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Empirical Scenarios for Emission Control and Economic Sustainability of Energy Input and Intervention of Agricultural Pesticides

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ABSTRACT

The application of pesticides have been out of control, therefore, it is damaging environment due to emissions of vary substances and gases, e.g., CO_2, SO_2, PO_4, and Summer Smog. This negative impact alone is also going to affect the paddy production. A comprehensive measure must be taken in order to create a sustainable development in agricultural sectors. Control on pesticides is one of the best practices to be proposed. This study used a quantitative methodology with a life cycle assessment (LCA) approach to test empirically the use of pesticides and to propose various scenarios in the effort of modification of environmentally friendly and low emission agriculture, which includes aspects of greenhouse, acidification, Eutrophication, SPM Smog. By using LCA with quantitative measurement using SimaPro 7, the findings show that ratio of emission rate of the existing condition to the proposed model proved a 34.5% decrease in CO_2 equivalent (136.4 kg) and 41.6% decrease in SO_2. As the environmental risks decreases, it is expected that the sustainable agricultural development of paddy commodity can be materialised. Some recommendations are given by the researc findings, i.e., distribution system according to the proposed model, recording, monitoring, and legal enforcement towards the sustainable development.

Keywords: Paddy, Pesticide Control, Agricultural Sustainability, Emission
JEL Classifications: K32, O13, P18

1. INTRODUCTION

Food Agricultural Organization defines agriculture as a human activity of making use, or exploiting, biological resources to produce cultivated land, industrial raw materials, or energy sources, which also involves environmental management (Poisot et al., 2004). Rimando (2004. p. 1) defines agriculture as an act of systematically growing plants and cattles/poultries under the management of human. Abellanosa and Pava (1987. p. 238) furthermore add that such activity is performed to fulfill the human needs. Agriculture according to Rubenstein (2003: 496) stands for a massive effort to change part of earth surface by way of plant and animal cultivation to fulfill nutrition of food and drink and economic benefit. Plant and animal agriculture are some of important knowledge in growing the plants and animal husbandry to fulfill the dietary and other needs and to pursue the economic benefit (Bareja, 2017). Agriculture is considered as sustainable if it is managed by an ecological concept, a study of correlation between organisms and their environment. Sustainable agriculture focuses on economic sustainability by efficient use of energy, minimum ecological footprint, efficient product or commodity packing, widespread local purchase, simple or immediate food supply chain, less processed foods, more community and household gardens, to mention some (Kunstler, 2012; McKibben, 2013; Palanichamy et al., 2017; Zhu et al., 2014).

According to EPA, pesticide is substance or organism used for vanquishing, paralysing, modifying, preventing growth and exiling pests. Pesticide can be made of either natural or synthetical chemical substance, the combination of the two, or living organisms that act as biological control agents. Pesticide used in agriculture is specifically dubbed as crop protection products. This is to differ from the similar products applied to other areas (Djojosumarto, 2008). The rapid development of agricultural technology has produced extensive results through the provision and diversity of food sources. On the other hand, agricultural technology cannot be separated from the use of chemical drugs in the form of pesticides. However, the use of pesticides is considered to harm the environment and degrade soil quality in continuous use. With the high dose and frequency of pesticide use, the burden of pesticide contamination on water quality, and soil fertility becomes increasingly high. Such changes occurring in soil, water, and air also have potential dangers to living organisms essential to the soil fertility and sustainability of the environment. This is a concern, because the excessive use of pesticides in the medium and long term will cause a burden on environmental degradation, increased emissions, and greenhouse effect (Balogh and Jámbor, 2017; Smagulova et al., 2017).

In Indonesia, the use of pesticides is very widespread and threatening, including in producing paddy (oryza sativa) as the main staple food source. Likewise, paddy is the major food for local community in Pati Regency, Central Java Province, Republic Indonesia. Therefore, its growth rate has become prominent. Efforts to improve paddy productivity by local farmers, however, have tended to depend on pesticides. Hence, this study aims to test empirically the use of pesticides and to propose various scenarios in the effort of modification of environmentally friendly and low emission agriculture, which includes aspects of greenhouse, acidification, eutrophication, SPM Smog, with the research object of paddy field in Pati Regency, one of the largest rice producing regions in Indonesia. This study applied a life cycle assessment (LCA) approach to better provide a systematic, factual, and accurate explanation of facts, characteristics, and correlation between phenomena. Moreover, by using the LCA approach to the sustainable paddy agriculture in Pati Regency, the distribution model can further be elaborated by involving local government, The Surveillance Commission on Fertiliser and Pesticide, and all stakeholders in supervising and controlling the use of pesticide as well as recording, monitoring, and legal enforcement towards the sustainable development.

