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Carbon–Methane Emissions and Sustainability of Agriculture: Empirical Evidence of Rice Cultivation

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***Abstract*—The presentation of this paper aims to evaluate the potential influence of carbon and methane gas emissions caused by rice farmers' production activities in Indonesia. According to the data and ranking released by Food and Agriculture Organization (2018) Indonesia is classified into the top three of the ten largest carbon emitting countries from the rice cultivation sector and ranked seventh in agriculture activities in total. Using the FAO data series and applying simple regression models found a significant relationship between rice production activities and increased carbon emissions equivalent (CO_2eq.) as well as rural populations. The recommendation of the results of this study is the extension of organic farming activities supported by the results of subsequent research in increasing sustainable rice cultivation.**

Keywords— CO_2, CH_2, Emissions, Rice cultivation, Rural population

I. INTRODUCTION

Green revolution that has changed the agricultural paradigm from traditional agriculture to modern agriculture in the short term has succeeded in overcoming the problem of food security and malnutrition in developing countries (Gómez et al., 2013; Moseley, 2015). The revolution in agriculture, especially in production techniques, has succeeded in increasing production in a number that has doubled, in other words, it has succeeded in increasing agricultural productivity and labor to encounter the demand and supply of domestic and world food needs and reduce poverty (Das, 1998; Moseley, 2015).

In the long run, recent studies have shown that the application of modern agricultural production has caused pollution and decreased environmental quality and decreased productivity of agricultural commodities and marginal agricultural products (Ragasa & Chapoto, 2017; Dawson, et al., 2016; Gómez et al., 2013; Ray & Ghose, 2014). It shows that to produce sustainable agricultural production in the application of modern technology needs to be thoroughly revised, so as to achieve balance in various aspects including production and markets, environment and health, social and demographic. In the presentation of this paper, we evaluate two aspects of rice production and rural populations and its effects on environmental quality in Indonesia.

The deterioration in environmental quality in the last few years, according to several studies conducted in Indonesia, generate from economic activities, especially in urban communities as found by Warr & Yusuf, (2011); Yusuf & Resosudarmo, (2009) and they predict an increase in carbon dioxide emissions, especially in clean air quality in urban areas in the next ten years. However, the potential and contribution of environmental pollution, especially caused by CO2. Corresponding to data and ranking released by the Food Agricultural Organization (FAO, 2018) Indonesia belongs to the top three of the ten largest carbon emitting countries from the rice cultivation and seventh in overall agricultural activities.

Similarly, the increase in rice consumption caused by the increase in population will encourage the growth of rice production, which in turn will increase gas emissions, while proving it to encourage production in the short term it still depends on the green revolution (Maraseni, et al., 2018; Headey & Hoddinott, 2016).

Sustainable of agricultural development has become global agenda, the definition and its application of sustainable agriculture has developed in such a way, but in achieving agricultural sustainability requires a multidisciplinary approach, for example Ekbom et al., (2001); Frimawaty et al. (2013); Kanchanaroek & Aslam, (2017); Martin-Guay et al. (2018); Pashaei et al. (2017); Qi et al. (2018); Wasiak (2017). The approach often used by scientists is the definition of the United Nations (FAO, 2014) with its expansion and development, such as saving agriculture's future agenda in terms of production of agricultural products, food security and nutrition, as well as maintaining the sustainability and quality of the global environment.

In an effort to overcome the problem of food security and nutrition, especially in developing countries and less developed countries is to adopt the green revolution technology (vonWirén-Lehr, 2001; Falcon, et al., 2004). The main strategy has been applied is to increase production, especially in food grains such as rice and wheat. Population growth is predicted to increase 30% by 2050 (Llewellyn, 2018) is a beneficial factor as well as a challenge to the strategy, so it needs to be studied in further discussion.

In this research sustainable agriculture is one that includes adopting ecological, environmental, economic and social sustainability issues in agriculture along with an unbalanced population growth rate with food security (Heslin, 2015; Llewellyn, 2018). The first issue, including carbon emissions and methane gas generated from rice cultivation from harvested areas and yields, the second issue, related to rice as food security, and the last issue is how these activities remain a source of sustainable livelihood for farmers by considering both the two previous issues.

