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# Economic Analysis of Environmental Benefits of Integrated Pest Management: A Philippine Case Study

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**Abstract:** Health and environmental concerns associated with pesticide use have motivated development of integrated pest management (IPM) programs around the world. Little empirical work has been completed to estimate the value of environmental benefits of IPM. This paper provides an approach to evaluate a broad set of such benefits for a vegetable program in the Philippines. Assessments was made of (1) IPM-induced reduction in environmental risks posed by pesticides in onion production in the Central Luzon and (2) willingness to pay to reduce those risks. The latter was based on a contingent valuation interview survey of 176 farmers. Risks to humans, birds, aquatic species, beneficial insects, and other animals were considered. IPM practices on onions reduced the use of specific pesticides from 25 to 65 percent, depending on the practice, and projected adoption of the practices varied from 36 to 94 percent. Estimated economic benefits varied from 231 pesos to 305 pesos per person per cropping season (40 pesos = $1 U.S.). The aggregate value of environmental benefits for the villages where the IPM research program was centered were estimated at $150,000 for the 4600 inhabitants. Assessment of environmental benefits can help in designing public policies and regulations and in justifying support for publicly-supported IPM programs.

## Economic Analysis of Environmental Benefits of Integrated Pest Management: A Philippine Case Study

### 1. Introduction

Concerns about health and environmental effects associated with pesticide use have motivated development of integrated pest management (IPM) programs in both developed and developing countries. Evidence of the pesticide threat to human health and of the tradeoffs between health and economic effects have been documented in recent studies in the Philipines (Rola and Pingali (1993); Pingali, Marquez, and Palis (1994); Antle and Pingali (1994); Pingali and Roger (1995)) and in Ecuador (Crissman, Cole, and Carpio (1994); Crissman, Antle, and Capalbo (1998)). Many of the pesticides commonly sold in developing countries are extremely hazardous Category I and II chemicals that are banned or restricted for use in developed countries (Pingali and Roger). The chemicals present hazards not only to human health, but to the well-being of other species and to the preservation of beneficial organisms. Because many of the pesticide impacts occur off the farm, policy interventions may be needed to reconcile differences in private and social benefits and costs. Unfortunately, pesticide policies and regulations are in their infancy in many developing countries and, as a result, pesticide misuse is prevalent (Tjornhom, et al., 1997). As countries work to improve their institutional arrangements in the pest management area, and to support research and educational programs such as IPM, it is useful to have economic assessments of the direct economic impacts of these changes as well as the indirect benefits associated with health and environmental improvements.

Previous studies in developing countries that have considered indirect effects have focused largely on valuing the health effects of pesticides. Little attention has been directed at other environmental categories. It would be helpful to have a cost-effective approach that could be applied across a wide spectrum of both health and environmental effects. In some cases, health effects may be so severe that they dominate concern over the environment, rendering a broad assessment of health and environmental effects less important. However, in other cases, without a full accounting of benefits and costs, policy-makers may find it difficult to ascertain the appropriate extent of pesticide restrictions or of support for IPM programs, especially given the productivity enhancement attributable to certain pesticides. The purpose of this paper is to present an approach used in the Philippines that considers a broad set of health and environmental effects. The objective is not to provide a method that is as in-depth on the health side as the combined medical-economic analyses provided by Rola and Pingali or Crissman et al, but to test a method that can handle a variety of environmental and health effects, and is relatively inexpensive. The method is applied to a vegetable IPM program.

Little empirical work has been completed that attempts to estimate the aggregate environmental effects of IPM, even in developed countries. Such estimation is difficult because assessing the physical or biological effects of alternative levels of pesticide use under various IPM practices is a challenge, and because most of the benefits are non-market. Also, in some countries or regions of countries, people may not be aware of hazards posed by pesticides (Antle and Capalbo, 1995).

A few studies do suggest possible approaches for measuring aggregate environmental costs and benefits associated with IPM. Kovach et al (1992) compared the environmental impacts of traditional pest management strategies with IPM strategies, using a scoring system to consider effects on farmers, consumers, farm workers, and ecology. They derived an environmental impact quotient (EIQ) by pesticide, but did not place an economic value on the differences in EIQs. Higley and Wintersteen (1992) used a contingent valuation (CV) approach to assess the value to farmers of avoiding environmental risks caused by pesticides. They considered effects of pesticides on surface water, groundwater, aquatic organisms, birds, mammals, beneficial insects, and humans (acute and chronic toxicity). Subsequent studies using CV analysis to evaluate impacts of pesticides and of IPM were completed by Owens et al (1997) and by Mullen et al (1997). While contingent valuation is controversial for several reasons mentioned below, particularly due to the hypothetical nature of the questions used to obtain willingness to pay estimates, steps can be taken to minimize biases. CV has the advantage of being potentially applicable for valuing a broad set of environmental effects. The study described below draws on CV for part of the analysis.

