applicable and analytically feasible for widespread use. Thus, the framework tends to suggest the methods for analysis (budgeting, ESA and various environmental techniques) and flexibility is achieved by adjusting procedures. Although somewhat more limited in scope than was initially envisioned, the framework should be applicable to almost any IPM program and if properly used will provide acceptable and appropriate impact assessments.

Analytical Requirements of the Analysis

The conceptual frameworks of the suggested types of analysis are straightforward and most trained analysts should be able to implement them without much input from economists or physical scientists. However, performing the assessments revealed that proper analysis requires extensive data manipulation and numerous calculations, particularly in the "in-depth" environmental sections. This may significantly burden analysts who are charged with performing assessments with little or no resources. In such cases, analysts often choose to ignore the environmental impacts of the program or to consider them only very simplistically.

To partially remedy this problem, a computer application was developed to assist analysts with environmental impact assessment. The application requires input on pesticide use by a sample of farmers and produces results similar to those produced in the "in-depth" environmental assessments presented in the case studies. The program is presented in detail in the appendix and source code and/or a compiled version can be obtained by contacting the author.

In-Depth vs. Basic Results

In-depth assessments expand on basic assessments by considering market level effects and by using environmental-economic models to value environmental benefits. In a complete basic assessment, the analyst considers farm level changes in yield, net revenue and pesticide use. In an in-depth assessment, farm level yield and net revenue changes drive market level effects and environmental-economic effects result from changes in pesticide use. Thus, basic and in-depth assessments should provide similar information. In both case studies, the basic results were consistent with the in-depth results. Both basic assessments estimated that adoption increases net revenue and decreases EIQ scores and active ingredient usage. As expected from the basic results, the in-depth assessments indicated that both programs had positive market level effects and environmental benefits.

While the fundamental conclusions of basic and in-depth assessments may often be similar, the assessments provide very different levels of information. Basic assessments do not attempt to link changes in revenue and pesticide use to endpoints, so the level of benefits is not actually assessed. For example, a basic assessment may find that a program reduces pesticide use. Such a reduction in pesticide use *implies* environmental benefits, but the level of benefits was not actually measured. If one is only concerned with the performance of an IPM program in causing changes in pesticide use and/or farm net revenue, a basic assessment might be appropriate. However, if the analyst is concerned with the level of *benefits* produced by the IPM program, an in-depth assessment is necessary.

Farmer Perceptions of Adoption

Based on the Massachusetts analysis, farmers' subjective perception of adoption is not an accurate indicator of IPM adoption. Perhaps this reflects differing definitions of IPM. However, no differences in practices or outcomes were detected between growers who consider themselves adopters and those who do not. This suggests that IPM has no standard meaning among the sampled growers and therefore that the term should be used with caution.

V.2: Risk Assessment

The impact assessment approach suggested in section 3 does not consider the impact of IPM adoption on farmer's economic risk. It might be argued that farm level profitability effects of a program cannot be properly understood without considering the program's effect on risk. Economists tend to view increased risk as the tradeoff one accepts for increased expected profits. In this context, "risk preferences" will differ among farmers – some will be willing to accept increased risk in exchange for increased expected profits and some will prefer the opposite. Thus, it is difficult to understand the meaning of risk without knowledge of individual risk preferences and the concept of risk is not easily applied to groups of individuals.

The techniques for assessing risk have relatively high data requirements and require specialized training for proper implementation and interpretation. As such, it is not practical for most individuals to conduct risk assessments and the techniques were not suggested in the framework. More information can be found in Norton and Mullen (1996) and Swinton and Williams (1998), both of which provide general discussions of risk assessment techniques.

V.3: Contributions

The main contribution of this thesis relates to the first objective of the study – "to identify and describe the various techniques and procedures of economic and environmental impact assessment that are generally applicable and appropriate for use in evaluating IPM programs." In meeting this goal, a set of conceptually valid and analytically feasible IPM impact assessment techniques were identified and described in the context of IPM appraisal. The resulting discussion of economic and environmental impact assessment techniques is useful as a resource for those who must conduct or interpret such analyses.

The second objective of the study was to "provide a recommended procedure for analyzing typical cases that can serve as a benchmark for other analyses." Typical IPM assessment techniques and procedures were generalized and organized into a broadly applicable framework for IPM impact assessment. The assessment framework provides general guidelines and is useful as a starting point when organizing and implementing an IPM impact assessment study.

The final objective was met by applying the framework to actual programs by performing case studies. The goals of the pilot studies were to evaluate and refine the impact assessment framework and to provide an example of how the framework might be applied. In addition to accomplishing these goals, the case studies provide valuable information to anyone concerned with the impacts of the Pennsylvania and/or Massachusetts sweet corn IPM programs. Finally, in meeting the last objective, it became clear that the analytical requirements of some of the environmental assessment techniques might be prohibitive when resources are limited. Thus, a set of computer tools was developed to provide an alternative to manual analysis (see Appendix A).

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Appendix

Appendix A: A Computer Application to Assess Pesticide Use

Assessing the environmental impacts of changes in pesticide use is sometimes a tedious task. Environmental impact assessment often involves numerous repetitive calculations to implement scoring and environmental-economic models. In many practical cases, the volume of calculations that must be done is prohibitive even though the methodology of the analysis is straightforward. This section presents a solution to this problem in the form of a computer application.

The program presented in this section was developed to enable IPM researchers to quickly and easily assess the impact and value of a change in pesticide use. The computer application was developed such that an analysis that is similar to the environmental analysis performed in the case studies can be performed very quickly. Although limited in scope, the program can be used to produce valid environmental risk assessments with little or no additional resource requirements.

Overview

The application is developed to allow the user to follow a series of logical steps to provide necessary information, setup models and develop results. Rather than taking input and providing output in a single step, the user is guided through the process thus allowing him/her to view intermediate results. This enables the researcher to develop a familiarity with the data and analysis similar to that obtained from performing the analysis manually. There are nine screens in the program:

1) "Crop/Region" – to choose a crop and region.
2) "Region Data" – provides basic data for the region (including a breakdown of pesticide use)
3) "Pesticides" – provides an interface for the input, viewing and management

of pesticide use data from a grower sample.

4) "Sample Data" - provides an interface for the input and viewing of non-pesticide adoption and demographic data.
5) "Environmental Risks" – calculates and presents a breakdown of pesticide use by risk to eight types of environmental assets.
6) "CV Setup" – presents and allows for editing of contingent valuation (CV) willingness to pay (WTP) values.
7) "Regression" - allows the user to setup regression models to correct for demographic factors.
8) "Results Table" - presents results in an unformatted format.
9) "Results 2" - presents results in a printable report.

The program relies on both secondary and primary data to perform the analysis. Specifically, the analysis requires:

1. Estimates of total pesticide use in the program area, broken down by active ingredient (AI) and crop.
2. Contingent valuation WTP estimates.
3. Data to categorize pesticides by the environmental risk they pose.
4. Environmental Injury Quotient (EIQ) coefficients for each AI.
5. Demographic and pesticide use data for a sample of growers.

The first four types of data (the secondary data) are provided in a database included with the program. Total pesticide use data for each state was extracted from the National Center for Food and Agricultural Policy's publicly available dataset (NCFCAP 1995). Contingent valuation WTP estimates and most pesticide risk classifications are from Mullen (1997) and EIQ coefficients are from Kovach (199X). The data supplied in the program can easily be updated or changed to meet the needs of the user. Demographic and pesticide use data is provided from a sample of growers served by the program under assessment. A summary of the inputs required by the program and the outputs it produces is presented in Figure 16.

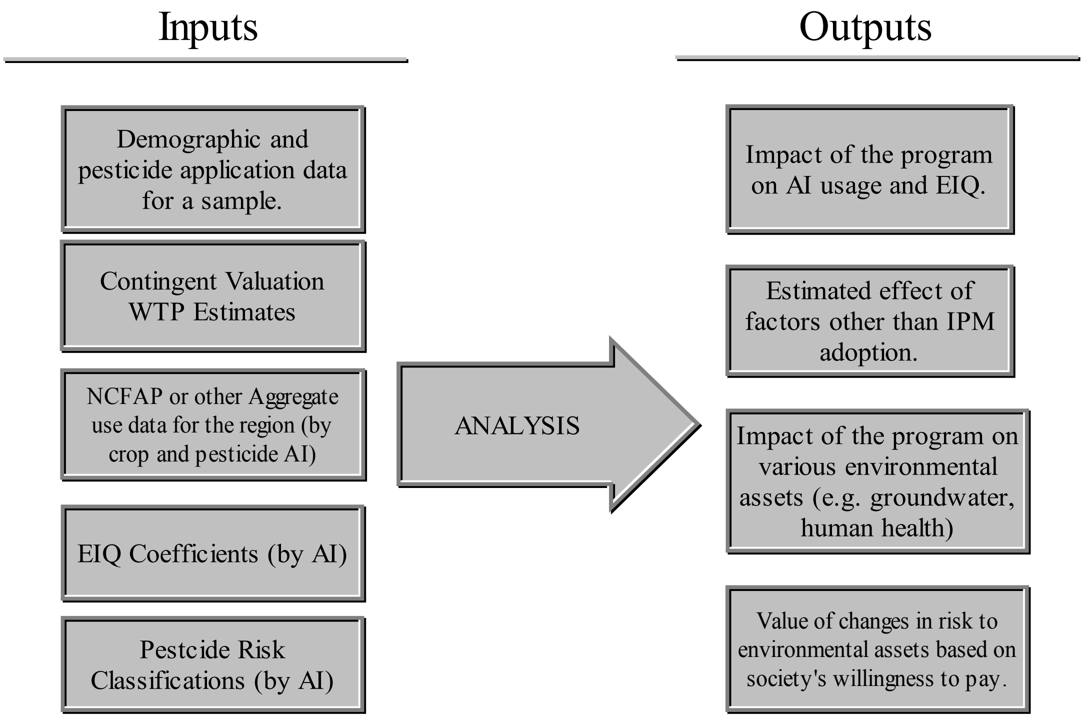


Figure 16: Inputs and Outputs for Environmental Analysis Program

Data

The program uses a Microsoft Access database to perform calculations and to store and manage data. Microsoft Access is not required to enter or change data as the program provides a basic interface for such tasks. However, it is easier to provide the data directly in the database since the Access interface is much more advanced. The data requirements of the program and the structure of the included database are described in this section.

The database table “totaluse” is used to provide pesticide application data for the crops in a region. The data included in this table is extracted from the NCFAP online databases for most U.S. states. Users can include other regions by supplying equivalent data. The data fields and an example entry are shown in Table 45 (note that all fields are not required).

Table 45: “totaluse” Fields

Field	Example	Description	Other Requirements
Region	AL	Region	None
Pesticide	METOLACHLOR	Chemical Name	None (see chemid)
Crop	POTATOES	Crop Name	None
Cropacres	10500	acreage of the crop in the indicated region	must match other entries for the same crop-region combination
% treated	10	% acres treated with pesticide	None
Rate AI	1.5	average lbs. A.I. Applied per acre	None
Acres Treated	1050	number of acres treated	None
LBS AI App	1575	pounds of active ingredient applied	none
CHEMID	2130	identifier for the pesticide active ingredient	must have a matching entry in the table "chemicals"

The database table “chemicals” provides a bridge between application data and other tables. This table has two fields “common” (in which pesticide names are entered) and “chemid.” Each chemical must have an entry in this table with a unique value in the field “chemid.” A given “chemid” can be used more than once if it refers to the same active ingredient even if different names or spellings are used for that active ingredient.

There are several fields in the EIQ table, but only two are used by the program: “ChemId” and “EIQ TOTAL.” “EIQ TOTAL” values represent the total EIQ per pound of active ingredient for the chemical represented by the “ChemId” field. Other fields are provided since they may be of interest to some users. The EIQ table is taken from Kovach (1995).

The “Households” table has two fields: “1990POP” and “Region.” “1990POP” represents the number of **households** in the region as indicated by census data. If a region is added to the “TOTALUSE” table, a corresponding entry must be placed in this table before it can be used in an analysis.

The “Mullen Risk” table has ten fields as shown in Table 46. Eight fields contain a value of “LOW,” “MID” or “HIGH.” These values are intended to indicate the relative risk each of pesticide to the corresponding type of environmental asset (see the box below). A detailed description of the environmental assets and the criteria for assigning risk levels is presented by Mullen (1995).

Table 46: Fields and Example Entry from "Mullen Risk" table

CHEMID	Common	GW	SW	AS	AH	CH	B	M	NT
4030	HEXAZINONE	HIGH	HIGH	LOW	HIGH	HIGH	LOW	LOW	LOW

- CHEMID – the chemical number corresponding to an entry in the “chemicals” table
- Common – the pesticide name
- GW – risk to ground water
- SW – risk to surface water
- AS – risk to aquatic species
- AH – acute human health risk
- CH – risk posed to humans from chronic exposure
- B – risk to avian species
- M – risk to mammals
- NT – risk to non-target arthropods

The risk categories form the basis of the analysis. The combination of three risk levels and eight environmental assets result in 24 asset/risk level categories. A major task of the assessment is to classify producer and overall pesticide applications into risk categories and to assess the IPM program's impact on each category. For example, the pesticide hexazinone poses a high risk to ground water so a reduction in hexazinone use will reduce "high level" risks to groundwater. It is assumed throughout the analysis that a change in AI usage (as measured by pounds of active ingredient) will result in a proportionate change in environmental risk. Using the previous example, a change in hexazinone usage would result in result in a change in high level risks to groundwater of:

$$\frac{\Delta USE}{TotalUse}$$

where ΔUSE is the average change in hexazinone use and TotalUse is the total pounds of active ingredients that pose high level risks to groundwater applied in the study area. More details can be found in the case studies and in chapter 2.