II. METHOD

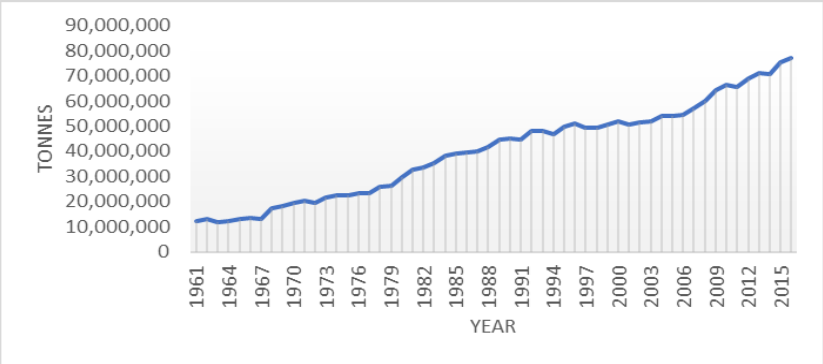
Agricultural activities carried out by rice farmers are sub-domains of general agricultural activities. This research was conducted in the case of production activities that produce residues from the use of fertilizers, crop residues, burning of unused plant residues, burning of grasslands for farming activities and energy use in the production of rice by farmers are the data that will be used in research this will be obtained how much the contribution and effects of these activities on changes in CO_2 carbon dioxide emissions and methane gas CH_4. To accommodate the two elements of the emission gas, equivalent CO_2 is used which describes the emissions in rice farming measured in gigagrams (gg) (IPCC, 2014; FAO, 2018).

Data sets were obtained from FAOSTAT with series data from 1961 to 2016 accessed in 2018. The analytical method was carried out by simple linear regression to identify the relationship and influences of agricultural production activities and dynamics of rural populations on changes in composition of emissions produced from rice cultivation.

III. FINDING AND DISCUSSION

Rice production in Indonesia is increasing every year, since the success of 1984/1985 rice self-sufficiency through the implementation of intensification patterns through BIMAS, improvement and improvement of irrigation networks, financing and distribution of rice marketing by KUD or Village Unit Cooperatives and Logistics Affairs Agency (BULOG), see this discussion at : Mears (1984); Simatupang & Timmer (2008); Majid, et al., (2017), the pattern of production at that time had become a practice of the intensification pattern through increasing the intensity of the use of seeds and non-organic production inputs which were characteristic to be maintained so far.

This indicates that the adoption pattern of the green revolution has become a necessity in rice cultivation after rice self-sufficiency through the BIMAS intensification program at that time. However, for the adequacy of domestic consumption needs have not achieved solid food security, because domestic sufficiency still needs to be supplied from significant quantities of rice imports.



Source: FAOSTAT, 2018.

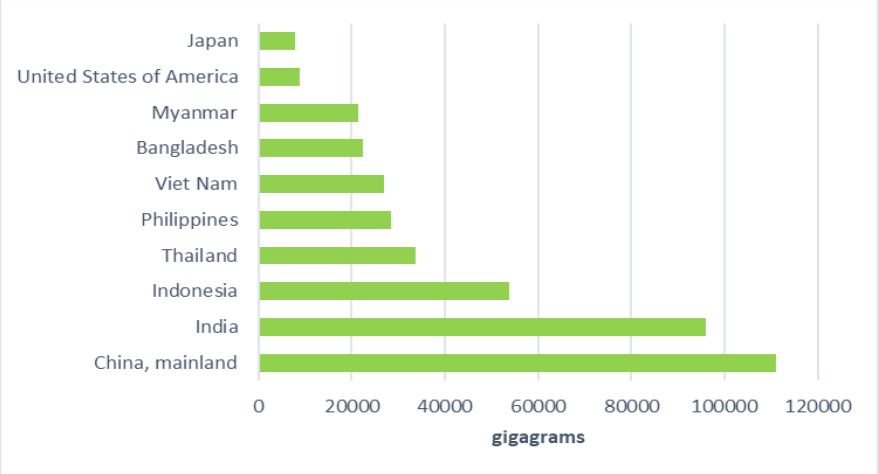
FIGURE I. RICE PRODUCTION IN INDONESIA SINCE 1961-2016

Changes in domestic consumption are closely related to the increase in population and diversification of consumption, which is still not effective up to now, especially in rural areas. The amount of rice consumption in rural areas reaches 24% compared with urban areas only 16% (Reardon, et al., 2015; Bourgeois & Kusumaningrum, 2008; Moslehpour, et al. 2014) and compared with the number of people in rural areas that increased significantly, this burden will boost significant rice production (Figures I and II).

