THE BENEFITS OF TRAINING THAT INTRODUCED ECOLOGICAL TECHNOLOGY: A CASE OF RICE FARMING

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ABSTRAK

Penelitian ini bertujuan untuk menganalisis manfaat penerapan teknologi ekologis yang disampaikan melalui pelatihan pengendalian hama terpadu, dan menghitung insentif ekonomi, kesehatan dan lingkungan. Studi ini memilih wilayah Jawa Tengah, sebaran pelatiha sudah merata. Penelitian ini menggunakan model analisis yang menunjukkan bahwa teknologi tidak hanya berpengaruh terhadap produktivitas total, tetapi juga berpengaruh terhadap elastisitas input. Karena fakta bahwa pestisida menyebabkan masalah kesehatan dan lingkungan, penelitian memberikan perhatian khusus pada penggunaan pestisida. Data panel agregat produksi padi selama periode 1999-2008 dikumpulkan dari beberapa instansi pertanian tingkat provinsi dan kabupaten di Jawa Tengah. Hasil penelitian menunjukkan bahwa dengan menyebarkan teknologi ekologis, masyarakat setempat mendapat berbagai manfaat. Manfaat ekonomi yang diperoleh oleh petani berasal dari peningkatan produktivitas karena mengadopsi teknologi ekologis, dan dari penurunan tingkat penggunaan pestisida. Manfaat kesehatan yang diperoleh oleh petani berasal dari penurunan tingkat penggunaan pestisida, dan manfaat yang diperoleh konsumen berasal dari konsumsi padi yang rendah residu pestisida. Lebih jauh lagi, masyarakat di wilayah tersebut mendapat manfaat lingkungan yang dihasilkan dari penurunan tingkat penggunaan pestisida. Nilai moneter yang disebabkan menerapkan teknologi tersebut relatif tinggi, dan diharapkan manfaat tersebut menjadi insentif bagi pemerintah daerah untuk menyebarkan teknologi.

Kata kunci: Insentif Ekonomi, Teknologi Ekologis, Nilai Moneter, Kesehatan dan Manfaat Lingkungan

INTRODUCTION

In any region where agriculture still dominates regional economy, agriculture is able to increase welfare because ‘regional income measures provide indications of personal and community welfare and economic growth, … a change in real income is usually taken to imply a change in welfare in the same direction’ (Bendavid 1974: 30). Unfortunately, the sector is frequently less preferred than other sectors. This brings about the local governments do not focus seriously on the sector.

In Indonesia, agricultural sector plays important role in economy because of the fact that agriculture still absorbs approximately 50% of employment and provides share around 20 % of GDP (Hill 2000). By 2005, agricultural employment is still dominant, particularly in rural areas, with 58% of the non-poor and 75% of the poor working in agriculture (McCulloch 2008). However, the share of agriculture in GDP remains 16% (Lee 2008).

In the era of decentralization in which the central government no longer get intervene the local governments; it is crucial for some local regions to exploit their own local resources, including agricultural resource. However, exploitation of the local resource needs to be conducted in wise manner. In some regions, where agriculture is one of the potential contributors in economy, have implemented ecological technology in order to improve the performance of its sustainability. The technology is well-known as integrated pest management (IPM). Despite the fact that the technology is based on plant protection, it does not merely advance plant protection strategy, but also improve agronomical practices. It is expected to be able to increase productivity and to reduce pesticide use, which is unwisely used during green revolution. One important thing to note is that during the green revolution, pesticide no longer diminished pest attack, but created other problems such as pest resistance, pest resurgence, human health and environmental pollution (Barbier 1989; Bond 1996; Conway and Barbier 1990; Kishi et al. 1995; Mariyono et al. 2010).

The technology is ecologically sound, because it definitely utilises the natural capability of controlling pest attack in agricultural production. The following principles of ecology that has been implemented are to grow healthy crops; to conserve and make use of natural enemies; to carry out regular field observations; and to develop farmers as IPM experts in their own field (Untung 1996).