## 2. Methods

The economic evaluation of the environmental benefits of the Philippine vegetable IPM program considered in this paper focuses on onions and contains two primary components. The first is an assessment of the effects of IPM on health and environmental risks posed by pesticides (hereafter referred to simply as environmental risks). The second is a determination of society's willingness to pay to reduce those risks.

### *2.1. Assessing risks*

The first component contains four steps: 1) classifying the environment into relevant impact categories, 2) identifying risks posed by individual pesticide active ingredients to each category, 3) defining the degree of IPM adoption, and 4) assessing the effects of IPM adoption on pesticide use. Environmental categories used in this study include the types of non-target organisms affected – humans (chronic and acute health effects), other mammals, birds, aquatic species, and beneficial insects. Previous studies (Higley and Wintersteen, 1992 and Mullen et al, 1997) have also included categories for mode of transmission such as surface and groundwater, but these latter categories were excluded for fear of double-counting (i.e., fish live in surface water).

Risks posed by specific pesticides applied to onions in the Central Luzon of the Philippines were assessed by assigning one risk level for each active ingredient for each environmental category using a rating scheme partially summarized in table 1. Hazard ratings from previous studies were used as well as toxicity databases such as EXTOXNET. Both toxicity and exposure potential were considered in arriving at the assigned risks for each of 44 pesticides (contact authors for details). An overall eco-rating score was then calculated with IPM adoption and without IPM adoption. The difference represents the amount of risk avoided due to the program. The formula for the eco-rating was: $ES_{ij} = (IS_j) \times (\%AI_i) \times (Rate_i)$, where $ES_{ij}$ is the pesticide risk score for active ingredient i and environmental category j, %AI is the percent active ingredient in the formulation, and $Rate_i$ is the application rate per hectare.

The onion IPM program evaluated had only been in existence for five years. Therefore most of the IPM techniques developed in the participatory research program had just been released, with little adoption yet beyond the local village where the research took place. Therefore, an interview survey of 176 growers in the broader region was conducted to assess farmers' willingness to adopt the IPM practices. Each practice was described to them in the

**Table 1. Pesticide Impact Scoring System**

| IMPACTS | INDICATORS | SCORE | | |
|---|---|---|---|---|
| | | **HIGH RISK = 5** | **MODERATE RISK = 3** | **LOW RISK = 1** |
| **Human Health** | | | | |
| *Toxicity* | | | | |
| Acute Toxicity | Pesticide Class (WHO Criteria) | Ia; Ib | II | III |
| | Signal Word (EPA Criteria) | Danger/Poison | Warning | Caution |
| Chronic Toxicity | Weight of Evidence of Chronic Effects | >1 Positive | Data Gap | Negative |
| | | Conclusive Evidence | Possible Probable | Inconclusive Evidence |
| *Exposure* | | | | |
| Leaching Potential | Groundwater Ubiquity Score | GUS > 2.8 | .8 > GUS > 2.8 | GUS < 1.8 |
| | Leaching Potential Score | High | Moderate | Low |
| Runoff Potential | No.of Red Flags Exceeded for the ffg:<br>Soil Adsorption (Koc) > 300<br>Soil 1/2-life > 21 days<br>Water Solubility > 30 ppm | > 2 red flags | 1 red flag | 0 red flag |
| | Surface Loss Potential | High | Moderate | Low |
| Air Contamination | Henry's Law Constant | | | |
| | Place of Application | Aerial | Crop/Soil Surface | Soil |
| Food Residues | Systemicity | | Systemic | Non-systemic |
| | Time of Application | | Post-emergent | Pre-emergent |
| | Plant Surface Residue Half-life | > 4 weeks | 2 - 4 weeks | 1 -2 weeks |
| **Aquatic Species** | | | | |
| *Toxicity* | 95 hr LC50 (fish) mg/L | | | |
| | Fish/Other Aquatic Species Toxicity | > 10 ppm | 1-10 ppm | <1 ppm |
| *Exposure* | Runoff Potential Score | High | Moderate | Low |
| **Beneficial Insects** | | | | |