2. LITERATURE REVIEW

Pesticides have become a common term in reference to substances used for exterminating, controlling, exiling, and decreasing crop germs (Margni et al., 2002). According to the general guide for pesticide assessment, pesticides contain chemical substances and compounds, tiny organisms, viruses, and other substances, which can be used to protect crops or plants as well as their parts and components. Pesticides used for agricultural activities have been specifically referred as products that protect the crops (crop protection products), as they may be separate from the similar products used for other activities (Djojosumarto, 2008; Soenandar et al., 2010). Sudarmo (1991. p. 19-20) mentions vary kinds of pesticide according to their functions and word origins, as follows: (a) Akarisida (from Latin arka); (b) algicide (from Latin alga); (c) avicide (from Latin avis); (d) bacteriside (from Greek bacterium); (e) fungicide (from Greek fungus); (f) herbicide (from Latin herba); (g) insecticide (from Latin insectum); (h) larvicide (from Greek lar); (i) mulluksicide (from Greek mulluscus); (j) nematicide (from Latin nema); (k) ovicide (from Latin ovum); (l) peduculicide (from Latin pedis); (m) piscicide (from Greek piscis); (n) rodentcide (from Greek rodera); (o) predicide (from Greek praeda); (p) silvicide (from Latin silva); and (q) termicide (from Greek termes).

Uncontrolled application of pesticides can contaminate soil, killing organisms that previously are not the main targets (Joko et al., 2017; Ramwell et al., 2002). Eco-efficiency is an effort to create and added value by performing better practices to fulfill the customers' need while maintaining, or decreasing, environmental impacts (DeSimone and Popoff, 2000. p. 2-3; Kurniawan, 2017). Eco-efficiency may be defined as a strategy, which bears in a particular product with a better performance by using efficient energy and natural resources. It is a combination between economic and ecological efficiencies under the principle of "doing more with less", i.e., producing more goods and services by consuming more efficient energy and natural resources (Environment Australia, 1999). Pati Regency, Central Java Province, is a region with huge potential of agriculture, in particular paddy. Of the total 150, 360-hectare area, 58,448 hectares are rice fields with technical irrigation. Pesticides become the main weapon to control and prevent the pests. As the application has become more widespread, alert must be taken into account for the environmental impacts. Pesticides have become prominent method that entails economic value in order to improve agricultural product output and quality nowadays. They are believed to have a significant role in controlling pests (Jin et al., 2010). The distribution chain of the pesticides from transportation to storage to application process becomes a series of actiivity that give impact on human health, flora and fauna, agricultural crops, and environmental risk. There must be any effort to minimise these impacts by a model design to guarantee the sustainability of the paddy crops. The model proposed here was approached by the LCA.

The followings are the previous studies concerning pesticides in agriculture. Van Hoi et al. (2013) reports the failure of Vietnam authority to regulate the pesticide trade. Jacquet et al. (2011) and Skevas et al. (2013) discuss tax scheme and economic incentives; and Pranetvatakul et al. (2011) reveals a grow of 10% of the pesticide use with high external cost in Thailand. Further study by Fan et al. (2015) finds that farmers knowledge correlates with the application of pesticide and policy implication. Al Zadjali et al. (2013) reports that extension and education of the farmers awareness are important in the pesticide application in Oman. Likewise, Widayati and Yusuf (2017) assess the effect of use of pesticide in Dieng Plateau, Central Java on the public health, social and economic performance. Phung et al. (2012) finds comprehensive risk and benefit of the evaluation of the pesticide registration and management. Juraske et al. (2009) discuss the pesticide application on fruits and vegetables. Whereas, Dijkman et al. (2012) compares the pesticide impacts. The similar conditions also occur in Indonesia, in which government has not effectively executed the surveillance of the overgrowth of the pesticide application.

The SWOT analysis resulted on strategies of the pesticide distribution model for paddy agriculture towards sustainable environment in Pati Regency, as follows. The first is improved capacity of the Surveillance Commission on Fertiliser and Pesticide for the pesticide management to increase rice production. Second is improved human resource and number of the extension staff for the pest surveillance at early stages with appropriate pesticide application. Third is improved performance of the Surveillance Commission on fertiliser and pesticide and more advanced technology to increase paddy production. Fourth is law enforcement of the PPNS performance to decrease the potential environment pollution across the agricultural area. Fifth is training for farmers in using the environmental-friendly pesticide practice, cultivation system, and ability to analyse the pest at early stage. Sixth is decreased dependence on pesticide use and focused on technological advance with an integrated pest control. Seventh is periodical monitoring and evaluation from juridical, technical, and human aspects in line with environmental management to eliminate the pollution. Lastly, it is needed the improved technological use in agriculture by a clear and environmental-friendly policy. The major objective of the LCA approach is to identify, compare, and evaluate the environmental components through a scenario to be developed to obtain the ultimate scenario De Backer et al. (2009). The function unit of the research is according to the range of the research location, i.e., per hectare area with the pesticide emulsion volume of 16 L.