Demographic data from a sample of farmers served by the program is entered in the "SampleData" table (either directly or via an interface provided in the program). Any variable can be entered although there are several requirements:

1. One variable must be called "adoption." Further, the adoption variable must be a binary indicator of adoption where adopters are assigned a value of one ("1") and non-adopters are assigned a value of zero ("0").
2. Variables with non-numeric values can be stored in the table, but cannot be used in the analysis.
3. Each variable must have values for all observations. Variables that do not meet this requirement may also be stored in the table, but cannot be used in an analysis.

4. One variable must be called “FARM NUMBER.” The farm number variable is a unique value the researcher assigns to each observation (farm). The “farm number” can also be entered as a string (e.g. a farmer’s name).

Pesticide use data from the farmers in the sample is stored in the “applications” table. Applications data can be entered directly into the database table although an elementary interface is provided in the program. The table contains four fields: “farm,” “Chemical,” “Rate” and “ChemId.”

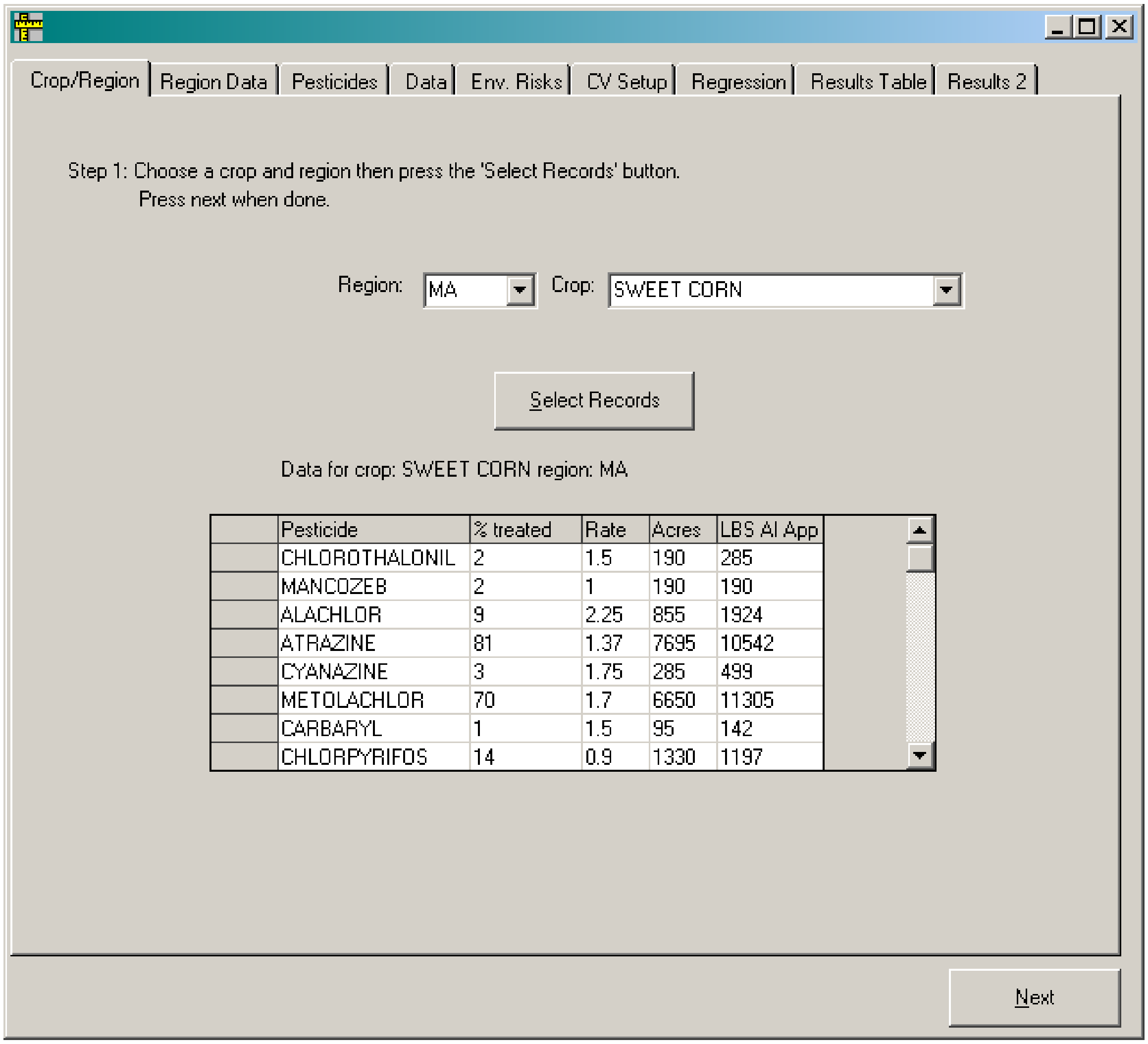
The “farm” filed is equivalent to the “FARM NUMBER” field in the demographic data. All farms in the applications table must have a corresponding entry in the “SampleData” table (and vice versa). The “chemical” and “ChemID” fields correspond to the “common” and “ChemID” fields in the chemicals table. It is important to be sure that pesticides in the applications table have matching entries in the “chemicals” table.

Finally, the WTP table provides household willingness to pay estimates to avoid risks described by each of the 24 environmental categories. These WTP estimates are from a survey preformed by Mullen (1995) and represent the national average of yearly values.

Program Operation

When the user starts the program, the database is located and a listing of available regions and crops is extracted (Figure 17). These are presented in drop-down boxes on the initial screen. The first step in operating the program is to choose a region and crop. After making this selection, the user presses the “select records” button and a subset of the data available to the program is presented for examination. The user finalizes the selections by pressing the “next” button to move to the next screen.

Pressing the “next” button moves the display to the region data screen (Figure 18). At this point, the program begins summarizing data from the “totaluse” table and presents it to the user in tables and text boxes. The crop summary frame contains information about the crop under analysis while the region summary frame contains information about other crops in the region (with the crop under analysis removed). The information in the crop summary frame is not used in the analysis. Two tables on the region data screen present total usage of active ingredient in the study area broken down into the 24 environmental risk categories.



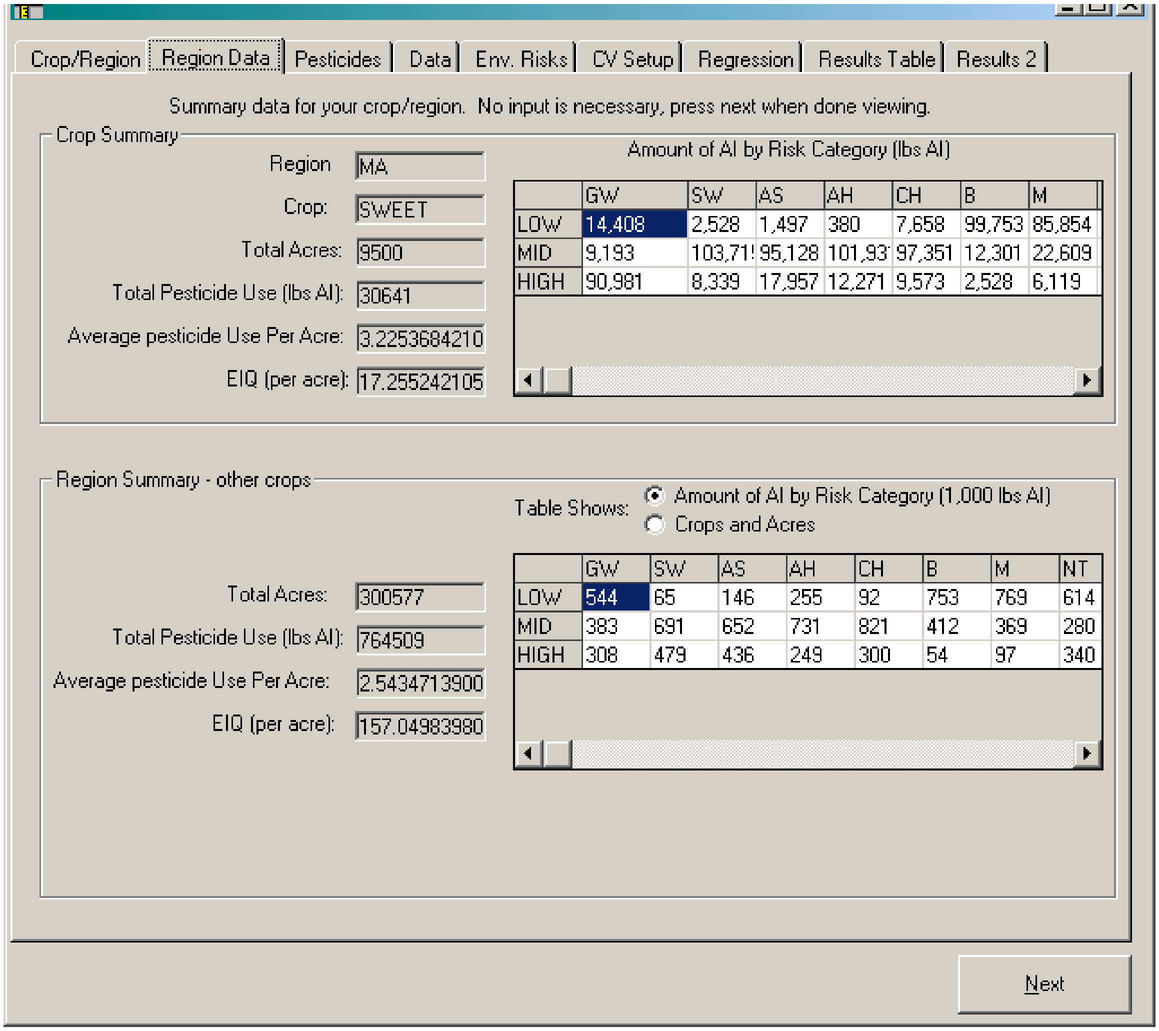
Step 1: Choose a crop and region then press the 'Select Records' button.
Press next when done.

Region: MA
Crop: SWEET CORN

Data for crop: SWEET CORN region: MA

	Pesticide	% treated	Rate	Acres	LBS AI App
	CHLOROTHALONIL	2	1.5	190	285
	MANCOZEB	2	1	190	190
	ALACHLOR	9	2.25	855	1924
	ATRAZINE	81	1.37	7695	10542
	CYANAZINE	3	1.75	285	499
	METOLACHLOR	70	1.7	6650	11305
	CARBARYL	1	1.5	95	142
	CHLORPYRIFOS	14	0.9	1330	1197

Figure 17: Crop and Region Setup Screen



Summary data for your crop/region. No input is necessary, press next when done viewing.

Crop Summary

Region: MA
Crop: SWEET
Total Acres: 9500
Total Pesticide Use (lbs AI): 30641
Average pesticide Use Per Acre: 3.2253684210
EIQ (per acre): 17.255242105

Amount of AI by Risk Category (lbs AI)

	GW	SW	AS	AH	CH	B	M
LOW	14,408	2,528	1,497	380	7,658	99,753	85,854
MID	9,193	103,71	95,128	101,93	97,351	12,301	22,609
HIGH	90,981	8,339	17,957	12,271	9,573	2,528	6,119

Region Summary - other crops

Table Shows:
● Amount of AI by Risk Category (1,000 lbs AI)
○ Crops and Acres

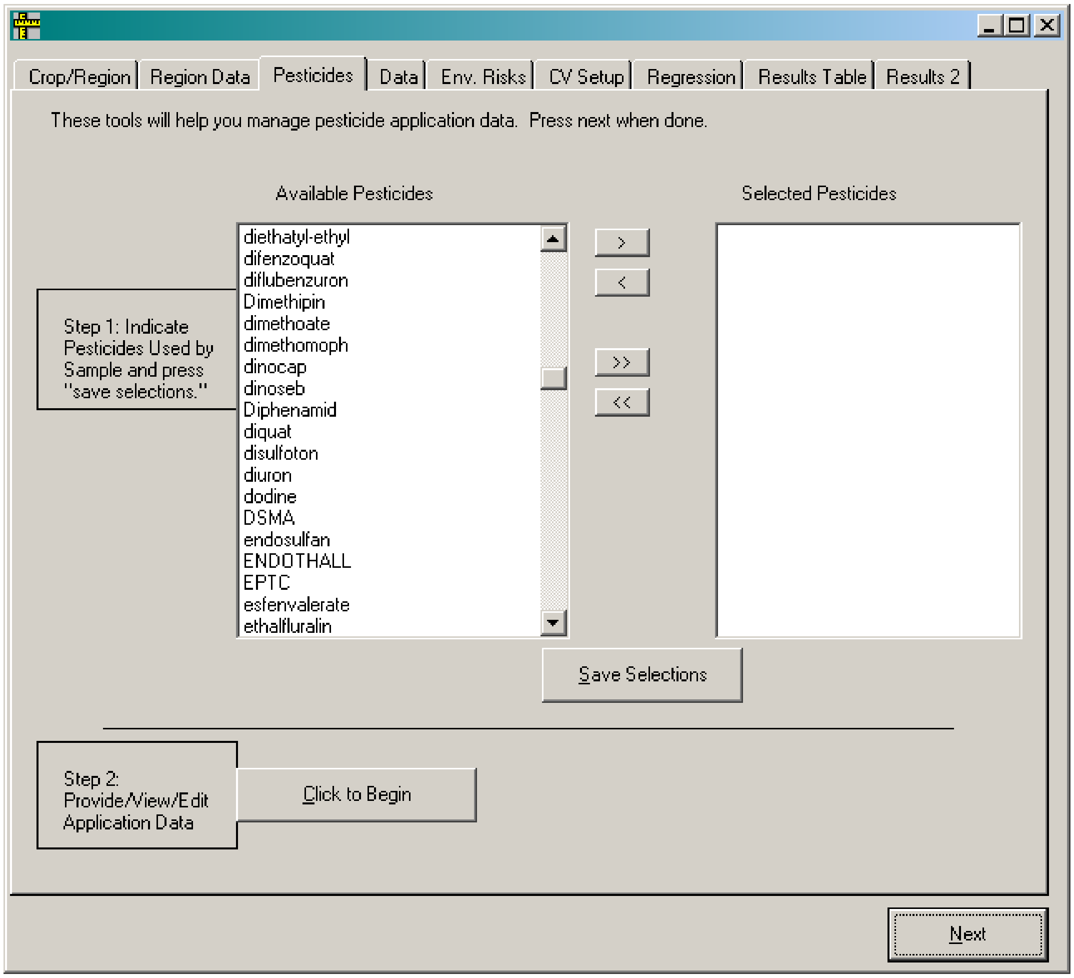
Total Acres: 300577
Total Pesticide Use (lbs AI): 764509
Average pesticide Use Per Acre: 2.5434713900
EIQ (per acre): 157.04983980

	GW	SW	AS	AH	CH	B	M	NT
LOW	544	65	146	255	92	753	769	614
MID	383	691	652	731	821	412	369	280
HIGH	308	479	436	249	300	54	97	340

Figure 18: Region Summary

No user input is required on the region data screen. After examining the data on this screen, the user presses the "next" button to move to the next step in the analysis, causing the program to move to the "pesticides" screen (Figure 19) which provides tools for viewing, entering and management of pesticide use data for the sample of growers. When the pesticides screen is loading, a list of pesticides is extracted from the database. This listing allows the user to indicate which pesticides are used by the sample growers. This feature is provided to limit the pesticides list to the relevant subset. As will be seen, this step may facilitate data entry. This step is optional and the analysis will not be affected if it is skipped.

