The Impact of Integrated Pest Management Technology on Insecticide Use in Soybean Farming in Java, Indonesia: Two Models of Demand for Insecticides

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ABSTRACT

This study aims to estimate the demand for insecticides in soybean farms in Java, Indonesia, and to analyze the impact of the integrated pest management (IPM) technology on insecticide use. It uses aggregate cross-section time series data during the period 1990-1998, when the IPM technology was disseminated in Indonesia. By using recursive and simultaneous equation models, it estimates the impact of the IPM technology on the demand for insecticides. The study finds that the IPM technology has reduced significantly the use of insecticides in soybean farming.

INTRODUCTION

Inspired by the Green Revolution, the Indonesian government has endeavored since the mid-1960s to increase food crop production by promoting an intensive agricultural technology. This intensified program is characterized by the use of high-yielding varieties, as well as a greater use of chemical inputs, including insecticides. For this purpose, the government has spent around US$725 million to subsidize agricultural inputs for the farmers. Around 40 percent out of the subsidy has been allocated for pesticides (Barbier 1989; Conway and Barbier 1990). Starting from 1975, the subsidy had increased substantially up to 1985 and then gradually decreased afterwards until the subsidy was completely stopped in 1989 (Useem et al. 1992).

The heavy use of insecticides has given rise to negative externalities, particularly for the environment (Pretty and Hine 2005) and human health (Kishi 2005). Kishi et al. (1995), Murphy et al. (1999) and Pawukir and Mariyono (2002) empirically showed that farmers had manifested the signs and symptoms of insecticide intoxication after spraying. These negative externalities constituted the important reason why the Indonesian government waived its subsidy for insecticides and at the same time introduced the integrated pest management (IPM) technology (Rölling and van de Fliert 1994). One of the expected outcomes of this policy was the reduction in pesticide use.

There are two conflicting views regarding the efforts of the Indonesian IPM program to reduce pesticide use. The first view (Useem et al. 1992; Untung 1996; Paiman 1998a, 1998b; Kuswara 1998a, 1998b; and Susianto et al. 1998) claims that the Indonesian IPM program has been successful in reducing insecticide use through the adoption and diffusion of the IPM technology. The proponents of this view have mostly used descriptive and simple statistical analyses of case studies to identify the impact of the IPM program; their analyses have been perceived as lacking in theoretical support.

On the other hand, another view (Feder et al. 2004a, 2004b) holds that the IPM program in Indonesia has been unsuccessful in reducing insecticide use. According to this assessment, there is no evidence that the expected environmental and health benefits of the program are significant since there is no effect of the program on insecticide use and there is no evidence of technology diffusion among farmers. Its main criticism of the earlier IPM impact studies centers on the selection bias resulting from the lack of adequate econometric procedures. In contrast, this view uses a rather complex econometric approach with a number of samples randomly drawn from Javanese farmers that have graduated from IPM training. This method is said to be able to remedy the selection biases. However, the failure of the Javanese IPM-trained farmers to reduce insecticide use does not necessarily mean that the IPM technology is inappropriate in reducing the use of insecticides; one explanation put forward points to the "administrative problems in implementing the project that was funded by the World Bank" (Pretty and Waibel 2005: 49).

Up to now, it is still disputable which of the two conflicting views has accurately assessed the situation. It seems that both parties cannot reconcile their positions because the fundamental debate comes from the different methodological approaches and the different samples used to evaluate the program. Neither camp uses aggregate data which represents the total number of farmers who have graduated from IPM training. Therefore, it is possible that both parties could have erred in estimating the impact of the IPM program.

Based on the strong claim about the superiority of the IPM technology, it has been assumed that if the total number of farmers who applied the IPM technology increased, the use of insecticides in the long run was expected to decrease. As evidence shows, however, the application of the IPM technology is not the only factor causing the declining tendency of insecticide use in Indonesia. Increases in the price of insecticide resulting from the elimination of insecticide subsidy may also contribute to such reduction. Theoretically, the effects of the price and the IPM technology on the use of insecticides can be analyzed using insecticide demand, which is derived from the profit function corresponding to Hotelling's lemma (Jehle and Reny 2001).