3. METHODOLOGY

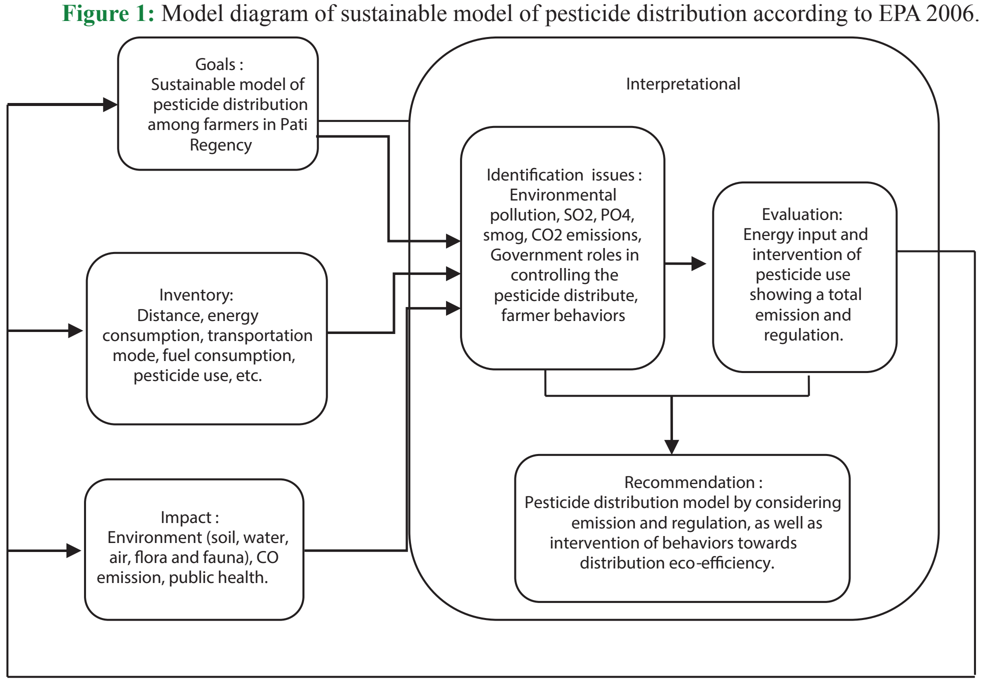
This study applied a LCA approach with an analytical descriptive method (Tien et al., 2007; Ingwersen et al., 2012). It aimed at providing a systematic, factual, and accurate illustration of facts, characteristics, and correlation between phenomena to be studied (Panichelli et al., 2009). A descriptive method was performed by a quantitative analysis, focusing on research samples obtained from the following villages: Srikaton, Sukorukun, Sriwedari, Ngurensiti, Bumiayu, Dukuhseti, and Kembang.

4. RESULTS

In relation to life cycle inventory, the spraying activity shall give impact on human as the one who performs it. Even the impact has already spread over the distribution phase. Pesticide results in CO_2, SO_2, eutrophication, carsinogenic, and summer smog. A 3-tonne capacity box truck with diesel engine travels at the distance of 212 km, consuming 60-67 kg fuels. To transport the pesticides for a single hectare area, 3-kg pesticides have a ratio of the diesel fuel use of 0.06 kg. The flow diagram already applied to the EPA since 2006 is as follow (Figure 1).

The distribution flow of the pesticides in Pati during this study was sampled from the producers that took the headquarters in Gresik Regency, East Java Province. The pesticide mixture and spraying process by 78 farmers as the respondents revealed that all of them did not we are protecting gloves and masks. They typically mixed three different pesticides (1 liquid pesticide; 2 powder pesticides) into the sprayer with a dose for 16 L. There were two different volumes of mixing containers used by the farmers to mix the pesticides: 58% of the farmers used 5-L containers and 42% of them used 12-L containers. They used wooden sticks to mix the pesticides without wearing any protection. The pesticides applied to the paddy crops in the morning during the rainy season and in the afternoon during sunny days. Most of the respondents (82%) did not wear footwear and most of them (65%) wear casual (not special-purpose) clothes. All the respondents (100%) did not

Figure 1: Model diagram of sustainable model of pesticide distribution according to EPA 2006.