The pesticides screen also provides two tools for the management of pesticide use data. These tools are accessed by pressing the “Go to Data” button. The first data management screen (Figure 20) initially shows a list of all pesticide applications in the database. Each application is entered into this table by chemical name and rate of active ingredient applied per acre. Users can add, delete and edit this data and corresponding changes will be made in the database. Records can also be shown by farm by making the appropriate selection in the drop down list at the top of the screen.



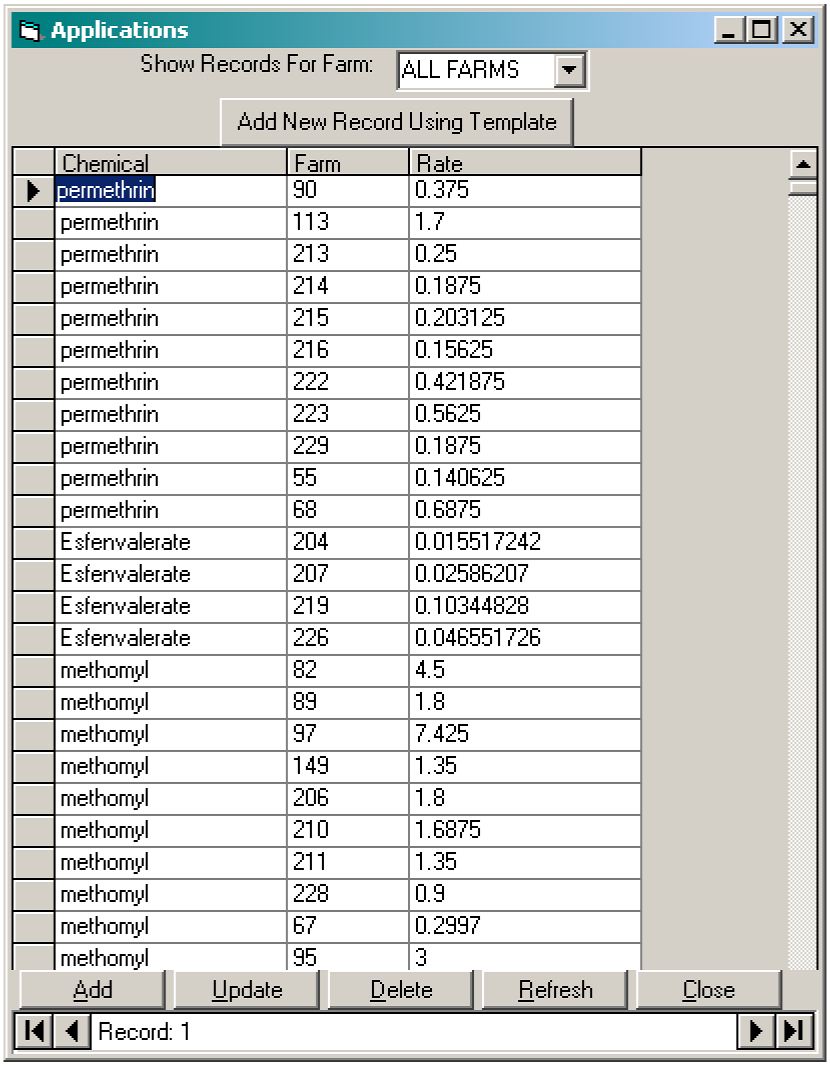
These tools will help you manage pesticide application data. Press next when done.

diethatyl-ethyl
difenzoquat
diflubenzuron
Dimethipin
dimethoate
dimethomorph
dinocap
dinoseb
Diphenamid
diquat
disulfoton
diuron
dodine
DSMA
endosulfan
ENDOTHALL
EPTC
esfenvalerate
ethalfluralin

Step 1: Indicate Pesticides Used by Sample and press "save selections."

Step 2: Provide/View/Edit Application Data

Figure 19: Pesticides Screen



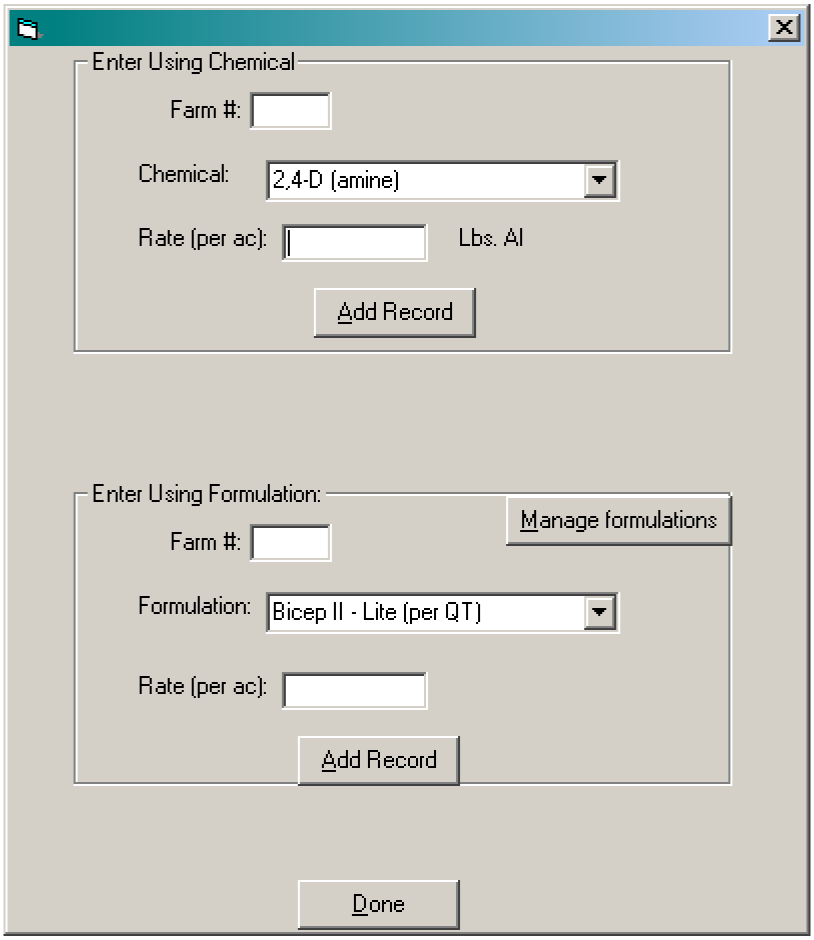
Show Records For Farm: ALL FARMS

Chemical	Farm	Rate
permethrin	90	0.375
permethrin	113	1.7
permethrin	213	0.25
permethrin	214	0.1875
permethrin	215	0.203125
permethrin	216	0.15625
permethrin	222	0.421875
permethrin	223	0.5625
permethrin	229	0.1875
permethrin	55	0.140625
permethrin	68	0.6875
Esfenvalerate	204	0.015517242
Esfenvalerate	207	0.02586207
Esfenvalerate	219	0.10344828
Esfenvalerate	226	0.046551726
methomyl	82	4.5
methomyl	89	1.8
methomyl	97	7.425
methomyl	149	1.35
methomyl	206	1.8
methomyl	210	1.6875
methomyl	211	1.35
methomyl	228	0.9
methomyl	67	0.2997
methomyl	95	3

Record: 1

Figure 20: Pesticide Application Data Management

A data entry tool is provided to make it easier to enter pesticide data (Figure 21). The tool provides a drop down listing of pesticides, thus reducing the data entry workload and number of entry mistakes. Unfortunately, it is difficult to enter pesticide use data in terms of pounds of active ingredient since farmers usually report usage in terms of formulations. Thus, the user can create a list of formulations by pressing the "manage formulations" button. To add a formulation, the user is asked to provide a listing of the active ingredients contained in the formulation and the pounds of active ingredient contained in each unit of each formulation. For example, the user could indicate that “Bullet” contains 0.625 lbs. of alachlor and 0.375 lbs. of atrazine per quart. This would add “Bullet” to the formulations drop-down list and the user could then enter Bullet entries in quarts rather than having to convert to the amount of active ingredient for each entry.

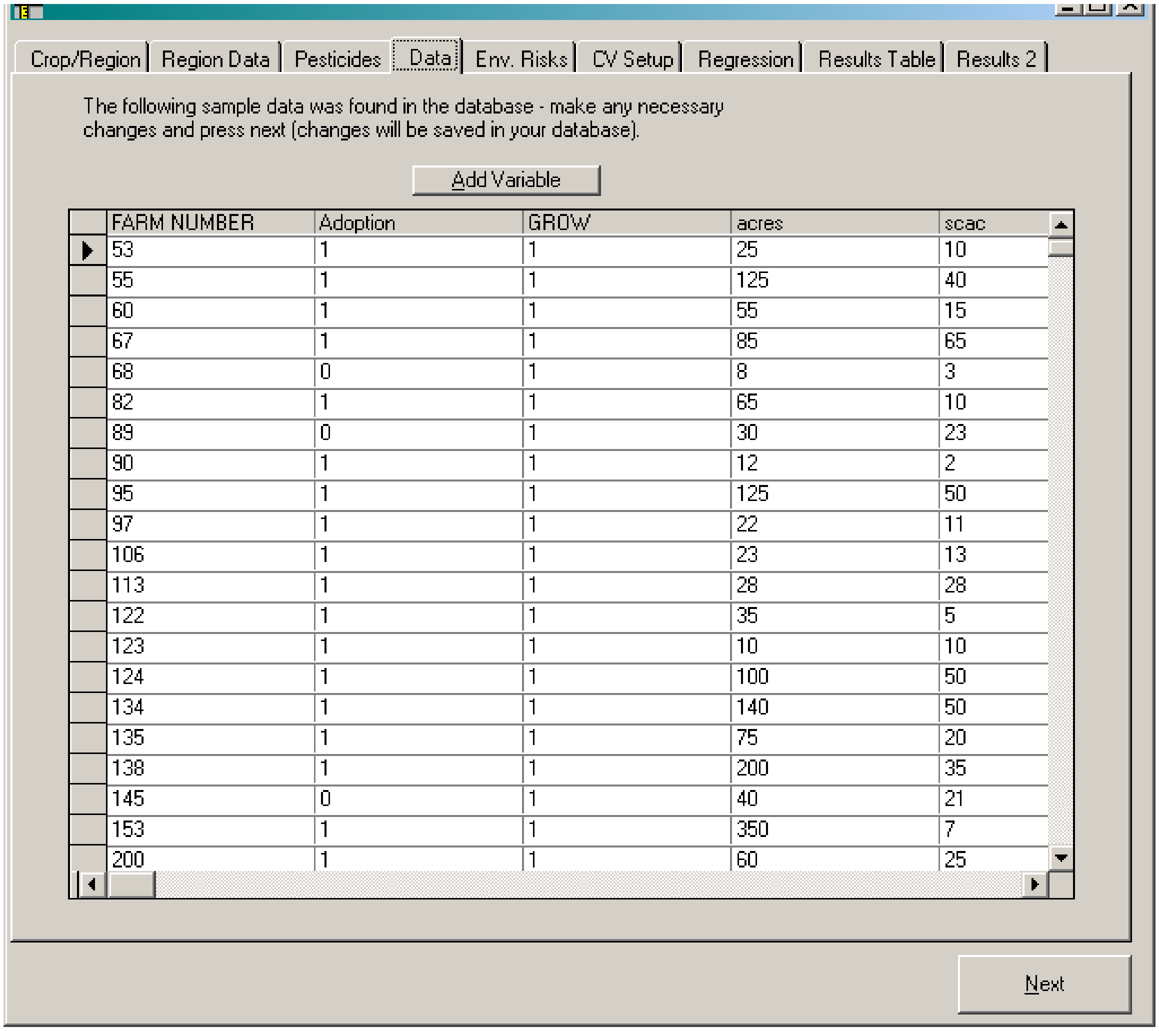


Chemical: 2,4-D (amine)

Formulation: Bicep II - Lite (per QT)

Figure 21: Data Entry Template

The next screen (Figure 22) allows the user to edit and view non-pesticide data from the “SampleData” table. Again, editing, deleting or adding records in the program will also change the table in the database. It is suggested that users enter data directly in the database since many convenience features are not provided in the program (such as importing or pasting from other applications).