The objectives of the study are to estimate the demand for insecticide in soybean farming and to analyze the impact of the IPM technology on the insecticide demand at the aggregate level. Soybean is selected as the object of this study because it is the second most important commodity and one of the main targets of the Indonesian IPM program (World Bank 1993). Moreover, soybean farming uses a high level of insecticides (Luther 1993), and its use of insecticides has been found to be inefficient (Mariyono 2005). Using aggregate data is expected to address the selection bias, because the aggregate data consists of IPM-trained, as well as non-IPM farmers. The findings of this study are expected to provide greater understanding on the economic impacts of the Indonesian IPM program.

THE IPM PROGRAM AND DISSEMINATION OF IPM TECHNOLOGY

The IPM program is one of the components of Indonesia's overall strategy to promote sustainable agriculture. The Indonesian Government started to disseminate the IPM technology among rice-based farmers through a pilot project in May 1989 with the support of the UN's Food and Agriculture Organization (FAO). The IPM program has been described as "an ideal case to contrast extension for sustainable agriculture with that supporting high external input agriculture. IPM is being introduced into a farming system, irrigated rice, in which the Green Revolution has been successful during the past twenty years" (Rölling and van de Fliert 1994: 98).

This program was the realization of a Presidential Decree (INPRES 3/86), instituted three years earlier, which banned 57 brands of insecticides from rice cultivation, and declared IPM the national pest control policy. A policy measure progressively reduced the subsidy on insecticides, which was previously 85%, to zero in 1990 (Untung 1996). These policy measures created a favorable climate for the implementation of Indonesia's National IPM Program. In its first phase covering the period 1989-1992, there was a large-scale attempt to systematically introduce sustainable agricultural practices as a national, public sector effort. During this phase, around 200,000 farmers underwent intensive training in the so-called farmers field school (FFS). The criteria for purposively choosing the sites of FFS were the easy accessibility, and the presence of active farmer groups. Farmers participating in the school were also purposively selected for the program. The more prosperous and better informed farmers in the selected villages were encouraged to undergo the training.

The second phase (1993-1999) was sponsored by the World Bank. In this phase the program was expanded. Since 1994, the FFS activities have been taken over by the National IPM Training Project funded by the World Bank (World Bank 1993). The project has promoted IPM and improved the cultivation of rice and other food and horticultural crops, including soybean. More regions have been covered and more actors have been involved. However, the target was not to reach all Indonesian farmers. Rather, the strategy of the program was to train a fraction of the farming community, instead of training all farmers in the community. Thus, the spread of IPM knowledge relied on farmer-to-farmer diffusion. During the implementation of the second phase of the project, the villages which served as FFS sites were still subjectively selected with the same criteria by the project management, in collaboration with Agricultural Services officials in both provincial and district levels. Assisted by the sub-district level agricultural officers and farmer group leaders, the program also purposively selected the farmers, through the use of such criteria, for instance, as literacy, and the ability to express one's ideas.

FFS: Process and Elements

The FSS, which represents a process of learning-by-doing, is at the core of Indonesia's IPM program. The World Bank, along with a number of development agencies, has promoted FFS since it is a more effective method to extend science-based knowledge and practices (Feder et al. 2004a). The method uses a participatory approach to help farmers develop their analytical skill, critical thinking, and creativity, and thereby aid them to make better decisions. In short, the objective of FFS is to enhance human resource development by making the farmers experts of IPM in their paddy fields. By participating in the FFS, the farmers are expected to be able to conduct observations, to analyze agro-ecosystems, to make decisions, and to implement pest control strategies based on the results of their field observations. In fact, the IPM technology involves not only pest control but also other aspects of farming such as balanced and efficient fertilizing, efficient use of water, crop rotation, and soil conservation. The following principles are central to the dissemination of the IPM technology: growing healthy crops; conserving and utilizing natural enemies; carrying out regular field observations; and developing farmers as IPM experts in their own field (Untung 1996).

