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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 the development of integrated pest management (IPM) programs around the world. Little empirical work has been completed to estimate the value of the 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 were 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 (CV) 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%, depending on the practice, and the projected adoption of IPM practices varied from 36 to 94%. Estimated economic benefits varied from 231 to 305 pesos per person per cropping season (40 pesos = 1 US$). The aggregate value of environmental benefits for the five villages where the IPM research program was centred was estimated at 150,000 US$ for the 4600 local residents. Assessment of environmental benefits can help in designing public policies and regulations, and in justifying support for publicly funded IPM programs.

Keywords: Integrated pest management; Philippines; Value of environmental benefits

1. Introduction

Concerns about the health and environmental effects associated with pesticide use have motivated the development of integrated pest management (IPM) programs in both developed and developing countries. Evidence of the pesticide threat to human health and of the trade-offs between health and economic effects have been documented in recent studies in the Philippines (Rola and Pingali, 1993; Pingali et al., 1994; Antle and Pingali, 1994; Pingali and Roger, 1995) and in Ecuador (Crissman et al., 1994; Crissman et al., 1998). Many of the pesticides commonly sold in developing countries are extremely hazardous categories I and II chemicals that are banned or restricted in use in developed countries (Pingali and Roger). Such chemicals present hazards not only to human health, but also 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 between 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

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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 (1993), or Crissman et al. (1994), but rather 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 challenging, 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 the aggregate environmental costs and benefits of 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 the ecology. They derived a pesticide-specific environmental impact quotient (EIQ), but did not place an economic value on the differences in EIQs. Higley and Wintersteen (1992) used a CV approach to assess the value to farmers of avoiding environmental risks caused by pesticides. They considered the effects of pesticides on surfacewater, groundwater, aquatic organisms, birds, mammals, beneficial insects, and humans (acute and chronic toxicity). Subsequently, Owens et al. (1997) and Mullen et al. (1997) used CV analysis to evaluate the impacts of pesticides and of IPM. While CV 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 minimise biases. The 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 the 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 the risks posed to each category by individual pesticide active ingredients, (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; Mullen et al., 1997) have also included

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 conclusive evidence	Data gap possible probable	Negative inconclusive evidence
Exposure				
Leaching potential	Groundwater ubiquity score	GUS > 2.8	0.8 > GUS > 2.8	GUS < 1.8
	Leaching potential score	High	Moderate	Low
Runoff potential	Number of red flags exceeded for the ffg: Soil adsorption (Koc) > 300; Soil half-life > 21 days; 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 h 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)	BENE > 50	25 < BENE < 50	BENE < 25
	Insect toxicity ratings	Extreme/high	Moderate	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	High/extreme	Moderate	Low
	8 day LC50	1–100 ppm	100–1000 ppm	>1000 ppm
Exposure	Soil half-life	>100 days	30–100 days	<30 days
	Plant surface half-life	>4 weeks	2–4 weeks	1–2 weeks

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 surfacewater).

The risks posed by specific pesticides applied to onions in 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 summarised in Table 1. Hazard ratings from previous studies as well as toxicity databases such as EXTOXNET were used. 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 and without IPM adoption. The difference represents the amount of risk avoided due to IPM. The formula for the eco-rating was

$$\mathrm{ES}_{ij} = (\mathrm{IS}_j) \times (\%\mathrm{AI}_i) \times (\mathrm{Rate}_i) \tag{1}$$

where ES_{ij} is the eco-rating score for active ingredient i and environmental category j, IS_j the risk-score for 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 had only been in existence for five years when it was evaluated. Therefore, most of the IPM techniques developed in the participatory research program had just been released to farmers, 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 questionnaire, and they were asked whether they would adopt a particular IPM practice were to become available to them next year. During the subsequent environmental impact analysis, sensitivity analysis was conducted with the results of the adoption survey, as the hypothetical nature of the questions posed casts some doubt on the accuracy of the responses. In addition, logit models were used to project adoption in the broader region by taking the responses provided by the 176 farmers and regressing their willingness to adopt specific technologies on a set of socio-economic characteristics. The actual characteristics of the broader population were then used in the model to predict the probability of adoption in the region as a whole. Details are provided in Cuyno (1999).

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 Philippine universities, two international agricultural research centres and three US 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, the environmental assessment was conducted, components of the IPM program were released (or about to be released) for *Thrips*, weeds, cutworms, and *Phoma*. These components included practices that reduced the usage per hectare of specific insecticides for *Thrips* and cutworms by 50%, herbicides by 65%, and fungicides for pink root by 25%.