Figure 1 explains the logical framework of analysis. When the technology is adopted and implemented by farmers, the process of production will be increased. The ecological technology is expected to increase rice production and reduce pesticide use simultaneously. This brings about increase in farmer health and profit, increase in biodiversity, and reduction in environmental contamination as a result of reduction of pesticide use. Higher income is obtained from increase in production.

The technology has been implemented in some regions where rice production, which is politically and economically strategic, is the major commodity. However, the social benefit that is exclusively attributable to the technology has not been analysed economically. This study, therefore aims to analyse the economics of implementation of ecological technology, and attempts to identify the economic, health and environmental benefits that can be obtained by local community of the regions. By showing the monetary value of social benefit, it is expected to be able to provide incentives and stimulate other regions to adopt and disseminate such technology widely.

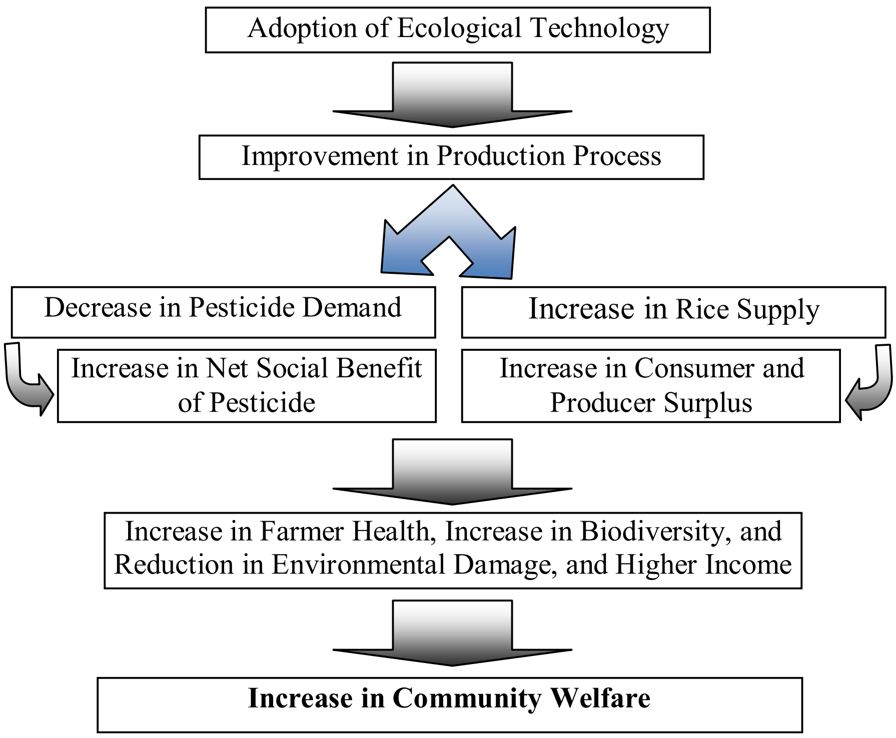

Figure 1. Conceptual framework

LITERATURE REVIEW

In Indonesia, farmers field school (FFS) has been a popular method to disseminate new ecological technologies for over 20 years, and it is practiced with various annual and perennial crops. Many FFS in Indonesia have focused on IPM. FFS evolved and got popularized after the Government of Indonesia revolutionized its policy on plant protection by implementing the national IPM program initiated in 1986 under Presidential Decree No. 3. The program was motivated by the fact that pesticides were not wisely used. The unwise use of pesticides led to economic losses associated with pest outbreaks in the 1960s (Settle *et al*. 1996) and in the 1980s (Barbier 1989). In addition, there were other adverse impacts of unwise use of pesticides such as environmental and health problems (Bond 1996; Kishi *et al*., 1995). The program was then conducted in 1989 (Rölling and van de Fliert, 1994), with the objectives of IPM training being: higher productivity, increased farmers' income, monitored pest populations (i.e. to keep pests below economic threshold levels), limited use of chemical pesticides, and an improved environment and better public health (Untung 1996).