There are essential processes that have to be fulfilled to enable the FFS to run normally. Braun et al. (2000) highlights the key processes as follows. Several weeks before planting, the group of facilitators has to consult and coordinate with other programs working in the regions; identify the communities that fulfill the criteria for establishing FFS; and identify the suitable participants. The tasks of observation, analysis and action take place in the 12 FFS sessions held weekly throughout the planting season that lasts around three months. The first meeting begins two to three weeks after planting. This is to cover the observation of all critical stages of growth and development of crops.

Improved decision-making arises from an iterative process of analyzing a situation from multiple points of view, synthesizing the analysis, making decisions correspondingly and implementing the decisions, observing the outcome, and then evaluating the overall impact. This process is carried out within the framework of an agro-ecosystem analysis. Within one planting season, all participants learn about the agro-ecosystem and the dynamics of the insect population during the process of making observations in the two plots. Agro-ecological systems are structured by a few key processes. The key to understanding pest outbreaks lies in the comprehensive relationships between the dynamics of the insect pest population and its natural enemies─a subject matter in which farmers lack knowledge of. The FFS training conducts the insect zoo activity which is designed to give the farmers a better understanding of the complexity of the agro-ecosystem. Farmers observe the dynamics of insects representing natural food chains in the agro-ecosystem. The most important concept discovered by farmers through this special topic is the ability to distinguish which of the insects are pests or natural enemies, and which insects are beneficial. In each FFS meeting, group dynamics exercises are held to strengthen teamwork and problem-solving skills, promote creativity, and impress on the farmers the importance of collective action. The facilitators suggest a problem or a challenge to be solved. The exercise usually involves physical activities but sometimes takes the form of puzzles or brainteasers which require mental efforts but are done in a spirit of fun.[1]

According to Braun et al. (2000), a unit of FFS in the IPM Program consists of a training group of 25 farmers, selected either from one farmer group, or across such groups within one village. As about 50 per cent of agricultural activities are carried out by woman farmers, it is expected that 30 per cent of participants are woman farmers (Kingsley and Siwi 1997). Each FFS has one training field, divided into two plots: one IPM- managed field, and one field with locally conventional management wherein insecticides are applied to eliminate the natural enemies of insect pests. The main activity of the participants is to go to the demonstration fields, first thing in the morning, in groups of five and observe sample plants, usually chosen randomly along a diagonal area across the field. Notes are made of insects, spiders, damage symptoms, weeds, and diseases, observed on each plant. The stage of the plant is carefully observed, as is the weather condition. Interesting insects and other specimens are caught and placed in small plastic bags, and will be used in group discussions with the facilitator. The field becomes the main training material, and the farmers' own observations the source of knowledge for the group. During each session, special topics are introduced, and these relate to field problems, such as the growth of the rat population, the effects of insecticides on natural enemies, and life cycles. Group dynamics exercises are held to enliven the field school and create a strong sense of belonging to the school. Farmers frequently keep an insect zoo by installing plastic netting around four

[1] For details on the daily activities of FFS, see Braun et al. (2000).

bamboo poles set around a plant. Inside, various pests and predators are introduced, and watched by farmers. Through their own experiments and observations, farmers gain ecological knowledge.

To fulfil the standards of learning, the FFS needs sufficient material and financial support. It has been reported that the average unit cost of an FFS, based on 1996-97 fiscal year costs, is US$599 (Anonymous 2002). This amount funds the honorarium of the facilitator, preparation and coordination expenses, facilitator's transport, materials, refreshments, compensation of land used for field trial, stipends for participants, and expenses for the closing ceremonies .

Although the IPM training was mostly based on rice, it was applicable to soybean and other crops. IPM-trained farmers who were growing rice were also growing soybean. Since 1993, more than 20 percent of FFS's conducted have been specially designed for soybean cultivation. The process and method of soybean-based FFS are similar to those of rice-based FFS. The main differences lie in the observed agro-ecosystem consisting of plants, pests, diseases, and other organisms. Some modifications related to the agronomy of soybean-growing are introduced in the section on special topics (Mariyono et al. 2003; Mariyono and Setyoko 2006).