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. The values of WTP were obtained through CV using a survey of 176 randomly selected farmers in Nueva Ecija district. Strategies were employed to minimise strategic, information, starting-point, vehicle, and hypothetical biases. Following van Ravenswaay and Hoehn (1991) and Owens et al. (1997), an approach was used to minimise hypothetical bias by simulating a market (buy and sell exercise) for a good that is similar to another good that is familiar to the respondents. Farmers were asked to provide WTP values for different formulations of their favourite 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 WTP to avoid pesticide hazards to the various environmental categories were then adjusted downward by 30% to reflect the fact that the pesticides in the local area were applied 70% on onions during the dry season, and 30% on other crops, principally rice and other vegetables.

2.3. Combining pesticide hazard and willingness to pay information

The percent reduction in the eco-rating given by Eq. (1) with and without IPM was multiplied by the WTP value for each category to arrive at an economic benefit per person. Aggregate benefits were obtained by multiplying the value per person by the number of people in the region. However, the resulting aggregate benefit is an underestimate for two reasons. First, the IPM technologies are likely to spread beyond the region, even if adopted at a lower rate. Second, benefits to onion consumers outside the region are assumed to be zero.

Table 2
Risk-scores for onion pesticides applied in the study area and affected by IPM practices[a]

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

[a] High environmental risk = 5; no toxicity = 0.

3. Results

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

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 of all active ingredients, 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 eco-rating for each pesticide as in Eq. (1). Eco-ratings with IPM account for the adoption projections, which ranged from 36% for an integrated weed/insect/disease control practice to 94%

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	64
	Insecticide	405	142	
	Fungicide	20	15	
Beneficial insects	Herbicide	332	117	61
	Insecticide	456	180	
	Fungicide	28	21	
Birds	Herbicide	122	43	60
	Insecticide	405	161	
	Fungicide	23	17	
Animals	Herbicide	323	114	64
	Insecticide	405	142	
	Fungicide	20	15	
Aquatic species	Herbicide	331	117	62
	Insecticide	358	132	
	Fungicide	27	20	

Table 4
WTP for environmental risk avoidance and the resulting economic benefits (pesos per season)

Category	Mean WTP[a]	WTP adjusted for pesticide on onions (%)	Economic benefits (%) (WTP adjusted risk avoidance)
Human health	680 (219)	476	305
Beneficial insects	580 (197)	406	248
Birds	577 (200)	385	231
Animals	621 (198)	434	278
Aquatic	551 (210)	404	250

[a] S.D. (standard deviation) is in parentheses.

for an IPM practice that reduced herbicide treatment from two sprays to one spray. The eco-ratings were reduced by between 60 and 64% as a result of the IPM program, depending on the environmental category (Table 3). These reductions represent the percent pesticide risk avoided.

The farmers' WTP to reduce pesticide risk to various environmental categories is presented in Table 4. Values range from 551 to 680 pesos per cropping season (40 pesos = 1 US$) and were within a reasonable range given household budgets in the area, although perhaps, a little on the high side[2]. The values were adjusted downward to reflect the use of the pesticides on other crops and were multiplied by the percent risk avoided to arrive at the benefits per person per season of 1312 pesos. These benefits represent more than 6 million pesos for the roughly 4600 local inhabitants in the five villages (rural neighbourhoods) where the IPM program is centred, or about 150,000 US$. While not all household or community members (i.e. children or non-farmers) may value the environmental and health benefits as much as the farmers who were interviewed, 150,000 US$ is likely to be an underestimate of the total benefits to the community because IPM practices are likely to spread well beyond the 10 km radius of the five local villages. In addition, farmers receive direct economic gains from the lower production costs associated with 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.

[2] Per capita income in the Philippines averaged 3800 US$, and incomes in the local area are perhaps two-thirds of that average.

4. Conclusions

IPM programs developed to help solve pest problems while minimising 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 by 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 reduces pesticide use by the indicated amount would generate these environmental benefits. In addition, while projected IPM adoption exceeded 90% for one IPM practice, it was only 36% for another. This leaves 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 acquiring information through a co-operative 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 the environmental benefits of IPM in a relatively low cost manner in a developing country using farmer surveys. The use of CV for such an analysis may in fact have an advantage in a developing country such as 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 pesticide use. However, to the extent that they have direct experience with the chemicals in question and represent a significant proportion of the rural population, growers are a logical group to survey. In developed countries, farmers account for a much smaller share 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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