There exists a strong claim that Indonesian IPM program has been able to reduce the use of pesticides significantly. In the field trials, the training has been able to cut down pesticide use by 50% without sacrificing the level of production (Bond 1996). Farmers have adopted the IPM principles (van den Berg 2004) and there is a strong indication of diffusion of IPM knowledge from farmers who participated in the program to neighbouring farmers (Mariyono 2007a, b). A recent study by Mariyono et al. (2010) shows that changing from the Green-Revolution-based technology to IPM-based technology in Indonesian rice production practices has also brought an agro-chemical saving technological progress by significantly decreasing pesticide use along with dissemination of IPM knowledge. By using a participatory approach, Mancini and Jiggins (2008) show, "that the deeper understanding of the occupational hazard of handling pesticides indeed induced a change in the FFS participants' attitudes towards pesticides". Underpinning the rise of participatory research has been a realization that the poor in general, and poor marginal farmers in particular, are far from being a homogeneous group. Thus, technologies have to be selected and adapted for particular systems. Based on an empirical study of successful adaptation and spread of pro-poor technologies, it is found that farmers who are members of FFS groups are significantly better off than non-member farmers (Lilja and Dixon 2008).

In other countries, FFS methods have been adopted to introduce new concepts and technologies. A summary of Lilja and Dixon (2008) reveals that participatory research involving an impact assessment of agricultural technology, farmer empowerment, and changes in opportunity structures in several countries argues that rural poverty has been reduced by combining farmer-empowerment and innovation through experiential learning in FFS groups, and changes in the opportunity structure through transformation of local government staff, establishment of new farmer-governed local institutions, and emergence of private service providers. In summary, FFS could be one effective method to disseminate improved technologies to farmers. Modified and adapted FFSs on other crops and topics are expected to have positive impacts on farming practices and improve understanding of farmers on such topics.

RESEARCH METHOD

Theoretical Framework

The theory of economics of production is utilized as fundamental framework. This framework relates to technological progress. Mathematically, with respect to introduction of ecological technology, the theory of firm explains that a firm produces single output Q, using multiple variable inputs X_i, and maximizing profit Π subject to constrain of fixed factor land L, technology T, and the other factors (ε), can be specified that the profit function which faced by farmers is:

$$\Pi = \pi\,(P_{Xi}, P_Q, L, T, \varepsilon) \qquad (1)$$

where: P_{Xi} is vector of variable input prices; P_Q is output price. Following Jehle and Reny

(2001), Hotteling's Lemma postulates that supply of output and demand for input equations corresponding to maximized profit derived from Π can be expressed as follow:

$$Q = q(P_{Xi}, P_Q, L, T, \varepsilon) \quad (2)$$

$$X_i = x_i(P_{Xi}, P_Q, L, T, \varepsilon) \quad (3)$$

In an economic view of plant protection, pesticides are not considered as productive input, but as protective inputs instead. This means that pesticides will provide a significant contribution if there is serious pest attack. If the pesticide works effectively to control the pest attack, this will save yield loss associated with the pest. Thus pesticides are not capable of increasing yield (Lichtenberg and Zilberman 1986). The ecological technology pays particular attention on the pesticide use, despite the fact that technology also considers agronomical advantages. The static comparatives of supply for output and demand for pesticide with respect to ecological technology therefore are expected to be $\partial Q/\partial T > 0$, and $\partial X/\partial T < 0$. These phenomena happen since the ecological technology does not only embody in technical efficiency, but also embody in production elasticity of inputs. This is unlike common use of technological progress analysis, which is typically Hick-neutral. Graphically, the impact of ecological technology on production economics of rice can be expressed as figure 2.