THEORETICAL FRAMEWORK: DEMAND FOR INSECTICIDES

This analysis is based on the idea that the nature of the relationship between the demand for insecticides and the level of pest infestations could be expressed in two ways. Firstly, we may postulate that the demand for insecticides will increase when pest infestations increase. This is mainly based on the pest control principle that insecticides are used whenever pest infestations exist (Rola and Pingali 1993). Secondly, it may be assumed that the level of pest infestations is dependent on the use of insecticides. This is also due to the fact that the level of pest infestations declines when the application of insecticide increases.

Demand for insecticides has a unique characteristic compared to the other common agricultural inputs such as labor, fertilizers, seeds, etc. First, insecticides act as a protective input, which indirectly affects the production. The direct impact of insecticides is to diminish the crop lost to pest infestations. Second, the effect of insecticides is uncertain because it is dependent on the nature of the pest infestations (Horowitz and Lichtenberg 1994). An effective effect will be observable when the pest infestations exist. In other words, the use of insecticides will be ineffective when no infestation exists. Based on the above arguments, the function of demand for insecticides needs to be modeled appropriately. Two models of demand for insecticides will be constructed, namely, a recursive model and a simultaneous model. By using both models, the impact of IPM technology on the demand for insecticide can be analyzed.

Recursive Demand Model

A recursive demand model is based upon an assumption that the IPM technology is not only able to control the pest but also affect the production technology, meaning that the marginal product of insecticides changes. In this case, the use of insecticides (*X*) will be influenced by the level of pest infestations (*I*), the relative price of the insecticide to the price of soybean (*P*), and the area planted to soybean (*A*). By using this assumption, it is expected that the IPM technology (*T*) determines both the level of pest infestations (*I*) and the level of insecticide use (*X*). The model is formulated as:

$$I = \kappa_{10} + \kappa_{11} T + u_1 \quad (1)$$

$$X = \kappa_{20} + \kappa_{21} I + \kappa_{22} T + \kappa_{23} P + \kappa_{24} A + u_2 \quad (2)$$

In this case, u_1 and u_2 are uncorrelated. By using the recursive model, the demand function

(2) can be directly estimated by using an ordinary least squares (OLS) method (Gujarati 2003). It is expected that $\kappa_{21} < 0$, meaning that the IPM technology is able to reduce the demand for insecticides.

Simultaneous Demand Model

Another assumption is that the IPM technology does not influence the production process such that the marginal product of insecticides does not change. Based upon this assumption, a simultaneous demand function is constructed. The IPM technology is an alternative of plant protection together with insecticide application. In this case, the use of insecticides (X) will be influenced by the level of pest infestations (I), the relative price of the insecticide to the price of soybean (P), and the soybean-planted area (A). The fact that insecticide use is affected by pest infestation is built upon an economic threshold. In this case, farmers will use insecticides based on their observation in the field (Mariyono 2007). By using this assumption, it is expected that the level of pest infestations will be affected by the use of insecticides (X) and the IPM technology (T). Based on the above idea, two structural equations are formulated as follows:

$$I = \beta_{10} + \beta_{11}X + \beta_{12}T + u_1 \quad (3)$$

$$X = \beta_{20} + \beta_{21}I + \beta_{22}P + \beta_{23}A + u_2 \quad (4)$$

However, the simultaneous equations cannot be estimated directly using the OLS method because endogenous variables exist on the right-hand side of both equations. A two-step estimation method can be used to deal with this problem (Gujarati 2003). The first step is to estimate reduced forms obtained by solving for I and X from the system equations (3) and (4). The reduced forms of the equations are expressed in the following equations:

$$\hat{I} = \varphi_{10} + \varphi_{11}T + \varphi_{12}P + \varphi_{13}A \quad (5)$$

$$\hat{X} = \varphi_{20} + \varphi_{21}T + \varphi_{22}P + \varphi_{23}A \quad (6)$$