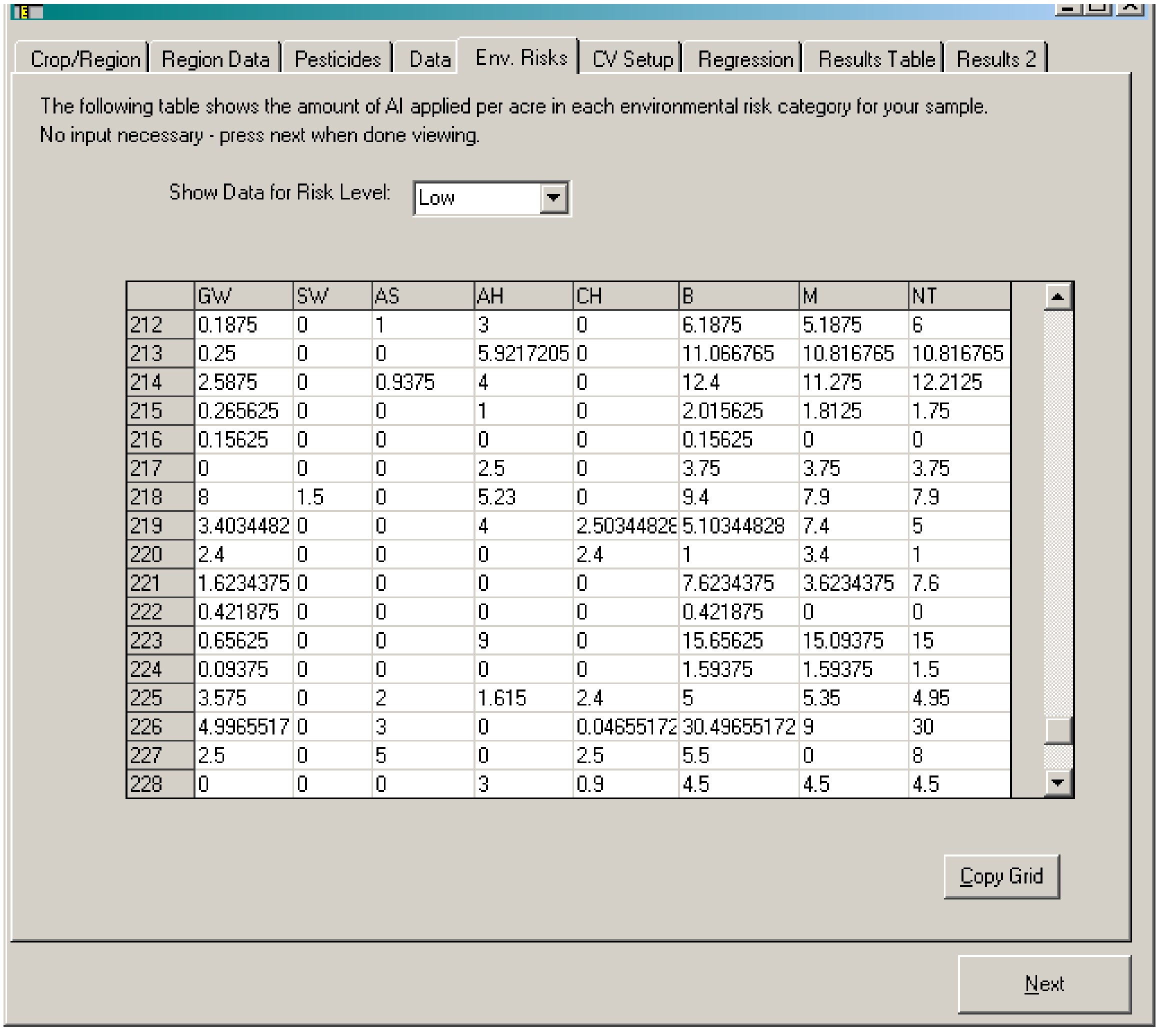


The following sample data was found in the database - make any necessary changes and press next (changes will be saved in your database).

FARM NUMBER	Adoption	GROW	acres	scac
53	1	1	25	10
55	1	1	125	40
60	1	1	55	15
67	1	1	85	65
68	0	1	8	3
82	1	1	65	10
89	0	1	30	23
90	1	1	12	2
95	1	1	125	50
97	1	1	22	11
106	1	1	23	13
113	1	1	28	28
122	1	1	35	5
123	1	1	10	10
124	1	1	100	50
134	1	1	140	50
135	1	1	75	20
138	1	1	200	35
145	0	1	40	21
153	1	1	350	7
200	1	1	60	25

Figure 22: Sample Data Screen

After entering or examining the adoption and demographic data, the user presses “next” to move to the environmental risks screen (Figure 23). The program will begin to make calculations, which may take a considerable amount of time (approx ½ sec per grower). The program will derive the total use of active ingredient for each farmer in the sample and will break it down into each of the 24 environmental risk categories. The resulting figures are presented in tables for low, mid and high risk levels. No input is required on this screen. Pressing the “Copy Grid” button will copy the table to the clipboard in a format that can be pasted into a spreadsheet application.



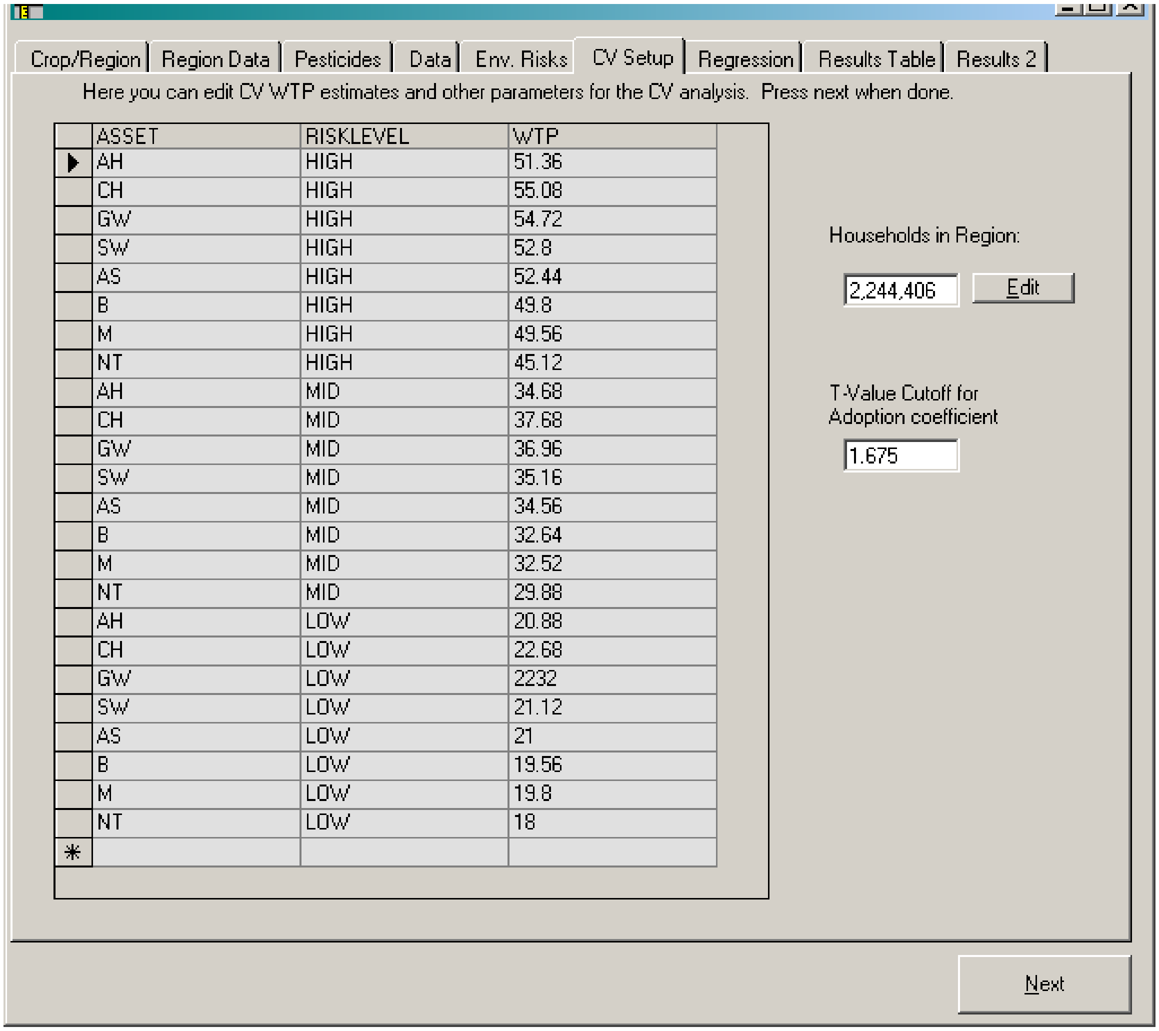
The following table shows the amount of AI applied per acre in each environmental risk category for your sample.
No input necessary - press next when done viewing.

Show Data for Risk Level: Low

	GW	SW	AS	AH	CH	B	M	NT
212	0.1875	0	1	3	0	6.1875	5.1875	6
213	0.25	0	0	5.9217205	0	11.066765	10.816765	10.816765
214	2.5875	0	0.9375	4	0	12.4	11.275	12.2125
215	0.265625	0	0	1	0	2.015625	1.8125	1.75
216	0.15625	0	0	0	0	0.15625	0	0
217	0	0	0	2.5	0	3.75	3.75	3.75
218	8	1.5	0	5.23	0	9.4	7.9	7.9
219	3.4034482	0	0	4	2.50344828	5.10344828	7.4	5
220	2.4	0	0	0	2.4	1	3.4	1
221	1.6234375	0	0	0	0	7.6234375	3.6234375	7.6
222	0.421875	0	0	0	0	0.421875	0	0
223	0.65625	0	0	9	0	15.65625	15.09375	15
224	0.09375	0	0	0	0	1.59375	1.59375	1.5
225	3.575	0	2	1.615	2.4	5	5.35	4.95
226	4.9965517	0	3	0	0.04655172	30.49655172	9	30
227	2.5	0	5	0	2.5	5.5	0	8
228	0	0	0	3	0.9	4.5	4.5	4.5

Figure 23: Environmental Risks Screen

The following screen (Figure 24) allows the user to view and edit the values used in the contingent valuation analysis. A table presents WTP estimates in $/yr/household for each environmental category. The WTP estimates can be changed by the user although the risk levels and environmental assets cannot. The screen also presents the number of households in the region and a "T-Value Cutoff." The t-value cutoff will be explained in the discussion of the "results table" screen.



Here you can edit CV WTP estimates and other parameters for the CV analysis. Press next when done.

	ASSET	RISKLEVEL	WTP
▶	AH	HIGH	51.36
	CH	HIGH	55.08
	GW	HIGH	54.72
	SW	HIGH	52.8
	AS	HIGH	52.44
	B	HIGH	49.8
	M	HIGH	49.56
	NT	HIGH	45.12
	AH	MID	34.68
	CH	MID	37.68
	GW	MID	36.96
	SW	MID	35.16
	AS	MID	34.56
	B	MID	32.64
	M	MID	32.52
	NT	MID	29.88
	AH	LOW	20.88
	CH	LOW	22.68
	GW	LOW	2232
	SW	LOW	21.12
	AS	LOW	21
	B	LOW	19.56
	M	LOW	19.8
	NT	LOW	18
*			

Households in Region: 2,244,406

T-Value Cutoff for Adoption coefficient 1.675

Figure 24: CV Setup Screen

Pressing "next" on the CV screen will display the "regression" screen (Figure

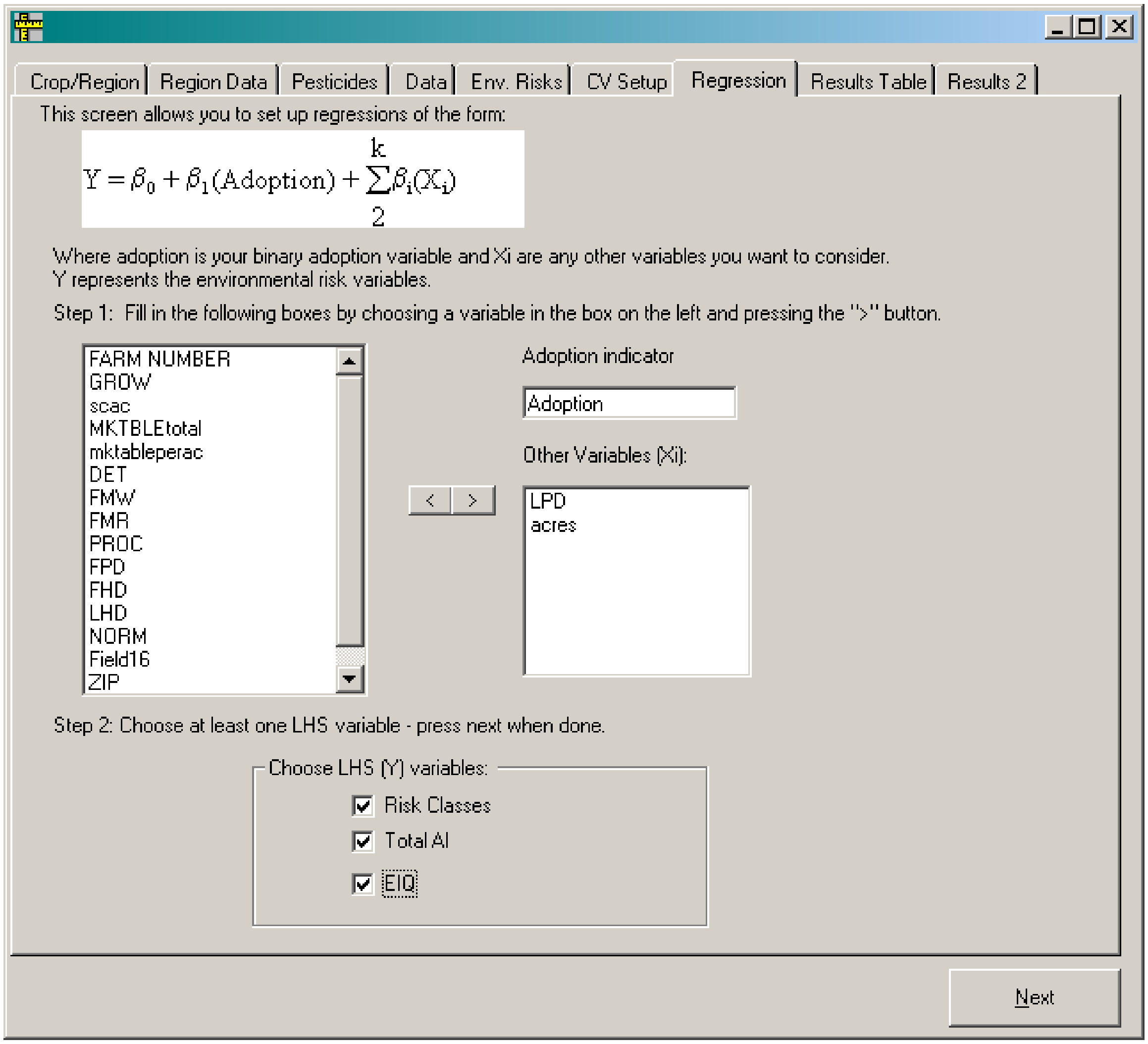
25). Regression analysis can be used to derive the effect of IPM adoption on pesticide use in each of the environmental categories, on total AI usage and/or on the average EIQ rating. The regressions must be of the form:

$$Y = \beta_0 + \beta_1(\text{adoption}) + \sum_{i=2}^{k} \beta_i(x_i)$$

Where:

- β_0 is an intercept term
- adoption is a binary adoption indicator equal to 1 for adopters and 0 otherwise.
- x_i are other continuous or binary numeric variables

When the screen is loaded, the program lists the variables in the dataset and checks for the existence of the adoption variable. Other variables can be added by selecting their name in the list of available variables and pressing the ">" button to move them into the box on the right side of the screen. After selecting variables, the user must choose at least one type of dependent (Y) variable (AI, EIQ and/or risk category). The regressions are run when the user presses "next."