Figure 2 illustrates production of Q using input X, which is protective input. Q=$F^0(X)$ is the initial production function. This function results in supply for output and demand for input S_Q^0 and D_X^0 respectively. If the product and input markets are close to competitive market, the producer aims to maximize profit, and the prices of Q and X respectively is P_Q^0 and P_X^Q , the level of production will be Q^0, and the level of input use will be X^0, where marginal product of X [slope of $F^0(X)$] is equal to ratio of P_X^0/P_Q^0 . Furthermore, along with implementation of ecological technology, the production function will move to $F^1(X)$. By holding assumption that P_Q^0 and P_X^Q remain constant, producer will allocate input at X^*, where slope of $F^1(X)$ is equal to ratio of P_X^0/P_Q^0 , and the new level of production is Q^*. Because of steadiness in P_X and P_Q, it is reasonable to say that supply for output moves from S_Q^0 to S_Q^1 and demand for input moves from D_X^0 to D_X^1. Thus, the increase in implementation of ecological technology in rice production lead to increase in production and decrease in input use. The decrease in input use does not reduce the level of production since the input, pesticides, are not productive input, but protective input instead (Lichtenberg and Zilberman 1986).

However, despite the fact that pesticides are protective to yield loss associated with pest attack, pesticides are destructive to human health and the environment. It is therefore pesticide use also leads to what called externality, which can be defined as a negative (or positive) effect of the actions of one individual, firm or nation on another without compensation (Seitz et al. 1994; Grafton et al. 2004). With respect to pesticide, negative externalities are unintentional side effects of pesticide use such as pesticide residues and health effects. The negative external effects can be subdivided into two categories. First, it is harmful to the user directly, and second, it eventually concerns both the user and the society in total (Jungbluth 1996).

Study Site and Data Sources

The study was carried out in Central Java where the ecological technology was intensively disseminated, and data related to the program have been well documented and available. Rice was selected as the object of this study since it is the main commodity and one of the main targets IPM program. In technically irrigated system, rice shows economic advantage (Mariyono and Kuntariningsih 2007).

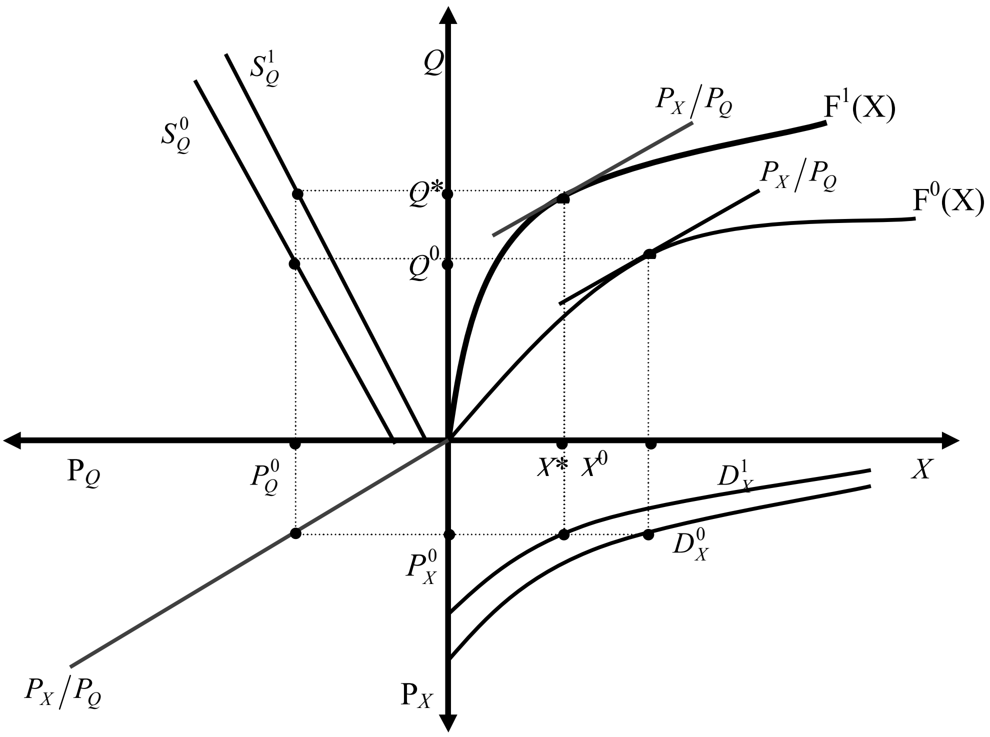

Figure 2. Effect of Ecological Technology on Economics of Rice Production

For practical estimation, the functional form of supply response of rice and demand for pesticides are respectively formulated as follow.