Using the above equations, the estimated values of $\hat{I}$ and $\hat{X}$, which are independent of each other, can be obtained. The second step is to estimate the structural demand function using the following equations:

$$I = \delta_{10} + \delta_{11}\hat{X} + \delta_{12}T + v_1 \quad (7)$$

$$X = \delta_{20} + \delta_{21}\hat{I} + \delta_{22}P + \delta_{23}A + v_2 \quad (8)$$

The above equations indicate that the IPM technology will reduce the insecticide use if it significantly diminishes the level of pest infestations ($\delta_{12} < 0$), while the use of insecticides is determined by pest infestations ($\delta_{21} > 0$). In a static comparative manner, the IPM impact on insecticide use can be expressed as:

$$\frac{\partial X}{\partial T} = \frac{\partial X}{\partial \hat{I}} \cdot \frac{\partial I}{\partial T} = \delta_{21} \cdot \delta_{12} < 0 \quad (9)$$

It is important to note that the prices of fertilizers are not included in the models. This relies on an assumption that fertilizers and insecticides are technically independent of each other, meaning that fertilizers are not a substitute and a complement for insecticides in the production process. Taking the price of insecticides and the price of soybean in ratio terms will reduce any *multicolinearity* problems in econometric estimations, and will eliminate the need to adjust those prices to a price index.

STUDY SITE, DATA, AND SOURCE

The study was carried out in Jogjakarta and Central Java where the IPM Program was intensively implemented, and data related to the Program have been well documented and

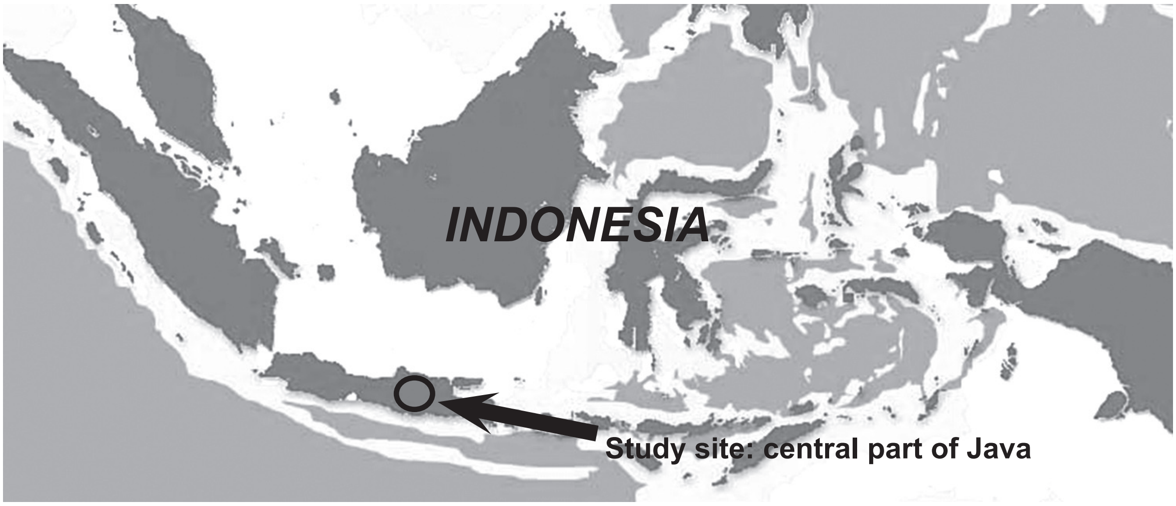

Figure 1. Location of study

available. Figure 1 shows the location of the study site.

Secondary cross-sectional and time-series (panel) data are employed in this study. The data contain 144 observations which are drawn from 16 regions during the nine-year period (1990–1998) when the IPM project was being implemented. The data are taken from a number of sources such as the Annual Report of the Provincial Agricultural Office, and statistical data published by Provincial and District Statistical Offices. The source of data on prices is the Statistical Office, and the source of data on insecticide use and pest infestation is the Laboratory of Observation and Forecasting of Pests and Diseases in Jogjakarta and Central Java. The source of data on IPM field school is the Agricultural Districts Service.