This screen allows you to set up regressions of the form:

$$Y = \beta_0 + \beta_1(\text{Adoption}) + \sum_{2}^{k}\beta_i(X_i)$$

Where adoption is your binary adoption variable and Xi are any other variables you want to consider.
Y represents the environmental risk variables.

Step 1: Fill in the following boxes by choosing a variable in the box on the left and pressing the ">" button.

FARM NUMBER
GROW
scac
MKTBLEtotal
mktableperac
DET
FMW
FMR
PROC
FPD
FHD
LHD
NORM
Field16
ZIP

Adoption indicator: Adoption

Other Variables (Xi):
LPD
acres

Step 2: Choose at least one LHS variable - press next when done.

Choose LHS (Y) variables:
☑ Risk Classes
☑ Total AI
☑ EIQ

Figure 25: Example Regression Screen

After the regressions are run, the results are presented on the "results table" screen (Figure 26). The table lists the coefficient estimates for each variable and each dependent variable. Pressing the "show t values" button will display coefficient regression t-statistics in place of coefficient estimates. The adoption rate for the sample is displayed at the top of the screen. Note that this value can be changed (e.g. if the sample is not representative).

Each row in the table also presents a "potential" and "actual" value. The potential value represents the potential reduction in external costs for the corresponding environmental asset. The value is calculated as:

$$\textbf{\textit{Potential Value}} = \textbf{\textit{Prop}}_{ij} * \textbf{\textit{WTP}}_{ij} * \textbf{\textit{Households}}$$

Where:

- $\textbf{\textit{Prop}}_{ij}$ is the proportionate change in usage of active ingredients that pose risk level j to environmental category i.
- $\textbf{\textit{WTP}}_{ij}$ is the yearly willingness to pay per household for total reduction of risk level j to environmental category i.
- ***Households*** is the number of households in the region.

$\textbf{\textit{Prop}}_{ij}$ represents the proportionate change in active ingredient usage, and is calculated as:

$$\textbf{\textit{Prop}}_{ij} = \frac{\Delta \textbf{\textit{USE}}_{ij}}{\textbf{\textit{TotalUse}}_{ij}\textbf{\textit{w/o}}}$$

Where:

- $\Delta \textbf{\textit{USE}}_{ij}$ is the total estimated change in usage of active ingredients that pose risk level j to environmental category i.
- $\textbf{\textit{TotalUse}}_{ij}\textbf{\textit{W/O}}$ is the total estimated use of active ingredient class ij in the absence of the IPM program.

The estimated coefficient on adoption from the regression analysis (β_{1ij}) represents the estimated average per acre change in usage of active ingredient class ij attributable to IPM adoption. Thus, the product of β_{1ij} and the number of acres served by the program will give the estimated change in a.i. usage with 100% adoption. In the present case, this figure is derived as ΔUSE_{ij}.

Finally, $TotalUse_{ij}W/O$ is calculated as:

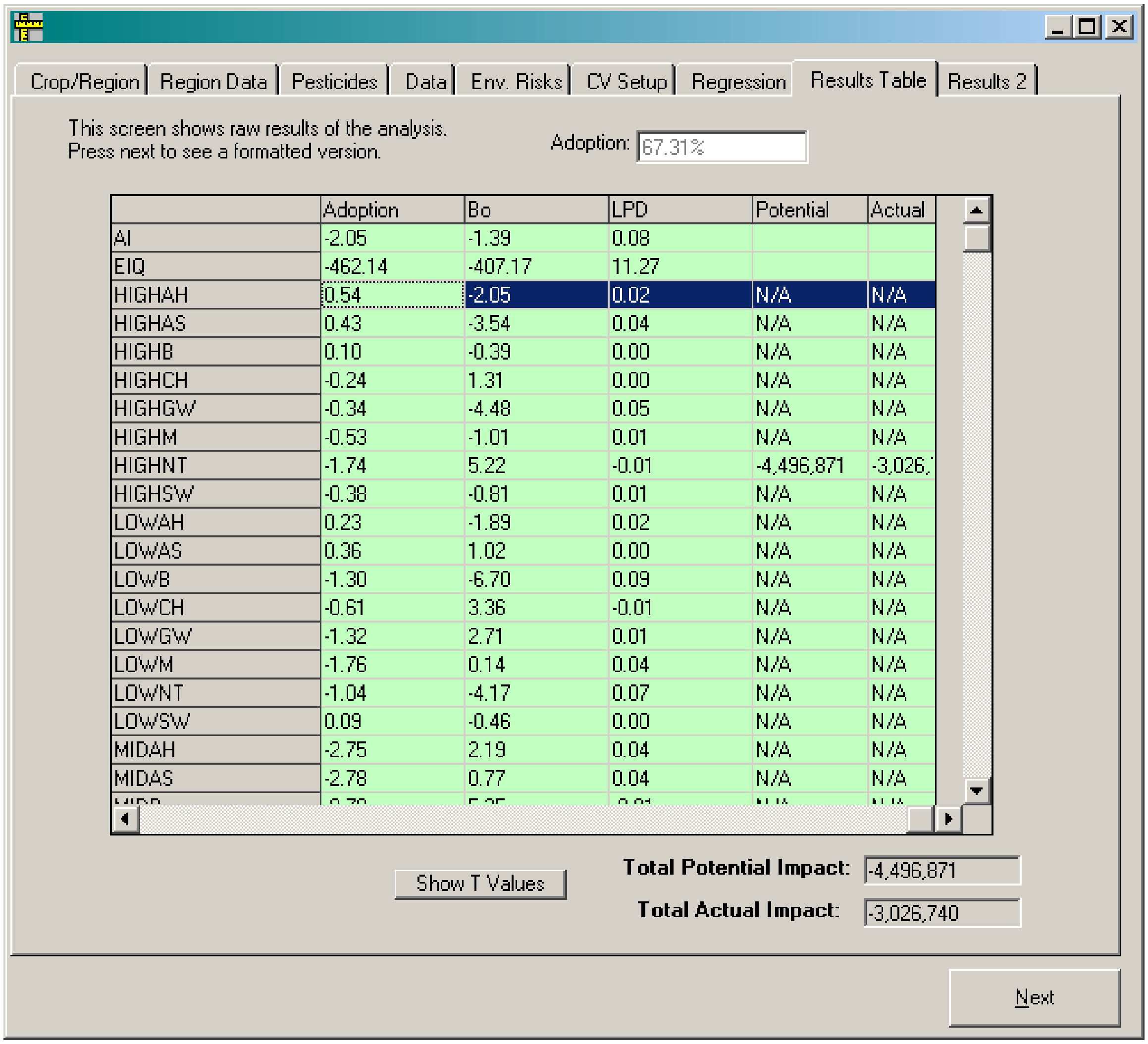
$$\beta_0 + \sum_{i=2}^{k} \beta_i(E(x_i)) * Acres + TotalUse_{ij}$$

Where

- $E(x_i)$ is the expected value of variable x_i
- $TotalUse_{ij}$ is the total use of class ij active ingredients in the study area for all crops except the study crop.

Thus, each "potential" value represents society's willingness to pay for the corresponding reduction in environmental risk if the program has 100% adoption. The "actual" value equals the product of the "potential" value and the adoption rate. The sum of the potential (actual) values for each dependent variable gives the total estimated potential (actual) change in external costs associated with IPM adoption. Note that a negative impact represents a benefit to society (a savings in external costs).

Potential and actual values are only calculated if the absolute value of the t-statistic associated with the adoption (β_1) coefficient is larger than the cutoff specified on the "CV Setup" screen. T-value tests the hypothesis that the β_1 coefficient is equal to zero. Large t-statistics provide evidence that the hypothesis is not true (and therefore that the IPM program has a statistically significant impact on the dependent variable).



This screen shows raw results of the analysis.
Press next to see a formatted version.

Adoption: 67.31%

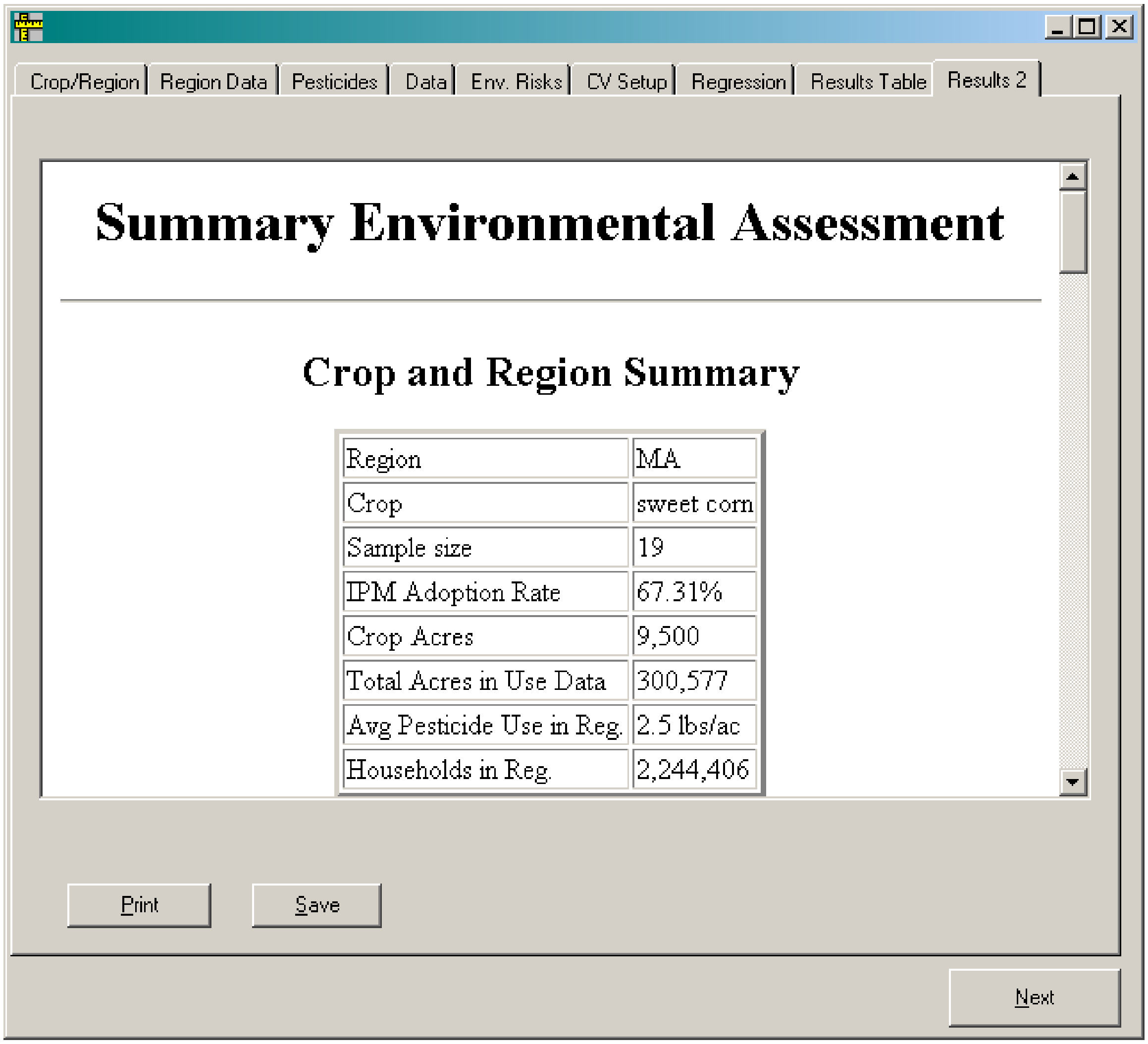
	Adoption	Bo	LPD	Potential	Actual
AI	-2.05	-1.39	0.08		
EIQ	-462.14	-407.17	11.27		
HIGHAH	0.54	-2.05	0.02	N/A	N/A
HIGHAS	0.43	-3.54	0.04	N/A	N/A
HIGHB	0.10	-0.39	0.00	N/A	N/A
HIGHCH	-0.24	1.31	0.00	N/A	N/A
HIGHGW	-0.34	-4.48	0.05	N/A	N/A
HIGHM	-0.53	-1.01	0.01	N/A	N/A
HIGHNT	-1.74	5.22	-0.01	-4,496,871	-3,026,
HIGHSW	-0.38	-0.81	0.01	N/A	N/A
LOWAH	0.23	-1.89	0.02	N/A	N/A
LOWAS	0.36	1.02	0.00	N/A	N/A
LOWB	-1.30	-6.70	0.09	N/A	N/A
LOWCH	-0.61	3.36	-0.01	N/A	N/A
LOWGW	-1.32	2.71	0.01	N/A	N/A
LOWM	-1.76	0.14	0.04	N/A	N/A
LOWNT	-1.04	-4.17	0.07	N/A	N/A
LOWSW	0.09	-0.46	0.00	N/A	N/A
MIDAH	-2.75	2.19	0.04	N/A	N/A
MIDAS	-2.78	0.77	0.04	N/A	N/A

Total Potential Impact: -4,496,871

Total Actual Impact: -3,026,740

Figure 26:Example of Results Screen

In the final screen, the results are formatted for printing (Figure 27). The results can also be saved or copied into a word processor. Results are copied to the system clipboard by selecting the desired portion of the results report then pressing CTRL-C.