| | | | | |
|---|---|---|---|---|
| *Toxicity* | Beneficial Effects Score (BENE)<br>Insect Toxicity Ratings | BENE > 50<br>Extreme/High | 25 < BENE < 50<br>Moderate | BENE < 25<br>LOW (1) |
| *Exposure* | Plant Surface Residue Half-life | > 4 weeks | 2 - 4 weeks | 1 -2 weeks |
| **Mammalian Farm Animals** | (same as human health) | | | |
| **Birds** | | | | |
| *Toxicity* | Bird toxicity ratings<br>8 day LC50 | High/Extreme<br>1 - 100 ppm | Moderate<br>100 - 1000 ppm | Low<br>> 1000 ppm |
| *Exposure* | Soil Half-life<br>Plant Surface Half-life | > 100 days<br>> 4 weeks | 30 - 100 days<br>2 - 4 weeks | < 30 days<br>1 -2 weeks |

survey, and they were asked if a particular IPM practice were to be available to them next year, if they would adopt it. Sensitivity analysis was conducted with the results.

Expected reduction in pesticide use as a result of adopting the IPM technologies was based on experiments conducted in farmers' fields through research supported by the IPM Collaborative Research Support Program (IPM CRSP). This program, based at the Philippines Rice Research Institute (PhilRice), and involving scientists from two Philippines universities, two international agricultural research centers and three U.S. universities, had developed an IPM program that encompasses practices to control a small red insect (*Thrips tabaci)*, weeds (especially *Cyperus rotundus*), cut worms (*Spodoptera litura)*, soil-borne diseases (particularly *Phoma terrestris* or pink root), and nematodes (*Meloidogyne graminicola*). By the time of the environmental assessment was conducted, components of the IPM program were released or near release for *Thrips*, weeds, cutworms, and *Phoma*. These components included practices that reduced the usage per hectare of specific insecticides for *Thrips* and for cutworms by 50 percent for those farmers who adopt them, herbicides by 65 percent, and fungicides for pink root by 25 percent.

*2.2 Willingness to pay*

To place a monetary value on the environmental benefits of the onion IPM program, estimates were needed of society's willingness to pay (WTP) to avoid pesticide risks to the five environmental categories. WTP values were obtained through CV using a survey of 176 randomly-selected farmers in Nueva Ecija district (out of 4600 total farmers). Strategies were employed to minimize strategic, information, starting-point, vehicle, and hypothetical biases. Following Van Ravensway and Hoehn (1991) and Owens et al

(1997), an approach was used to minimize hypothetical bias by simulating a market (buy and sell exercise) for a good that is similar to another good familiar to the respondents. Farmers were asked to provide willingness-to-pay values for different formulations of their favorite pesticides. Five formulations were offered, one that avoids risk to each of the five environmental categories. For example, farmers were asked whether they would purchase their most commonly used pesticide, reformulated to avoid risk to human health, at a series of prices (in 50 peso increments) higher than its existing price. The estimates of willingness to pay to avoid pesticide hazards to the various environmental categories were then adjusted downward by 30 percent to reflect the fact that the pesticides in the local area were applied 70 percent on onions during the dry season, and 30 percent on other crops, principally rice and other vegetables.

### *2.3. Combining pesticide hazard and willingness to pay information*

Reductions in pesticide hazards due to implementation of the five IPM practices were calculated by multiplying the risk score for each pesticide by the percent active ingredient, and then multiplying this result by the application rates per hectare, with and without the IPM practices. The percent reduction in this eco-rating hazard was multiplied by the willingness-to-pay value for each category to arrive at an economic benefit per person. Aggregate benefits were obtained by multiplying the per person value by the number of people in the region.

## 3. Results

The Thrips control practices developed in the IPM program involved reduced frequency of applying pesticides with the active ingredients Clorpyifos + BPMC. The weed control

IPM practices reduced the use of Glyphosate, Fluazifop P-Butyl, and Oxyfluorfen. The cutworm IPM practices reduced the use of Lambdacylhalothrin, Cypermetrin, and Deltametrin. The disease control IPM practices reduced the use of Benomyl and Mancozeb. The risk scores for these pesticides are presented in Table 2.

Table 2. Risk scores for onion pesticides applied in the study area/affected by IPM practices (5 = high environmental risk … 0 = no toxicity).

| Active Ingredient | Environmental Category | | | | |
|---|---|---|---|---|---|
| | Human | Animals | Birds | Aquatic | Beneficials |
| Benomyl | 4 | 4 | 3 | 5 | 5 |
| Mancozeb | 3 | 3 | 3 | 5 | 5 |
| Fluazifop-P-Butyl | 4 | 4 | 0 | 5 | 5 |
| Glyphosate | 4 | 4 | 3 | 3 | 3 |
| Oxyflourfen | 4 | 4 | 1 | 5 | 5 |
| Chlorpyrifos + BMPC | 3 | 3 | 5 | 5 | 5 |
| Cypermethrin | 3 | 3 | 5 | 5 | 5 |
| Deltamethrin | 4 | 4 | 3 | 4 | 5 |
| Lambdacyhalothrin | 3 | 3 | 3 | 4 | 5 |

Risk scores were calculated for an additional 34 pesticides (not presented due to space limitations) because calculation of the percent reduction in environmental hazards required consideration all A.I.s, not just the ones used for onions and the particular pests addressed.