The types of data to be analyzed are:

1. the annual aggregate use of insecticides on soybean (kg);
2. the average annual price of soybeans (Indonesian Rupiah (=IDR) kg^{-1});
3. the average annual price of fertilizers and pesticides (IDR kg^{-1});
4. the aggregate level of pest infestation in soybeans (% = ratio of area invaded by pests to total soybean-cultivated area);
5. the cumulative number of IPM farmers' field school units that have been established; and
6. the annual soybean-sown area (ha).

The number of field schools is a proxy for the dissemination of technology. Using the number of field schools can possibly result in biased estimators in the event of measurement errors in the independent variables (Gujarati 2003), but this can be overcome by employing a panel regression method, which is used in this study (Verbeek 2004). The various pests studied here consist of the armyworm (*Spodoptera* spp.), pod worm (*Helicoverpa armigera* Hubn.), pod borer (*Etiella zinckenella* Tr.), and pod suckers (*Nezara viridulla* L. and *Riptortus linearis* L.). These pests have been identified as particularly occurring in soybean cultivation in Indonesia (Kalshoven 1981). The summary statistics for the variables are given in Table 1.

RESULTS AND ANALYSIS

Recursive Insecticide Demand Function

Table 2 presents the resulting estimates of insecticide demand using the recursive demand

Table 1. Summary statistics for variables.

	Obs.	Mean	Std. dev.	Min.	Max.
Insecticide use (kg)	144	5692.68	4327.41	1835.60	12636.00
Pest infestations (%)	144	5.85	5.78	0.00	26.07
Price of insecticides (IDR)	144	6931.38	1696.60	5237.75	11229.48
Price of soybean (IDR)	144	1278.19	663.55	825.00	3148.09
Amount of training (unit)	144	646.88	445.68	84	1432
Soybean-sown area (ha)	144	53114.24	76127.36	2012	226600

Source: author's calculation

Table 2. Recursive model of demand function for insecticides.

Variables	Coefficient	t-value
Intercept	1,754.2	4.52***
Relative price	- 220.43	-3.71***
Pest infestations (%)	27.13	3.87***
IPM (amount of IPM training)	-2.60	-6.16***
Soybean-sown area (ha)	0.040	8.51***
R^2	0.739	
F-value	23.010***	

*Note: dependent variable is insecticide use; *** significant at 1%; ** significant at 5%; * significant at 10%.*

Source: author's estimation.

function. The goodness of fit shows that about 74% of the variation in insecticide use can be explained by all the variables included in the model. Each variable (namely: relative price of insecticides, level of pest infestations, IPM technology, and soybean-planted area) significantly influences the demand for insecticides.

Partially, the relative price of insecticides has a significant effect in reducing the demand for insecticides. Going by the theory that the farmers will exhibit rational behavior, it would be logical to expect that they will respond to the declining marginal product of insecticides by reducing the amount of insecticide until the new level of marginal product equals the relative price of the insecticides. The level of pest infestations shows a significant effect on the increase in insecticide demand. This is still consistent with the IPM concept that insecticide will be applied when there exist serious pest infestations (Mariyono 2007).

Simultaneous Insecticide Demand Function

Given the results of the first-stage regression analysis shown in Table 3, the estimated values of pest infestations ($\hat{I}$) and insecticide use ($\hat{X}$) for a given period of analysis and different district can be obtained. Those estimated values, which have been free from endogenous effect, are then used to estimate the relationship between insecticide use and pest infestation. Such relationship is indeed a demand function for insecticides since there is insecticide price.

Table 4 indicates that the level of pest infestations is significantly reduced by insecticide application. Interestingly, the IPM technology also

Table 3. Estimates of reduced forms (first step).

Independent Variables	Dependent Variables			
	Pest infestation		Insecticide Use	
	Coefficient	t-value	Coefficient	t-value
Intercept	11.732	1.26 ns	1,607.06	2.96***
IPM (amount of IPM training)	-0.013	-1.36 ns	-2.895	-5.00***
Price ratio	-0.416	-0.29 ns	-149.155	-1.77*
Soybean-sown area (ha)	-8.629 E-05	-1.64*	0.012	3.93***
R^2	0.160		0.564	
F-value	2.032*		13.780***	

Note: *** significant at 1%; ** significant at 5%; * significant at 10%; ns not significant.