Summary Environmental Assessment

Crop and Region Summary

Region	MA
Crop	sweet corn
Sample size	19
IPM Adoption Rate	67.31%
Crop Acres	9,500
Total Acres in Use Data	300,577
Avg Pesticide Use in Reg.	2.5 lbs/ac
Households in Reg.	2,244,406

Figure 27: Example of Formatted Results Screen

Limitations

Computer applications necessarily encapsulate assumptions about end users, thus limiting the types of analysis that can be performed. For example, in the present case it was assumed that users are interested in assessing the environmental impact of an IPM program defined in terms of a single commodity. The types of analysis preformed by the program are limited and may not be applicable to some programs.

However, the source code of the program can easily be edited to perform analyses using other "non-location specific" pesticide impact models to assess IPM programs. The following paragraphs discuss some of the limitations of the program and provide suggestions for extending the program to meet the needs of other users.

Assessment of Programs that are not in the Database

Recall that aggregate records for the crop under assessment (e.g. in the totaluse table) are only needed to derive the TotalUse_{ij} parameters for other crops. This is used to approximate pesticide usage without the program. If the crop under assessment is not included in the TotalUse table, analysis can proceed by adding records to the table indicating estimated overall usage of each pesticide AI for the crop. If the commodity appears in the table, it can be used in the analysis even if use of zero active ingredient is indicated. This approach might be adequate for crops with little pesticide use relative to the total use in the region.

Multi-Year Analysis

The program performs analysis for a single period. However, the program's output can be used as input for multi-year analyses. The simplest way to perform such an analysis would be to predict adoption into future years and assume that IPM adoption will always produce the same impact per-acre (e.g. that B_1 is constant over time). The impact in a future period would be equal to the potential impact reported by the program multiplied by the expected adoption rate during the future period. A series of such calculations could then be entered into NPV-type formulas to derive the current value of expected future impacts.

Assessment of other Regions

Any type of regional IPM program can be assessed as long as it is defined in terms of crops. If a region does not appear in the database, assessment can be performed by providing the total use of each pesticide AI not including the crop under assessment. This data does not need to be broken down by crop. The region is added by adding at least one record to the "TotalUse" table and one record to the households table.

Extension of the Program

Additional scoring models and analytical techniques can be easily incorporated into the program by any programmer who is familiar with SQL and Visual Basic. Proficiency is not required as existing code can be used as a template. Some suggestions for extension of the program are presented below:

1. Assessment by type of pesticide AI (e.g. by chemical class) could be incorporated by adding a column to the chemicals table indicating the class of chemical represented by the record. A single query could then extract farm level application data broken down into any desired chemical classification scheme. Pounds of AI applied by classification could then be used as dependent variables in the regression analysis.
2. Inclusion of pesticide costs in the model could be accomplished by providing a table of costs for each pesticide AI. The approach would be very similar to the EIQ routines, which could be used as a template.
3. Estimation of changes in revenues or yields associated with IPM adoption. This would require the user to provide a yield variable, which would be used as a dependent variable in the regression analyses.

Coding of the Program

The program is written in Visual Basic 6.0 using the ActiveX Data Objects object model (ADO) to manage the database. The code was written to maximize transparency. For example, most communications with the database are achieved by passing SQL statements to the database rather than by binding controls directly to data objects. This makes the code more “readable” as the communications between the database and program are explicitly written into the code. The program writes formatted output in the HTML format, which is readable by all modern word processors.

The speed of the program could be improved in several places by writing queries that are more efficient. For example, the per-farm “totaluse” calculations query the database for each environmental category for each farmer in the sample. This requires 24*n queries, which the program must write dynamically. This could be accomplished with eight queries by extracting the per-farm AI use by environmental category for each risk level. However, the limited audience of the program, the expected use of relatively small datasets and the speed of modern desktop computers make it favorable to concentrate development efforts on analysis rather than on efficiency.

Conclusion

The program is intended to assist individuals who are charged with the task of performing an environmental assessment. The methods used in the analysis are applicable to most crop IPM programs and the source code can be used as a template for developing programs that incorporate other types of analysis. The program is most valuable when the resources devoted to an environmental assessment are limited. In such cases, analysts often choose to ignore environmental impacts or to only report changes in total AI. This application gives analysts the option of considering environmental impacts without incurring large additional analytical costs.

Appendix B: Risk Levels for Pesticide Active Ingredients[24]

Common	GW	SW	AS	AH	CH	B	M	NT
2,4-D (amine)	MID	HIGH	HIGH	HIGH	MID	MID	MID	HIGH
2,4-D butyl ester	MID	HIGH	MID	LOW	LOW	LOW	LOW	LOW
Abamectin	LOW	LOW	MID	HIGH	LOW	LOW	HIGH	HIGH
Acephate	LOW	LOW	LOW	LOW	LOW	MID	MID	HIGH
Acifluorfen	MID	MID	LOW	HIGH	MID	MID	LOW	LOW
Alachlor	MID	MID	MID	MID	HIGH	LOW	MID	LOW
Aldicarb	HIGH	HIGH	MID	HIGH	LOW	HIGH	HIGH	LOW
Atrazine	HIGH	MID	MID	MID	MID	LOW	LOW	LOW
Azinophos-methyl	LOW	HIGH	HIGH	HIGH	MID	MID	HIGH	HIGH
Benefin	LOW	HIGH	HIGH	MID		LOW	LOW	LOW
Benomyl	HIGH	HIGH	HIGH	MID	HIGH	LOW	LOW	HIGH
Bensulide	MID	MID	HIGH	LOW	MID	MID	MID	HIGH
Bentazon	HIGH	MID	LOW	MID	MID	LOW	MID	LOW
Bifenthfin	LOW	MID	HIGH	MID	MID	LOW	MID	
Bromoxynil	LOW	MID	HIGH	MID	MID	HIGH	MID	LOW
Bt	LOW	LOW	LOW	LOW	MID	LOW	LOW	MID
Butylate	MID	MID	MID	LOW	HIGH	LOW	LOW	LOW
Calcium Polysulfide	LOW	LOW	MID	LOW	LOW	MID	MID	MID
Captan	LOW	LOW	LOW	HIGH	HIGH	LOW	LOW	LOW
Carbaryl	LOW	MID	MID	MID	LOW	MID	LOW	HIGH
Carbofuran	HIGH	LOW	MID	HIGH	LOW	HIGH	HIGH	HIGH
Carboxin	LOW	MID	HIGH	LOW	LOW	LOW	LOW	LOW
Chloramben			LOW	MID	HIGH	LOW	LOW	
Chlorimuron	HIGH	MID	MID	LOW	LOW	LOW	LOW	MID
Chlorimuron Ethyl	HIGH	LOW	MID	LOW	LOW	LOW	LOW	HIGH
Chloropicrin	LOW	LOW	LOW	HIGH	LOW	LOW	LOW	LOW
Chlorothalonil	LOW	HIGH	HIGH	HIGH	MID	LOW	LOW	LOW
Chlorpyrifos	LOW	HIGH	HIGH	MID	MID	MID	HIGH	HIGH
Clomazone	MID	MID	HIGH	LOW	LOW	LOW	LOW	
Copper Sulfate	LOW	LOW	MID	HIGH	LOW	LOW	HIGH	HIGH
CRYOLITE	LOW	HIGH	LOW	LOW		LOW	LOW	LOW
Cyanazine	MID	MID	LOW	MID	HIGH	MID	MID	LOW
Cyfluthrin	LOW	MID	HIGH	MID		MID	MID	
Cypermethrin	LOW	MID	HIGH	HIGH	MID	LOW	MID	HIGH
DCNA (dichloran)	LOW	MID	LOW	LOW	LOW	LOW	LOW	LOW
DCPA (chlorthal)	LOW	MID	LOW	LOW	LOW	LOW	LOW	LOW

---

[24] Most pesticide risk levels are from Mullen (1995); risk levels for 21 active ingredients were added.

Common	*GW*	*SW*	*AS*	*AH*	*CH*	*B*	*M*	*NT*
Diazinon	MID	MID	HIGH	MID	HIGH	HIGH	MID	HIGH
Dicamba	HIGH	LOW	LOW	MID	MID	LOW	LOW	LOW
Diclofop	LOW	MID	HIGH	HIGH		LOW	LOW	
Dicofol	LOW	HIGH	HIGH	MID	LOW	LOW	MID	LOW
Dicrotophos	MID	HIGH	LOW	HIGH	MID	HIGH	HIGH	HIGH
Dimethipin	HIGH	HIGH	MID	LOW			LOW	
Dimethoate	MID	LOW	LOW	MID	MID	HIGH	HIGH	HIGH
Dinocap	LOW	MID	LOW	LOW	HIGH	HIGH	MID	LOW
Diphenamid	MID	HIGH	MID				LOW	LOW
DIQUAT	LOW	HIGH	LOW	MID	LOW	MID	HIGH	LOW
Disulfoton	LOW	MID	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH
Diuron	MID	HIGH	MID	MID	MID	LOW	LOW	LOW
Dodine	LOW	MID	HIGH	HIGH	MID	LOW	LOW	LOW
DSMA	LOW	HIGH	LOW	LOW			LOW	
Endosulfan	LOW	HIGH	HIGH	HIGH	MID	MID	HIGH	LOW
EPTC	MID	MID	LOW	MID	LOW	LOW	LOW	LOW
Esfenvalerate	LOW	HIGH	HIGH	MID	LOW	LOW	MID	HIGH
Ethanfluralin	LOW	HIGH	HIGH	MID	HIGH	MID	LOW	LOW
Ethephon	LOW	MID	LOW	MID	HIGH	LOW	LOW	LOW
Ethion	LOW	MID	HIGH	HIGH	HIGH	HIGH	HIGH	LOW
Ethoprop	HIGH	MID	HIGH	HIGH	MID	HIGH	HIGH	HIGH
Etridiazole	MID	HIGH	MID	MID		LOW	LOW	LOW
Fenamiphos	HIGH	LOW	HIGH	HIGH	LOW	HIGH	HIGH	LOW
Fenarimol	HIGH	HIGH	HIGH	MID	HIGH	LOW	MID	LOW
Fenbutatin Oxide	LOW	MID	HIGH	HIGH		LOW	LOW	LOW
Fenoxaprop	LOW	HIGH		MID			LOW	
ferbam	MID	MID	LOW	LOW	MID		LOW	MID
fluazifop	LOW	HIGH	HIGH			LOW	LOW	LOW
fluazifop-P-Butyl	LOW	HIGH	HIGH	HIGH	MID	LOW	LOW	LOW
fluometuron	HIGH	HIGH	LOW	MID	HIGH	LOW	LOW	LOW
fonofos	MID	HIGH	HIGH	HIGH	LOW	HIGH	HIGH	HIGH
formetanate	HIGH	LOW	LOW	HIGH		HIGH	HIGH	MID
Formetanate HCL	LOW	HIGH	MID	HIGH		HIGH	HIGH	MID
glyphosphate	LOW	HIGH	MID	HIGH	LOW	LOW	LOW	MID
Hexazinone	HIGH	HIGH	LOW	HIGH	HIGH	LOW	LOW	LOW
imazaquin	HIGH	HIGH	LOW	LOW		LOW	LOW	
imazethapyr	HIGH	HIGH	LOW	LOW		LOW	LOW	
iprodione	LOW	MID	MID	LOW	MID	LOW	LOW	LOW
isopropalin	LOW	MID	HIGH	LOW	HIGH	LOW	LOW	
lamda-cyhalothrin	LOW	MID	HIGH	MID		LOW	LOW	
lindane	HIGH	HIGH	HIGH	MID	LOW	MID	MID	HIGH
linuron	MID	MID	LOW	LOW	MID	MID	LOW	LOW
malathion	LOW	LOW	LOW	MID	HIGH	MID	LOW	HIGH