$$S_Q = \beta_0 + \beta_1 P_Q + \beta_2 P_F + \beta_3 P_{XQ} + \beta_4 L + \beta_5 \ln T + \varepsilon \quad (4)$$

$$D_X = \delta_0 + \delta_1 P_Q + \delta_2 P_F + \delta_3 P_{XX} + \delta_4 L + \delta \ln T + \varepsilon \quad (5)$$

where S_Q is supply of rice; D_X is demand for pesticides; P_Q is price of rice, P_F is price of fertilizers; P_X is price of pesticides; L is rice-planted areas; T is technology, ε_Q and ε_X are error terms for rice and pesticides respectively.

Secondary cross-sectional and time series data were employed in this study. The data comprise four districts in the nine-year period (from 1999 to 2008) in four regions of Central Java, at which time the technology was being disseminated. The secondary data were compiled 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. Types of data to be analysed here are: rice production (ton), level of pesticide use (kg), number of units training on ecological technology, annual average price of rice (Rp/kg), annual average price of fertilizers and pesticides (Rp/kg) and the areas cultivated to rice (ha). Estimation of the supply and demand functions was conducted using a panel regression with random effect, which is suitable to this case (Greene 2003; Wooldridge 2000).

RESULTS AND DISCUSSION

The estimated supply function for rice and the estimated demand function for pesticide in rice farming are respectively indicated in Table 1 and Table 2.

Table 1. Supply function for rice

Independent variable	Coef.	z-ratio
Constant	10961	0.47
Price of rice	31.73	0.42
Price of fertilizer	-18.17	0.62
Price of pesticide	-7.69	0.14
Ecological technology (ln)	**9517**	**2.13****
Rice-planted Area (ha)	5.81	43.13**
χ^2 joint test for restriction of price coefficients=0		12.46**
R^2		98.71

Dependent variable: produced rice (tons); **) significant at α=0.01; *) significant at α=0.05

Table 2. Demand function for pesticides

Independent variable	Coef.	z-ratio
Constant	2560	3.41**
Price of rice	2.97	1.56
Price of fertilizer	0.99	0.56
Price of pesticide	-0.32	-1.25
Ecological technology (ln)	**-470**	**-2.16***
Rice-planted area (ha)	0.02	3.24**
χ^2 joint test for restriction of price coefficients=0		8.53*
R^2		48.63

Dependent variable: pesticide use (kg); **) significant at α=0.01; *) significant at α=0.05

Table 1 shows that implementation of ecological technology significantly leads to increase in supply for rice. One percentage increase in disseminating ecological technology causes an increase rice production by around 9,517 ton. Furthermore, Table 2 shows that the dissemination of ecological technology, at the same time, also significantly leads to decrease in pesticide use. One percentage increase in implementing ecological technology brings about a decrease in level of pesticides applicable to rice farming by approximately 470 kg.

With respect to changes in prices, joint test indicates that prices have significant impact on supply for rice and demand for pesticides in rice farming. Based on estimated regional supplies for rice and demand for pesticides, it is explainable that implementing ecological technology has brought rice production process into better condition, called "clean" production process that discharges lower pesticides waste. It contributes any benefits both in private and social terms. Below are the benefits of implementing ecological technology.

Increase in yield, which is showed by the increase in supply for rice. The increase in supply for will enhance consumer surplus and, certainly producer surplus if the demand of product is elastic. Decrease in pesticide use, which leads to additional profit because of less input use, particularly for pesticide. The decrease in pesticide use, in turn will lead to health and environmental benefits since the decrease in pesticide use will reduce pesticide externality (Jungbluth 1996).