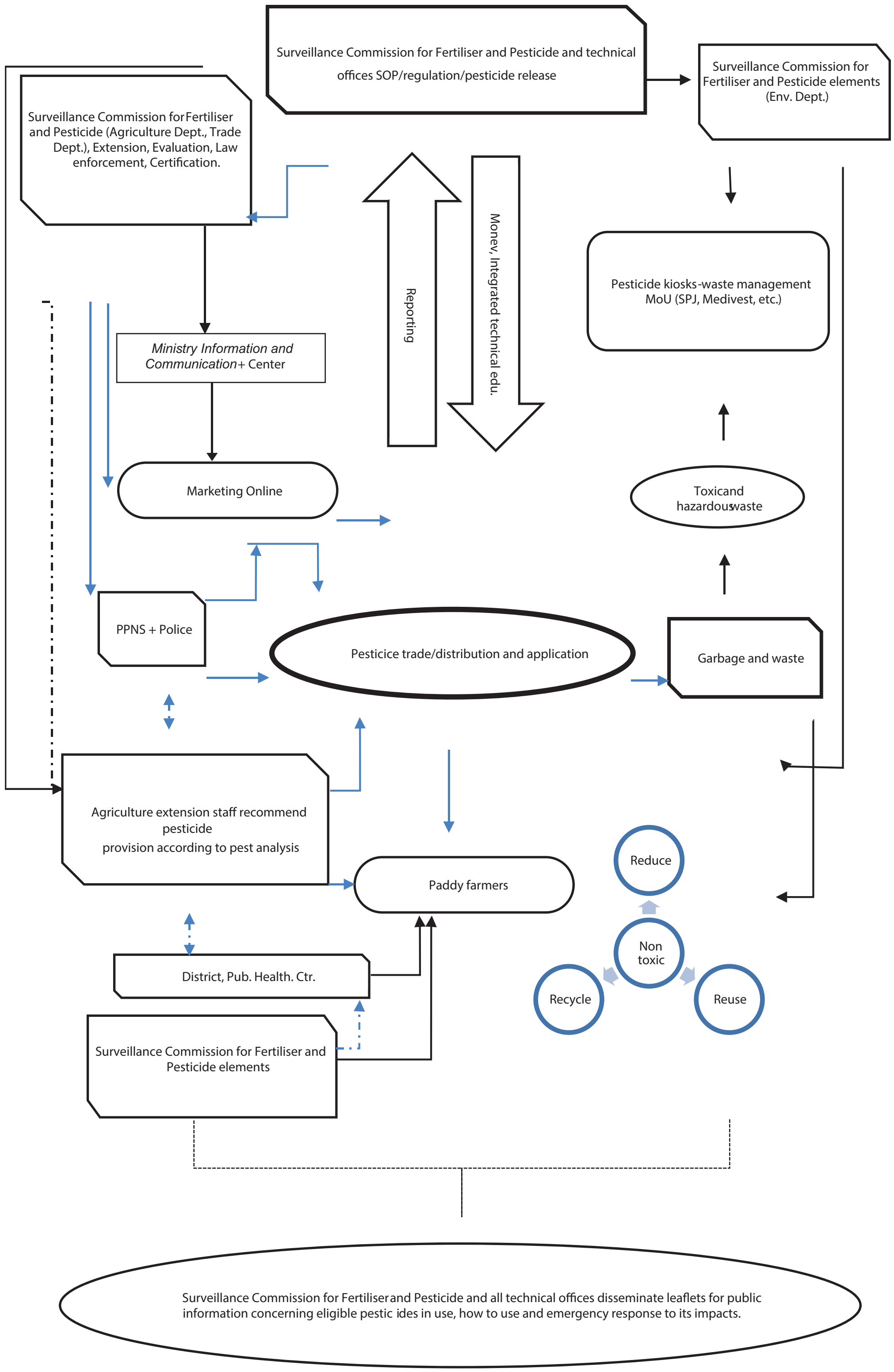
Source: United States Environmental Protection Agency, 2006, with modification and adjustment to research

Table 1: Emission comparison by LCA technical scenarios

Component	Greenhouse (CO_2) (in kg)	Acidification (SO_2) (in kg)	Eutrophication (PO_4) (in kg)	SPM Smog (SMOG) (in kg)
Existing	5029.7	32.7	2.05	22.9
Scenario 1	5178.07	31.43	2.11	28.41
Scenario 2	5209.70	31.93	2.14	28.86
Scenario 3	4113.80	25.00	1.68	22.68