Common	*GW*	*SW*	*AS*	*AH*	*CH*	*B*	*M*	*NT*
maleic hydrazide	HIGH	HIGH	LOW	LOW	LOW	LOW	LOW	LOW
mancozeb	LOW	HIGH	HIGH	LOW	HIGH	LOW	LOW	HIGH
Maneb	LOW	MID	MID	LOW	HIGH	LOW	LOW	LOW
MCPA	LOW	MID	LOW	HIGH	HIGH	MID	LOW	LOW
MCPB			LOW	LOW		LOW	LOW	LOW
mepiquat chloride	LOW	HIGH	LOW	MID		LOW	LOW	LOW
metalaxyl	HIGH	LOW	LOW	MID	LOW	LOW	LOW	LOW
metam sodium (metham)	MID	HIGH	HIGH	HIGH	HIGH	LOW	MID	LOW
Methamidophos	MID	HIGH	LOW	HIGH	HIGH	HIGH	HIGH	HIGH
methazole	LOW	LOW	LOW	MID			LOW	HIGH
methidathion	LOW	MID	HIGH	HIGH	MID	HIGH	HIGH	HIGH
methomyl	HIGH	MID	HIGH	HIGH	LOW	MID	MID	MID
methoxychlor	LOW	MID	HIGH	LOW	LOW	LOW	LOW	HIGH
methyl bromide	HIGH	HIGH	LOW	HIGH	HIGH	HIGH	HIGH	HIGH
Methyl Parathion	LOW	MID	HIGH	HIGH	MID	HIGH	HIGH	MID
methyl parathion	LOW	LOW	MID	HIGH	MID	LOW	MID	HIGH
metiram	LOW	HIGH	LOW	LOW	HIGH	LOW	LOW	LOW
metoachlor	MID	MID	MID	LOW	MID	LOW	LOW	LOW
metribuzin	HIGH	MID	LOW	LOW	LOW	MID	MID	LOW
MSMA	LOW	HIGH	LOW	LOW			LOW	
myclobutanil				HIGH	LOW		LOW	
napropamide	MID	HIGH	MID	LOW	MID	LOW	LOW	LOW
naptalam	HIGH	HIGH	LOW	MID			LOW	LOW
napthalene acetic acid	MID	MID				LOW	LOW	
Nicosulfuron	HIGH	HIGH	LOW	LOW	HIGH	LOW	LOW	LOW
norflurazon	LOW	MID	LOW	LOW	LOW	LOW	LOW	LOW
oryzalin	LOW	MID	MID	LOW	MID	LOW	LOW	LOW
Oxamyl	LOW	HIGH	MID	HIGH	LOW	HIGH	HIGH	HIGH
oxyflurofen	LOW	HIGH	HIGH	MID	HIGH	LOW	LOW	HIGH
oxythioquinox	LOW	MID	HIGH			HIGH	LOW	LOW
paraquat	LOW	HIGH	MID	HIGH	HIGH	MID	HIGH	LOW
PCNB	LOW	HIGH	HIGH	MID	MID	MID	LOW	LOW
pebulate	LOW	MID	MID	LOW	MID	LOW	LOW	
pendimethalin	LOW	HIGH	HIGH	MID	MID	LOW	LOW	LOW
permethrin	LOW	HIGH	HIGH	MID	MID	LOW	MID	HIGH
petroleum distillate	LOW	LOW	LOW	LOW	MID	LOW	LOW	HIGH
phorate	LOW	HIGH	HIGH	HIGH	LOW	HIGH	HIGH	MID
phosmet	LOW	MID	HIGH	MID	MID	LOW	MID	MID
phosphamidon	HIGH	LOW	MID	HIGH	MID	HIGH	HIGH	HIGH
primisulfuron				LOW	LOW	LOW	LOW	LOW
profenofos	LOW	LOW	MID	HIGH		HIGH	MID	HIGH
Propachlor	LOW	HIGH	HIGH	MID	LOW	MID	LOW	MID
propargite	LOW	HIGH	HIGH	HIGH	MID	LOW	MID	LOW
propiconazole	MID	MID	LOW	MID			LOW	LOW

Common	*GW*	*SW*	*AS*	*AH*	*CH*	*B*	*M*	*NT*
pyridate			LOW	LOW		LOW	LOW	LOW
quizalofop ethyl	LOW	HIGH	HIGH	LOW	LOW	LOW	LOW	LOW
sethoxydim	LOW	LOW	LOW	MID	LOW	LOW	LOW	LOW
simiazine	HIGH	MID	MID	LOW	MID	LOW	LOW	LOW
streptomycin	LOW	LOW	MID	MID	LOW	MID	MID	MID
sulfur	LOW	LOW	LOW	LOW	LOW	LOW	LOW	HIGH
Tefluthrin			HIGH	MID		LOW	LOW	HIGH
terbacil	HIGH	HIGH	LOW	LOW	LOW	LOW	LOW	LOW
terbufos	LOW	MID	HIGH	HIGH	LOW	HIGH	HIGH	LOW
thidiazuron	MID	MID	LOW	LOW		LOW	LOW	
thidophanate methyl	LOW	MID	HIGH	LOW	LOW	LOW	LOW	HIGH
thiodicarb	LOW	MID	HIGH	MID	LOW	LOW	MID	
Thiophanate Methyl	LOW	LOW	LOW	LOW		LOW	LOW	LOW
thiram	LOW	LOW	MID	LOW	HIGH	LOW	LOW	LOW
tralomethrin	LOW	MID	HIGH	MID		LOW	LOW	
Triadimefon	MID	HIGH	LOW	MID	MID	LOW	MID	LOW
triadmefon	MID	MID	MID	MID	MID	LOW	MID	LOW
tribufos	LOW	LOW		MID				
trichlorfon	HIGH	LOW	LOW	HIGH	HIGH	HIGH	MID	HIGH
trifluralin	LOW	HIGH	HIGH	MID	MID	LOW	LOW	LOW
Triforine	MID	MID	LOW	HIGH	LOW	LOW	LOW	LOW
vernolate	LOW	LOW	LOW	LOW		LOW	LOW	MID
vinclozolin	LOW	LOW	LOW	MID	LOW	LOW	LOW	LOW
ziram	LOW		MID	HIGH	HIGH	MID	LOW	LOW

Appendix C: Descriptive Data for Case Study Samples

This section presents summary data collected from the Pennsylvania and Massachusetts surveys. Tables 47-49 describe the Pennsylvania data and Tables 50-52 describe the Massachusetts data.

Table 47: Summary Data for Pennsylvania Survey: Section 2

	Units	Average	Median	Stdev.	Skewness	Kurtosis	Min.	Max.	n
2.1) Please answer the following for last year:									
a) How many total acres did you farm?	Acres	246.1	105.0	428.7	4.21	21.24	2.5	2500	38
b) How many acres were devoted to sweet corn?	Acres	35.0	15.0	48.2	2.79	8.76	1.0	235	39
c) Approximately how much marketable sweet corn did you produce per acre?	Doz. Ears	809.5	810.0	321.4	-0.11	0.69	50.0	1600	33
d) Approximately what percentage of your sweet corn was sold in each of the following markets?									
fresh market wholesale	Percent	31.3	5.0	41.1	0.88	-1.04	0.0	100	39
fresh market retail	Percent	66.2	95.0	42.2	-0.75	-1.28	0.0	100	39
processing	Percent	2.6	0.0	16.0	6.24	39.00	0.0	100	39
2.2) Considering your use of inputs and intensity of management, what level of yield can you expect to achieve in a normal year (per acre)?	Doz. Ears	964.1	951.2	503.8	2.15	7.53	166.7	3000	34
2.4) How many years have you been farming sweet corn? _______ years	Years	19.3	16.0	13.1	1.66	4.61	1.0	70	39
2.5) When did you plant and harvest sweet corn last year?									
First planting date	Day of Yr.	105.0	104.0	15.3	0.08	0.10	76.0	139	39
Last planting date	Day of Yr.	177.1	181.0	17.2	-0.72	-0.06	134.0	202	39
First harvest date	Day of Yr.	193.0	193.0	14.8	1.07	3.53	164.0	247	39
Last harvest date	Day of Yr.	261.2	259.0	17.9	-0.40	0.09	219.0	298	39

Table 48: Summary Data for Pennsylvania Survey: Section 3

Please provide your best estimate of how severe each pest was over the past year on your farm relative to your perception of the average severity on the average Pennsylvania sweet corn farm.

Enter a number from 0 to 3, where:
0 - indicates the pest was completely absent,
1 - indicates the pest population was relatively low,
2 - indicates the pest population was moderate or average and,
3 - indicates the pest population was relatively high.

	Percent Responding:				
Category	**0**	**1**	**2**	**3**	**N**
Insects					
sap beetles	17.6%	52.9%	23.5%	5.9%	34
aphids	27.0%	45.9%	21.6%	5.4%	37
fall armyworm (FAW)	13.2%	34.2%	31.6%	18.4%	38
corn earworm (CEW)	2.6%	23.7%	44.7%	28.9%	38
corn rootworm	18.2%	36.4%	33.3%	12.1%	33
European corn borer (ECB)	0.0%	23.1%	48.7%	28.2%	39
worms (if not specified above)	46.2%	30.8%	15.4%	7.7%	13
other (specify) ___________	22.2%	0.0%	72.2%	5.6%	18
Weeds					
perennial weeds	10.3%	38.5%	30.8%	20.5%	39
annual broadleaf weeds	2.6%	33.3%	35.9%	28.2%	39
annual grasses	7.7%	51.3%	20.5%	20.5%	39
Diseases					
Stewart's Wilt	47.2%	33.3%	13.9%	5.6%	36
smut	15.4%	69.2%	10.3%	5.1%	39
rust	29.7%	56.8%	10.8%	0.0%	37

Table 49: Summary Data for Pennsylvania Survey: Sections 4-5

	Units	Yes	No	Don’t Know	Average	Median	Stdev.	n
4.1 b) If you did not plant a transgenic (Bt) variety, would you be interested in planting one in the future?	Percent	74.4%	15.4%	10.3%	--	--	--	39
4.2) Do you rotate any sweet corn fields with other crops? (if no, skip to part d)	Percent	92.3%	7.7%	--	--	--	--	39
a) Average % of sweet corn acreage rotated?	Percent	--	--	--	68.64	75.00	32.01	39
b) How long have you been rotating sweet corn?	Years	--	--	--	15.97	13.00	11.84	37
c) Approximately what % of rotated fields still needed a soil insecticide?	Percent	--	--	--	29.55	-	42.59	32
d) Over the next 5 years, do you plan to rotate sweet corn fields?	Percent	94.6%	5.4%	0.0%	--	--	--	37
4.4b) Did you scout for target pests before deciding whether to apply a soil insecticide?	Percent	35.5%	64.5%	0.0%	--	--	--	31
5.2) Did you scout for weeds before deciding whether to apply post-emergent herbicides?	Percent	91.4%	8.6%	0.0%	--	--	--	35
a) What was the approximate % of sweet corn acreage scouted?	Percent	--	--	--	79.00	100.00	35.04	32
b) How long have you been scouting for weeds before post-emergent herbicide application?	Years	--	--	--	12.31	10.00	5.05	29
c) Over the next 5 years, do you plan to scout for weeds?	Percent	96.9%	3.1%	0.0%	--	--	--	32
on ____ % of acres	Percent				97.17	100.00	7.36	23
5.3) Did you cultivate to control weeds? (if no, skip to part c)	Percent	60.5%	39.5%	0.0%	--	--	--	38
a) On approximately what percentage of cultivated acreage were post-emergent herbicides still necessary to control weeds?	Percent	--	--	--	26.24	-	35.12	29
b) How long have you been cultivating to control weeds?	Years	--	--	--	18.05	13.50	13.39	22

	Units	Yes	No	Don't Know	Average	Median	Stdev.	n
c) Over the next 5 years, do you plan to cultivate to control weeds?	Percent	72.4%	27.6%	0.0%	--	--	--	29
6.2) Did you scout your fields for insects before deciding whether or not to apply insecticides?	Percent	76.9%	23.1%	0.0%	--	--	--	39
a) Approximate % of sweet corn acreage scouted for insects	Percent	--	--	--	55.26	75.00	45.80	39
c) How long have you been scouting for insects?	Years	--	--	--	10.62	9.00	8.42	29
d) Over the next 5 years, do you plan to scout your fields for insects?	Percent	91.4%	8.6%	0.0%	--	--	--	35
on ____ % of of acres	Percent				85.96	100.00	31.18	26
6.3) Did you use action thresholds for making decisions about applying insecticides?	Percent	69.2%	30.8%	0.0%	--	--	--	39
6.4) Over the next 5 years, do you plan to use action thresholds for making your insecticide application decisions?	Years	74.4%	25.6%	0.0%	--	--	--	39
on ____ % of acres	Percent	--	--	--	0.84	1.00	0.37	32
6.5) Did you use any traps (pheromone or light traps) to help you make decisions regarding insecticide applications?	Percent	38.5%	61.5%	0.0%	--	--	--	39
6.6) Did you call 1-800-PENN-IPM to get a pest status report before making decisions regarding insecticide applications?	Percent	50.0%	50.0%	0.0%	--	--	--	38
If yes, approximately how many times did you call?	Calls	--	--	--	4.69	-	9.35	36
7.2) Did you plant tolerant/resistant varieties for controlling maize dwarf mosaic, common rust, smut, and/or Stewart's wilt?	Percent	70.6%	23.5%	5.9%	--	--	--	34
7.3) Over the next 5 years, do you plan to plant tolerant/resistant varieties for controlling maize dwarf mosaic, common rust, smut, and/or Stewart's wilt?	Percent	82.9%	8.6%	8.6%	--	--	--	35

Table 50: Summary Data for MA Survey: Section 1

Question	Units	Average	Median	Stdev.	n
1a) How many total acres did you farm?	Acres	60.15	35	63.74	54
1b) How many acres were devoted to sweet corn?	Acres	23.58	15	22.39	54
1c) How much marketable sweet corn did you produce?	Doz. Ears	16,788.04	10,000	18,778.08	53
1d) Approximately what percentage of your sweet corn was sold in each of the following markets?					
fresh market - wholesale	Percent	23.46	5	32.92	54
fresh market - retail	Percent	76.35	95	32.90	54
processing		0.00	0.00	0.00	54
1e) When did you first plant and harvest sweet corn?					
First planting date	Day of Year	109.96	107	13.10	53
Last Planting Date	Day of Year	178.58	185	19.74	53
First harvest date	Day of Year	192.57	194	14.53	53
Last harvest date	Day of Year	256.62	263	25.28	53
2) What level of yield can you expect to achieve in a normal year (per acre)?	Doz. Ears	876.96	847	431.10	53