Using average prevailing prices of rice and pesticides, there will be financial benefit of technology adoption; and the financial benefit can be directly calculated. For economic and social benefits, the external costs of pesticides need to be determined. However, since external costs associated with pesticide use in Indonesia have not been well estimated, it is adequate to use the benefit transfer concepts that 'refers to the process by which a demand function or value, estimated for one environmental attribute or group of attribute at a site, is applied to assess the benefits attribute to similar attribute or site (Garrod and Willis 1999: 331)'. If it is the case, producer health cost of certain amount of pesticide use obtained from a study conducted in the Philippines by Rola and Pingali (1993) is 1,623,137.34 • $470^{0.62}$ = Rp 73,630,193. This amount of monetary value of health benefit will be gained by producers as a result of adopting ecological technology. Furthermore, Mourato et al. (2000) have well estimated external costs of pesticide application by using a contingent valuation method to estimate consumers' willingness to pay (WTP) of a kilogram decrease in pesticide use. The consumers' WTP represents the value of health resulting from consuming low-pesticide residue, and the value of increase in environmental quality. The estimated external costs associated with pesticide application of one-kilogram pesticide are equivalent to 60% of average price of pesticides, that is 0.6 • 11,200 • 470 = Rp 3,158,400. If the estimated external costs can be assumed as a shadow price of pesticide pollution, an increase in disseminating ecological technology will reduce external costs of about Rp 73,630,193 + Rp 3,158,400 = Rp 76,788,593. The amount of external costs reflects an additional increase in utility, which will be gained by both farmers and other people in the regions.

CONCLUSION

Adoption of ecological technology has been to reduce level of pesticide use and increase rice production; and this has provided benefits to community. In terms of monetary value, the benefits of ecological technology were significantly high. Based on such benefits, the rice farming practices in regions that adopted the technology went into the direction of what called 'sustainable fashion'. Barbier (1989) states that sustainable agriculture occurs when both the real costs and the real environmental costs of production are expected to remain constant or fall as production expands. The same criteria stated by Acton and Gregorich (1995) and Norman et al. (1997), indicate that the technology has brought agriculture into a sustainable fashion because of the following reasons. First, it satisfied human food and fibre needs, which was demonstrated by the increase in rice production. Second, it enhances environmental quality and the natural resource base on which the agricultural economy depends, which was demonstrated by the decrease in pesticide application that pollutes the environment. Third, it caused the most efficient use of non-renewable resources and on-farm resources; and integrates, wherever appropriate, natural biological cycles and controls. It was demonstrated by lower level of pesticide application with higher level of rice production. Fourth, it was sustaining the economic viability of farm operations that was demonstrated by higher profit of rice farming practice derived from lower pesticides use and higher production of rice. Last, it was enhancing the quality of life of farmers and society as a whole that was demonstrated by lower externality resulting in safe food for farmer and other societies.

LIST OF REFERENCES

Acton, D.F. and Gregorich, L.J. 1995. *The Health of Our Soils: Toward Sustainable Agriculture in Canada*. Research Branch of Agriculture and Agri-Food, Canada.

Barbier, E.B., 1989. Cash Crops, Food Crops, and Sustainability: The Case of Indonesia. *World Development*, *17 (6): 879-895.*

Bendavid, A., 1974. *Regional Economic Analysis for Practitioners*. Praeger Publisher New York.

Bond, J. W., 1996. *How EC and World Bank Policies Are Destroying Agriculture and the Environment*. AgBé Publishing, Singapore.

Conway, Gordon R. and Barbier, Edward B., 1990. *After Green Revolution, Sustainable Agriculture for Development*. Earthscan Publication, London.

Garrod, G. and Willis, K.G., 1999. *Economic Valuation of the Environment: methods and case studies*. Cheltenham, UK.

Grafton, R.Q., Adamowicz, W., Dupont, D., Nelson, H., Hill, R.J. and Renzetti, S., 2004. *The Economics of the Environment and Natural Resources*, Blackwell Publishing, Carlton.

Greene, W.H., 2003. *Econometric Analysis*. Prentice Hall, New Jersey.

Hill, H., 2000. *The Indonesian Economy*. Cambridge University Press, Cambridge.

Jehle, G.A. and Reny, P.J., 2001. *Advanced Microeconomic Theory*, Addison-Wesley, Boston.