Consequently, efforts to boost production that has been carried out for decades have succeeded in encouraging increased rice cultivation with trends that tend to increase every year. The consequences of this are that there is an increase in emissions from the use of inputs and the process of cultivating land and harvesting by farmers. The tendency of increasing CO2 levels eq. and CH4 methane gas shows that the contribution of global warming from the agricultural sector is significant.

Indonesia's agricultural activities which are dominated by rice cultivation are in the top three for their contribution to carbon and methane gas emissions previous to China and India. In the meantime, as a country that produces and suffices high consumption of rice with a relatively large potential land area were three countries (Figure II.). Rice planting from tillage to harvesting in fact is part of the cause to increased emissions, such as land processing activities using non-organic material

fertilizers, superior seed varieties such as those occurring in Bangladesh on critical lands (see: Sabiha, et al, 2016) and post-handling harvesting from unused crop residues by burning it can be one of the most dominant causes carried out by farmers in Indonesia. FAO data shows that rice cultivation and cultivation of organic soils are the main causes besides management of manure from any unused post-harvest agricultural products, for instance straw and so on.



Source: FAOSTAT, 2018.

FIGURE II. TEN EMITTERS CO_2 AND CH_4 FROM RICE CULTIVATION ON AVERAGE 1990 – 2016

In the meantime, to find out more about the determining factors and their relationship with increasing carbon emissions and methane gas from rice cultivation. The following is empirical evidence regarding the increase in the amount of rice production, the number of rural population, the harvest area and yields with the increase in emissions in Indonesia. based on the estimation results obtained that there is a significant relationship with increasing levels of emissions contributed by rice cultivation activities. Trend of population growth in rural areas indicates an increase in consumption needs and employment in rural areas. in line with that research from Reardon & Timmer (2014) find the same facts about the level of consumption, especially staple foods.

In addition, the policy of agricultural commercialization to increase the income of small farmers is an interesting issue to be explored broadly, because of the implications of this policy are to encourage increased production of land, infrastructure and markets extension, it will potentially generate environmental damage. corresponding to several studies related to agricultural commercialization such as Mitiku (2014); Riwthong et al., (2017) also found the correlation, especially in the use of pesticides, this indicates the use of non-organic inputs significantly increase rice production. However, this has led to raise the emissions resulting from rice cultivation.

The implications of food security problem are an important agenda to be explained while the issue of global warming is also crucial, sustainable agricultural solutions by considering these two aspects can be used as a reference in the formulation and application in the agricultural sector, including the issue of rice cultivation. An increase in the population coupled with a decrease in air quality is an accumulation that has the potential to have a negative impact on food security itself and also on environmental health.

TABLE 1. THE ESTIMATION RESULTS AND FACTORS THAT DETERMINE EQUIVALENT CO_2 CARBON EMISSIONS

VARIABLES [a]	***Coefficient*** [b]	***t-Statistic***	***Adjusted R-squared***	***DW***	***RMSE***	***P. Value***
PRODUCTION	0.3646	36.2222	0.9597	0.2761	0.0409	0.0000
	(0.0101)					
Intercept	1.3256					
RURAL POPULATION	0.6540	46.7976	0.9755	1.0149	0.0319	0.0000
	(0.013)					
Intercept	2.835001					
AREA HARVESTED	16.1045	1193.888	0.9999	0.1367	0.0012	0.0000
	(0.0135)					
Intercept	-34.0672					
YIELD	0.5527	22.4725	0.9016	0.2760	0.0639	0.0000
	(0.0246)					
Intercept	4.9213					

Note: a) all variables in the linear form of natural logarithms, the dependent variable is CO_2,
b) the numbers in parentheses are error terms

Other factors that need to be considered are land use, the estimation results show a positive linear relationship with the emissions produced, in accordance with FAO emitter ranks where China is the country with the largest land area for farming activities also supplies the largest emissions of rice cultivation. This linear relationship shows that land use is an important factor for policy makers to issue optimal policies.