Table 4. Impacts of insecticide and IPM technology on pest infestations.

Variables	Coefficient	t-value
Intercept	13.508	3.19***
Insecticide use (kg)	-0.007	-1.43*
IPM (amount of IPM training)	-0.027	-2.10**
R^2	0.165	
F-value	3.270**	

Note: dependent variable is pest infestation; *** significant at 1%; ** significant at 5%; *significant at 10%; *significant at 10%.

has a significant effect in reducing pest infestation. The explanation for this finding is that the IPM principle is implemented so that pest infestations could be maintained at a low level; hence, the use of insecticides becomes considerably low as the farmer delays the application of insecticide. In other words, insecticides become the last alternative for crop protection. The regression coefficient of pest infestations that shows a considerably low value is mainly because the level of pest infestations itself is very low.

Table 5 shows that the increase of insecticide use is significantly caused by the increase in pest infestation. This is understandable because farmers will rationally apply insecticides only when pest infestations exist; in contrast, the conventional notion is that the scheduled application of insecticide becomes a primary measure for crop protection regardless of the level of pest infestations (Irham and Mariyono 2001; Mariyono 2007).

From the relationship between insecticide use and pest infestations (Table 4 and Table 5), it is reasonable to say that the demand for insecticides in soybean farming could be explained by using the demand function since the assumption that the IPM technology is able to reduce insecticide use is fulfilled. Table 4 shows that all variables included in the model can explain 53% of insecticide demand variation. In particular for the IPM variable, the regression result shows that the dissemination of the IPM technology leads to a reduction in the percentage of pest infestations. The reduction in pest infestations then reduces the amount of insecticide use. By using the simultaneous demand equations, it is

Table 5. Simultaneous model of demand function for insecticides.

Variables	Coefficient	t-value
Intercept	-901.81	-10.97***
Pest infestation (%)	207.60	11.14***
Price ratio	-47.343	-5.09***
Soybean-sown area (ha)	0.026	10.24***
R^2	0.537	
F-value	10.477***	

Note: dependent variable is insecticide use; *** significant at 1%

found that the IPM technology indirectly reduces the application of insecticide, as this technology is able to reduce the intensity of pest infestation. In terms of the effect of the IPM technology on demand for insecticides in soybean farming, this model has a consistent result with the recursive one.

The relative price of insecticides significantly reduces the amount of insecticide use in soybean farming, as expected. The price of insecticides during the period increased substantially because of the elimination of subsidy on insecticides (Useem et al. 1992). The increase in the price of insecticides is expected to increase the relative price, because the price of soybean tends to be stable. This implies that the use of insecticides has decreased.

With respect to the soybean-sown area, the use of insecticides will increase as the area increases. This phenomenon is theoretically justifiable, because the area represents the economies of scale. Usually, as the scale of the production increases, it will be followed by an increase in all inputs, including insecticides.

Figure 2 shows the impact of the IPM Program on insecticide use. By examining closely the use of insecticides during the dissemination of the IPM technology, it can be observed that there is a sharp fall in the use of insecticides at the beginning of the period. This sharp fall is likely caused by the elimination of the pesticide subsidy in 1990 (Untung 1996). After that, the insecticide use tends to decrease moderately, despite the increase in 1993 as a response to the increase in pest infestation.[2] The average fall in the use of pesticides could be jointly influenced by the elimination of subsidy, which caused an increase in insecticide price, and the dissemination of the IPM technology. The joint effect of both factors has been shown in the analysis using demand models for insecticides.

Two estimated models show similar results, that is, the IPM Program was able to diminish the use of insecticides. Owing to the basic concept of the economic threshold — which is a crucial factor in the relationship showing that the use of insecticides is based on the observation of pest infestation, it is likely that the simultaneous model is more accurate than the recursive one. It is shown in Figure 2 that there is a correlation between pest infestation and insecticide use.