Jungbluth, F., 1996. *Crop Protection Policy in Thailand: economic and political factors influencing pesticide use.* A Publication of the Pesticide Policy Project 5

Kishi, M.; H., Norbert; Djayadisastra, M.; Satterlee N. L.; Strowman, S. and Dilts, R., 1995. Relationship of Pesticides Spraying to Signs and Symptoms in Indonesian Farmers. *Scandinavian Journal of Work, Environment, and Health, 21: 124-133.*

Lee, Jen-chyuan, 2008. Major agricultural statistics. Food & Fertilizer Technology Center. http://www.agnet.org/situationer/stats/ (downloaded on March 5th 2010).

Lichtenberg, E. and Zilberman, D., 1986. The Econometrics of Damage Control: why specification matters. *American Journal of Agricultural Economics, 68: 261-273.*

Lilja, N. and Dixon, J., 2008. Operationalizing participatory research and gender analysis: new research and assessment approaches. *Development in Practice*, *18 (4-5):467-478*

Mancini, F. and Jiggins, J., 2008. Appraisal of methods to evaluate farmer field schools. *Development in Practice*, *18 (4): 539-550.*

Mariyono, J. 2007a. Adoption and diffusion of integrated pest management technology: a case of irrigated rice farm in Jogjakarta Province, Indonesia. *Asia-Pacific Journal of Rural Development, 17 (1): 29-38*

Mariyono, J. 2007b. The impact of IPM training on farmers' subjective estimates of economic thresholds for soybean pests in central Java, Indonesia. *International Journal of Pest Management, 53 (2): 83-87.*

Mariyono, J. and Kuntariningsih, A., 2007. Keunggulan ekonomi, penerapan teknologi PHT dan sosial ekonomi usahatani padi beririgasi teknis di Kecamatan Moyudan, Jogjakarta. *Jurnal Studi Ekonomi*, 2 (2):155-168.

Mariyono, J., Kompas, T. and Grafton, R.Q. 2010. Shifting from Green Revolution to environmentally sound policies: technological change in Indonesian rice agriculture. *Journal of the Asia Pacific Economy, 15: 128–147.*

McCulloch, N., 2008. Rice prices and poverty in Indonesia. *Bulletin of Indonesian Economic Studies. 44 (1): 45–63.*

Mourato, S.; Ozdemiroglu, E.; and Foster, V., 2000. Evaluating Health and Environmental Impact of Pesticides Application: implication for the design of ecolabel and pesticides taxes. *Environ. Sci. Technol. 34 (8): 1456-1461*

Norman, D., Janke, R., Freyenberger, S., Schrule, B. and Kok, H., 1997. *Defining and Implementing Sustainable Agriculture.* Kansas Sustainable Agriculture Series, Paper #1.

Rola, A.C. and Pingali, P.L., 1993. *Pesticides, Rice Productivity, and Farmer's Health: an economic assessment*. IRRI and World Resource Institute, Washington.

Rölling, N. and van de Fliert, E., 1994. Transforming extension for sustainable agriculture: the case of Integrated Pest Management in rice in Indonesia. *Agricultural and Human Value 11 (2/3): 96-108.*

Seitz, W.D., Nelson, G.C. and Halcrow, H.G., 1994. *Economics of Resources, Agriculture, and Food. McGraw-Hill, New York, U.S.A.*

Settle, W.H., Ariawan, H., Astuti, ET., Cahyana, W., Hakim, A.L., Hindayana, D., Lestari, A., Pajarningsih and Sartanto, 1996. Managing Tropical Rice Pests through Conservation of Generalist Natural Enemies and Alternative Prey. *Ecology*, *77 (7): 1975-1988.*

Untung, K., 1996. Institutional constraints on IPM implementation in Indonesia. *Publication of the Pesticide Policy Project, Publication Series , 3A: 37-47.*

van den Berg, H., 2004. *IPM Farmer Field Schools: a synthesis of 25 impact evaluations*. Wageningen University, The Netherlands. 53 pp.

Wooldridge, J.M., 2000. *Introductory Econometrics: A modern approach*. South-Western College Publishing, Australia