The scores assigned to each pesticide active ingredient (by category) were combined with usage data to arrive at an overall ecological rating for each pesticide as noted above. Eco-ratings with the IPM program took into account the adoption projections which ranged from 36 percent for an integrated weed/insect/disease control practice to 94 percent for an IPM practice that reduced herbicide treatment from two sprays to one spray.  The eco-ratings were reduced from 60 to 64 percent as a result of the IPM program, depending on the environmental category (table 3). These reductions represent the percent pesticide risk avoided.

Table 3. Eco-ratings with and without the vegetable IPM program

| Category | Type of pesticide | Eco-ratings without IPM | Eco-ratings with IPM | Aggregate % risk avoided |
|---|---|---|---|---|
| Human health | Herbicide | 323 | 114 | |
| | Insecticide | 405 | 142 | 64 |
| | Fungicide | 20 | 15 | |
| Beneficial insects | Herbicide | 332 | 117 | |
| | Insecticide | 456 | 180 | 61 |
| | Fungicide | 28 | 21 | |
| Birds | Herbicide | 122 | 43 | |
| | Insecticide | 405 | 161 | 60 |
| | Fungicide | 23 | 17 | |
| Animals | Herbicide | 323 | 114 | |
| | Insecticide | 405 | 142 | 64 |
| | Fungicide | 20 | 15 | |
| Aquatic species | Herbicide | 331 | 117 | |
| | Insecticide | 358 | 132 | 62 |
| | Fungicide | 27 | 20 | |

The farmers' willingness to pay to reduce pesticide risk to various environmental categories is presented in table 4. These values ranged from 551 to 680 pesos per cropping season (40 pesos = $1 U.S.) and were within a reasonable range given household budgets in the area. The values were adjusted downward to reflect the use of the pesticides on other crops and were multiplied by the percent risk avoided to arrive at the benefits per person per season (1312 pesos). These benefits represent more than 6 million pesos for the roughly 4600 local inhabitants in the villages where the IPM program is immediately centered or about $150,000. In addition to these benefits, farmers received additional direct economic gains from applying these practices. For example, the savings in direct pesticide costs for some of the IPM practices are roughly twice the environmental benefits, based on separate calculations.

Table 4. Willingness to pay for and economic benefits from environmental risk avoidance

| Category | Mean WTP (pesos per season) | WTP adjusted for % of pesticides on onions | Economic benefits (WTP adjusted by % risk avoided) |
|---|---|---|---|
| Human health | 680 (219)[1] | 476 | 305 |
| Beneficial insects | 580 (197) | 406 | 248 |
| Birds | 577 (200) | 385 | 231 |
| Animals | 621 (198) | 434 | 278 |
| Aquatic | 551 (210) | 404 | 250 |

1. Standard deviation is in parentheses

**4. Conclusion**

IPM programs developed to help solve pest problems while minimizing pesticide use are potentially a win-win situation. They may raise agricultural productivity while reducing environmental damage. Most IPM programs involve some public support, at least for research and information dissemination. While such support may be justified on their productivity effects alone, in many cases, a significant share of the benefits may be missed if environmental gains are ignored.

The results of this study may also assist in designing pesticide regulations. Any institutional arrangement that serves to reduce pesticide use by the indicated amount would generate these environmental benefits. In addition, while projected IPM adoption exceeded 90 percent for one IPM practice, it was only 36 percent for another. Leaving substantial room for public policies that might encourage adoption. To gain additional insights, willingness to adopt estimates were included in a logit model with several explanatory variables, using additional data from the farmer survey. One conclusion was that gaining information through a cooperative significantly increased the chances of IPM adoption as did farm size and general awareness of IPM.

The analysis in this paper illustrates that it is possible to estimate these benefits in a relatively low cost manner in a developing country using farmer survey. The use of CV for such an analysis may in fact have an advantage in a developing country like the Philippines where many of the beneficiaries are farmers who are familiar with pesticide use. It is often said that growers in such a country may be less aware of the dangers of pesticides. However, to the extent that they have direct experience with the chemicals and yet represent a significant proportion of the rural population, they are a logical group to survey. In developed countries, farmers are a much smaller percent of the population and hence a CV survey on pesticide risk would need to focus mostly on consumers who may have very little experience with farm chemicals.

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