Table 51: Summary Data for MA "Importance" Questions

Item	Percent responding:			n
	"not important"	"somewhat important"	"very important"	
effectiveness of the pesticide	0.0%	11.3%	88.7%	53
impact on ground and/or surface water	0.0%	22.6%	77.4%	53
cost	15.1%	62.3%	22.6%	53
availability of chemicals (e.g. leftover from other crops)	29.2%	60.4%	10.4%	48
safety of workers	0.0%	9.4%	90.6%	53
impact on beneficial insects	5.7%	28.3%	66.0%	53
impact on other non-target organisms (e.g. birds fish)	5.7%	22.6%	71.7%	53

Table 52: Summary Data for MA Survey: Adoption

Practice	% indicating use:
Stubble was turned under or harrowed before planting	63.5%
Sweet corn was rotated with other crops.	57.7%
A winter cover crop was used for weed control.	76.9%
Sprayers were calibrated at the start of the season.	73.1%
Separate sprayers were used for insecticides and herbicides.	57.7%
Sprayer calibration was checked at least once during the season.	42.3%
A boom sprayer with double drop nozzles was used where coverage of the ear zone was desirable.	34.6%
When a mist blower was used for ear zone coverage, blocks were not more than 12 rows wide.	34.6%
Records of planting and harvest dates of treated fields were maintained by block.	75.0%
Pesticide coverage of target and non-target areas was tested using water sensitive spray cards.	38.5%
corn earworm (CEW) populations were monitored using pheromone traps	51.9%
European corn borer (ECB) populations were monitored using pheromone traps	51.9%
fall armyworm (FAW) populations were monitored using pheromone traps	34.6%
Insecticides applied to control corn earworm (CEW) corresponded to recommended thresholds	67.3%
Insecticides applied to control European corn borers (ECB) corresponded to recommended thresholds	69.2%
Insecticides applied to control fall armyworm (FAW) corresponded to recommended thresholds	48.1%
Other insect pests for which thresholds are not available, were treated only after scouting.	55.8%
Floating row covers were used in early corn through the whorl stage to inhibit ECB.	7.7%
Insects were successfully kept below the economic injury level through non-chemical means such as biological insecticides (e.g. B.t.'s) or beneficial insects on part of the sweet corn acreage.	3.8%
Sweet corn fields were scouted for weeds during the	19.2%

Practice	% indicating use:
previous season and a weed map was created.	
Weeds were controlled by cultivation and no herbicide was applied.	5.8%
Herbicide rates were reduced through banding of herbicides and cultivation.	32.7%
Herbicide rates were reduced through delayed application of reduced rates of the herbicide(s).	51.9%
Weeds in fields, alleys and roadways were prevented from going to seed.	57.7%
Tolerant/resistant varieties were used to control Stewart's wilt or maize dwarf mosaic virus (MDMV)	61.5%

Appendix D: Survey Instruments

The Pennsylvania survey instrument is presented on pages 186-191 The Massachusetts survey instrument can be found on pages 192-197.

Section 2: General Information

2.1) Please answer the following for last year:

a) How many total acres did you farm? _________ac.

b) How many acres were devoted to sweet corn? _________ac.

c) Approximately how much marketable sweet corn did you produce per acre?
__________ [] doz. ears or [] crates (check one)

d) Approximately what percentage of your sweet corn was sold in each of the following markets?

fresh market wholesale	_____ %
fresh market retail	_____ %
processing	_____ %

2.2) Considering your use of inputs and intensity of management, what level of yield can you expect to achieve in a normal year (per acre)? _________ [] doz. ears or [] crates (check one)

2.3) What is your ZIP code? __ __ __ __ __

2.4) How many years have you been farming sweet corn? _______ years

2.5) When did you plant and harvest sweet corn last year?
First planting date: _____________ Last planting date: ____________
First harvest date: _____________ Last harvest date: _____________

Section 3: Pests

Please provide your best estimate of how severe each pest was over the past year on your farm relative to your perception of the average severity on the average Pennsylvania sweet corn farm.

Enter a number from 0 to 3, where:
0 - indicates the pest was completely absent,
1 - indicates the pest population was relatively low,
2 - indicates the pest population was moderate or average and,
3 - indicates the pest population was relatively high.

Pest	Severity
Insects	Less ←→ More
sap beetles	[] 0 [] 1 [] 2 [] 3 [] don't know
aphids	[] 0 [] 1 [] 2 [] 3 [] don't know
fall armyworm (FAW)	[] 0 [] 1 [] 2 [] 3 [] don't know
corn earworm (CEW)	[] 0 [] 1 [] 2 [] 3 [] don't know
corn rootworm	[] 0 [] 1 [] 2 [] 3 [] don't know
European corn borer (ECB)	[] 0 [] 1 [] 2 [] 3 [] don't know
worms (if not specified above)	[] 0 [] 1 [] 2 [] 3 [] don't know
other (specify) ___________	[] 0 [] 1 [] 2 [] 3 [] don't know
Weeds	Less ←→ More
perennial weeds	[] 0 [] 1 [] 2 [] 3 [] don't know
annual broadleaf weeds	[] 0 [] 1 [] 2 [] 3 [] don't know
annual grasses	[] 0 [] 1 [] 2 [] 3 [] don't know
Diseases	Less ←→ More
Stewart's Wilt	[] 0 [] 1 [] 2 [] 3 [] don't know
smut	[] 0 [] 1 [] 2 [] 3 [] don't know
rust	[] 0 [] 1 [] 2 [] 3 [] don't know

Section 4: Pre-emergent Practices

4.1) What variety (or varieties) of Sweet Corn did you plant?

____

If you did not plant a transgenic (Bt) variety, would you be interested in planting one in the future?
[] No [] Yes [] Don't know

4.2) Do you rotate any sweet corn fields with other crops? No [] Yes [] (**if no**, skip to part d)

a) Average % of sweet corn acreage rotated? ________ %

b) How long have you been rotating sweet corn? _______ years

c) Approximately what % of rotated fields still needed a soil insecticide? _______ %

d) Over the next 5 years, do you plan to rotate sweet corn fields? No [] Yes []

4.3) Please choose one of your sweet corn fields which you feel is most typical of your management strategies and answer the following questions:

How large is the field? ________ ac

How many separate plantings of sweet corn were in the field last year? _____ plantings

4.4) Did you apply a soil insecticide on the field identified above? (e.g. Lorsban, Force, Counter, etc)?
No [] Yes [] (**if no**, skip to part b)

a) Insecticide used: _____________ Formulation:___________
Rate:____________ **OR** Total amount applied:___________

A listing of many insecticide and herbicide formulations is provided on the last page.

b) Did you scout for target pests before deciding whether to apply a soil insecticide? No [] Yes []

4.5) Did you apply any pre-emergent herbicides? No [] Yes[] (**if no**, skip to the next question)

a) For the field identified above (in question 4.3), please list all <u>pre-emergent</u> herbicides applied last year. <u>Please list multiple applications of the same herbicide separately.</u> (A listing of many herbicide formulations used on sweet corn is attached.)

Herbicide 1: ________________________ formulation ______________
month _________ application method_____________
target weed _____________
rate ___________ **OR** total amount applied ___________

Herbicide 2: ________________________ formulation ______________
month _________ application method_____________
target weed _____________
rate ___________ **OR** total amount applied ___________

To save time, you may use the following codes to indicate **<u>application methods</u>**:
(GB) for Ground Broadcast
(Air) for Arial Spray
(SF) for Seed Furrow
(IRR) for Irrigation Water
(B) for Banded
(DS) for Directed or Foliar Spray
(S) for Spot Treatment

(continued on next page)

Herbicide 3: _________________________ formulation ______________
month _________ application method_____________
target weed ____________
rate ___________ **OR** total amount applied ___________

a) Who applied most of your pre-emergent herbicides?
[] employee [] self, partner or family member
[] custom applicator [] other (please specify) ______________

Section 5: Post-emergent Weed Control

5.1) Did you apply any post-emergent herbicides? No [] Yes [] (**if no**, skip to question 5.2)

a) For the field used above, list all post-emergent herbicides applied. Please list multiple applications of the same herbicide separately. (A listing of many herbicide formulations used on sweet corn is attached.)

Herbicide 1: _________________________ formulation ______________
month _________ application method_____________
target weed ____________
rate ___________ **OR** total amount applied ___________

Herbicide 2: _________________________ formulation ______________
month _________ application method_____________
target weed ____________
rate ___________ **OR** total amount applied ___________

To save time, you may use the following codes to indicate application methods:
(GB) for Ground Broadcast
(Air) for Arial Spray
(SF) for Seed Furrow
(IRR) for Irrigation Water
(B) for Banded
(DS) for Directed or Foliar Spray
(S) for Spot Treatment

Herbicide 3: _________________________ formulation ______________
month _________ application method_____________
target weed ____________
rate ___________ **OR** total amount applied ___________

Herbicide 4: _________________________ formulation ______________
month _________ application method_____________
target weed ____________
rate ___________ **OR** total amount applied ___________

b) Who applied most of your post-emergent herbicides?
[] employee [] self, partner or family member
[] custom applicator [] other (please specify) ______________

5.2) Did you scout for weeds before deciding whether to apply post-emergent herbicides?
No [] Yes [] (**if no**, skip to part c)

a) What was the approximate % of sweet corn acreage scouted? ___ %

b) How long have you been scouting for weeds before post-emergent herbicide application?
_____ years

c) Over the next 5 years, do you plan to scout for weeds?
No [] Yes [] on ______ % of acres

5.3) Did you cultivate to control weeds? No [] Yes [] (if no, skip to part c)

a) On approximately what percentage of cultivated acreage were post-emergent herbicides still necessary to control weeds? _____ %

b) How long have you been cultivating to control weeds? _____ years

c) Over the next 5 years, do you plan to cultivate to control weeds?
No [] Yes []

Section 6: Post-Emergent Insect Control

6.1) Did you apply any insecticides (besides soil insecticides)? No [] Yes [] (**if no**, skip to question 6.2)

a) For the field used above, list all insecticides applied. Please list multiple applications of the same insecticide separately. (A listing of many insecticide formulations used on sweet corn is attached.)

To save time, you may use the following codes to indicate application methods:
(GB) for Ground Broadcast
(Air) for Arial Spray
(SF) for Seed Furrow
(IRR) for Irrigation Water
(B) for Banded
(DS) for Directed or Foliar Spray
(S) for Spot Treatment

Insecticide 1: _________________________ formulation ______________
month _________ application method_____________
target pest ____________
rate ___________ **OR** total amount applied ___________

Insecticide 2: _________________________ formulation ______________
month _________ application method_____________
target pest ____________
rate ___________ **OR** total amount applied ___________

Insecticide 3: _________________________ formulation ______________
month _________ application method_____________
target pest____________
rate ___________ **OR** total amount applied ___________

Insecticide 4: _________________________ formulation ______________
month _________ application method_____________
target pest ____________
rate ___________ **OR** total amount applied ___________

Insecticide 5: _________________________ formulation ______________
month _________ application method_____________
target pest ____________
rate ___________ **OR** total amount applied ___________

Insecticide 6: _________________________ formulation ______________
month _________ application method_____________
target pest ____________
rate ___________ **OR** total amount applied ___________

Insecticide 7: _________________________ formulation ______________
month _________ application method_____________
target pest____________
rate ___________ **OR** total amount applied ___________

Insecticide 8: ________________________ formulation ______________
month _________ application method_____________
target pest ____________
rate ___________ **OR** total amount applied ___________

b) Who applied most of your insecticides?
[] employee [] self, partner or family member
[] custom applicator [] other (please specify) ______________

6.2) Did you scout your fields for insects before deciding whether or not to apply insecticides?
Yes [] No [] (**if no**, skip to part d)

a) Approximate % of sweet corn acreage scouted for insects______

b) Who did **<u>most</u>** of the scouting?
[] self, partner or family member [] an employee or paid scout
[] commercial pesticide applicator [] other (specify) __________

c) How long have you been scouting for insects? ______ years

d) Over the next 5 years, do you plan to scout your fields for insects?
No [] Yes [] on ______ % of acres

6.3) Did you use action thresholds for making decisions about applying insecticides?
No [] Yes []

6.4) Over the next 5 years, do you plan to use action thresholds for making your insecticide application decisions?
No [] Yes []

6.5) Did you use any traps (pheromone or light traps) to help you make decisions regarding insecticide applications?
No [] Yes[]

6.6) Did you call 1-800-PENN-IPM to get a pest status report before making decisions regarding insecticide applications?
No [] Yes []
If yes, approximately how many times did you call? ____ times

Section 7: Disease Control

7.1) Did you apply any fungicides to sweet corn? No [] Yes [] (**if no**, skip to question 7.2)

a) For the field used above, list all fungicides applied. Please list multiple applications of the same fungicide separately.

Fungicide 1: __________________________ formulation ______________
month _________ application method_____________
target pest ____________
rate ___________ **OR** total amount applied ___________

Fungicide 2: __________________________ formulation ______________
month _________ application method_____________
target ____________
rate ___________ **OR** total amount applied ___________

Fungicide 3: __________________________ formulation ______________
month _________ application method_____________
target ____________
rate ___________ **OR** total amount applied ___________

Fungicide 4: __________________________ formulation ______________
month _________ application method_____________
target ____________
rate ___________ **OR** total amount applied ___________

b) Who applied most of your fungicides?
[] employee
[] custom applicator
[] self, partner or family member
[] other (please specify) ______________

7.2) Did you plant tolerant/resistant varieties for controlling maize dwarf mosaic, common rust, smut, and/or Stewart's wilt? No [] Yes []

7.3) Over the next 5 years, do you plan to plant tolerant/resistant varieties for controlling maize dwarf mosaic, common rust, smut, and/or Stewart's wilt?
No [] Yes []

Section 8: Comments (optional)

If you have any comments, suggestions or complaints about this survey, please write them on the back of this page. If you would like a response to your comments, please write them on the back of the first page (the page that will be torn off for the drawing).

YOUR PARTICIPATION IN THIS SURVEY IS VERY MUCH APPRECIATED