Source: Data proccessed, 2017. LCA: Life cycle assessment

Figure 2: Pesticide distribution model



Source: Research findings, 2017

wear any protection gloves. The packs of the used pesticides were dumped nearby the paddy crops and then burnt after the harvest time. The spraying equipments were cleaned by 4.5-5.5-L water and the washing water were disposed to the rice fields water tract. The SimaPro 7.0 revealed CO_2 emission of 6209.7 kg eq., as the main element of greenhouse effect, SO_2 31.93 kg as the main element of acid rain, eutrophication by nutrition 2.14 kg, smog due to pesticide spraying 28.86 kg with its negative impact on the environment. The health risk on farmers consisted of symptomatic dizzines (24.46% of the respondents), headache (22.05%), fatigue (17.83%), nausea (26.63%), and skin heating (16.63%). The was a strong correlation of the body protectors and dosage of the applied pesticides to the farmers pain complaints. The health risk of the pesticide distribution was estimated having a contribution to low weight birth in Pati Regency. Children exposed by the unused pesticides was also severe due to pure method of storage. Three technical scenarios of the LCA approach were discovered along the pesticide distribution in Pati Regency. The following Table 1 is the result of the SimaPro 7.0 analysis.

The Table 1 explains that the comparison of the CO_2 emission to the third scenario resulted in the lowest emission (4113.80 kg CO_2 eq). Compared to the first scenario, it was 1064.27 kg CO_2 eq lower, a 20% decrease. The lowest rate of SO_2 was found in the second scenario (25.00 kg SO_2 eq). Whereas, the lowest PO_4 (1.6 kg) and smog were from the third scenario. The third scenario (Scenario 3) proposed a model, which had the lowest emission based on SWOT (strength, weakness, opportunity, and threat) analysis to get the appropriate strategy. The model and strategy to perform the pesticide distribution towards sustainable environment is as illustrated in the following figure (Figure 2).

Using the LCA approach to the sustainable paddy agriculture in Pati Regency, the distribution model can further be elaborated as follows:

a. The government of Pati Regency is present in the governance of the pesticide distribution across the region by strengthening the Surveillance Commission on Fertiliser and Pesticide and other related technical offices, e.g., Agriculture, Health, Environment, and Food Security;
b. The Surveillance Commission on Fertiliser and Pesticide develops a Standard Operational Procedure (SOP) and disseminates information to the public on the eligible pesticides in use, pesticide governance, and pesticide trade and application through technical education, monitoring and evaluation, and coordination of the existing regulations and rules of law;
c. All pesticide distribution levels apply the predetermined SOP by recording and reporting all pesticide transports and the management of the wastes, including those generated by the farmers;
d. The Regency Office of Agriculture, through its pest surveillance and control division and extension staff, performs an integrated guidance to the farmers and recommends the use of particular pesticides in co-ordination with the Surveillance Commission on Fertiliser and Pesticide;
e. The Civil Servant Ombudsman (known as PPNS in Indonesian) contributes to the surveillance of the pesticide distribution to prevent any violation. In doing so, PPNS may need for additional help from the police department by rules of law. An online surveillance is also necessary;
f. The surveillance of the online transaction must be anticipated by co-operation with the Department of Communication and Information nationwide;
g. The Regency Office of Environment and Forestry continues to monitor the chemical hazards and toxic substances in co-operation with the waste managers for the disposal of pesticide cartoon packs uncontaminated by the pesticides. The “reduce,” “reuse” and “recycle” principles must apply to the chemical hazards and toxic substances; and
h. All the activities are compiled to be data and information to be disseminated publicly through brochures and leaflets. Any licensed and registered pesticides must be socialized and recommended according to prescribed dose and the timely application.

5. CONCLUSIONS

The role of the Pati Regency Government in the pesticide distribution had not been fulfilling the need for the environment-based pesticide control and prevention toward agricultural sustainability. The environmental and health risks exposed by the pesticide distribution in Pati Regency is necessary to be minimised by calculating the risk factors according to the LCA. All concerned parties, either public sector, private sectors, business world, or civil societies are expected to work in concert to materialise the paddy agriculture sustainability.

The study recommends institutional strengthening and empowerment, in particular the Monitoring Commission for Fertilizers and Pesticides, budget allocation and political support, registration of all agricultural product kiosks, human resources development, standard operation procedure development, legal enforcement, technical guidance of all levels, promotion, monitoring and evaluation, and further studies.

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