[2] In 1993, the author was involved in the process of transition at which the IPM Program previously managed by BAPPENAS was taken over by MOA. During this transition, the implementation of FFS in the field became very disorganized. Farmers did not fully attend the training and a lot of farmers used pesticides without taking pest infestation into consideration. These conditions were likely to contribute to the increase in insecticide use during this time.

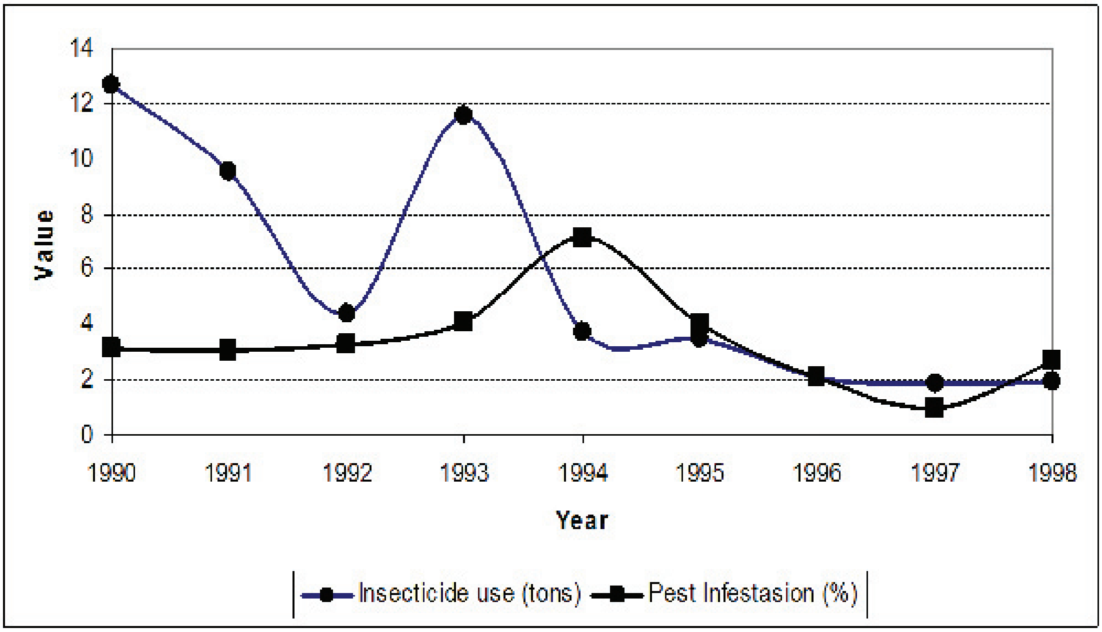

Figure 2. Trends of insecticide use and pest infestation on soybean during the implementation of IPM program

Both tend to decrease and fluctuate in the middle periods. Thus the mechanics of reduction in insecticide use could be like this: The IPM technology causes pest infestation to fall, which in turn, leads to a decrease in insecticide use. In this case, farmers delay using insecticides because the pest infestation has not exceeded the economic threshold (Mariyono 2007).

CONCLUSION

Aggregate regional data has been used to analyze the impact of the IPM Program in Indonesia. By using two models of demand for insecticides, the estimation results showed that the decrease in insecticide use was due simultaneously to the dissemination of the IPM technology and the increase in the relative price of insecticides. The increase in relative price was a consequence of the pesticide subsidy elimination at the beginning of the program.

Based on the simultaneous demand model, it was found that the IPM technology indirectly reduced the application of insecticides, as this technology was able to reduce the intensity of pest infestations. The analysis using the simultaneous demand model has a consistent result with that using the recursive demand model in terms of explaining the impact of the IPM technology on demand for insecticides. However, the simultaneous model appears to be more accurate since it captures the nature of reversible relationship between pest infestation and insecticide use.

The study found that the IPM program has reduced significantly the use of insecticides in soybean farming in Jogjakarta and Central Java during the period of dissemination of the IPM technology. The successful efforts of the IPM program to reduce the insecticide demand was deemed attributable to two important aspects of the program, namely: the elimination of insecticide subsidy, and the dissemination of the IPM technology.

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