TABLE 2. THE ESTIMATION RESULTS AND FACTORS THAT DETERMINE EQUIVALENT CH_4 CARBON EMISSIONS

VARIABLES [a]	*Coefficient* [b]	*t-Statistic*	*Adjusted R-squared*	*DW*	*RMSE*	*P. Value*
PRODUCTION	0.3646	36.22217	0.9597	0.2761	0.0409	0.0000
	(0.0101)					
Intercept	1.3256					
RURAL POPULATION	0.6549	46.7976	0.9755	1.0149	0.0319	0.0000
	(0.0139)					
Intercept	-0.2095					
AREA HARVESTED	44.7536	877.9146	0.9999	0.1367	0.0017	0.0000
	(0.0509)					
Intercept	-38.0991					
YIELD	0.5527	22.47249	0.9016	0.2760	0.0639	0.0000
	(0.0246)					
Intercept	1.8768					

Note: a) all variables in the linear form of natural logarithms, the dependent variable is CO_2.
b) the numbers in parentheses are error terms

Estimation and forecasting results from a simple linear regression model using the Root Mean Square Error or the RMSE method indicate that a positive relationship between rice production factors, rural population harvested area, rice yields and an increasing trend in the future. RMSE test with Theil coefficient value that is less than one, then the prediction results can be concluded accurately (Woschnagg & Cipan, 2004). The forecasting test results show that emissions will tend to increase positively if rice harvesting activities are still carried out using the similar method. Although, the relatively high R^2 value which implies a collinearity in the model (Granger, 1974), therefore, for the accuracy of prediction, regression techniques are used separately. Thus, we can still draw conclusions from the estimation results (Figure III).

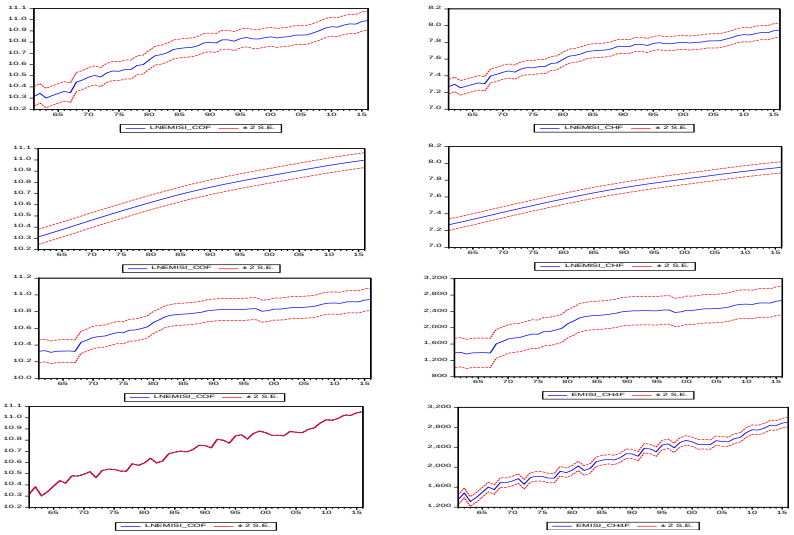


FIGURE III. TRENDS AND FORECASTING IN INCREASING CO2 EQ. AND CH4 GAS FROM RICE CULTIVATION IN INDONESIA

IV. CONCLUSION

Environmental damage can occur from the production and post-production processes. The reason is the practical processing of conventional and modern by adopting the technology of the green revolution is more efficient, but this requires adaptation, with a modern integrated organic farming system, so that further investigation is needed regarding the feasibility in terms of operational and market. The issue of food security that encourages large improvements without regard to environmental aspects needs to be evaluated, e.g. non-organic production-input subsidy such as fertilizers and pesticides. Another interesting issue is the commercialization in agriculture, which improving the income and welfare of smallholder farmers by growing rice cultivation.

The limitations of this research as well as being the next research schedule are trade off emissions between production, population or land use and the increased emissions and commercialization of agriculture, especially rice production as food

security has not been explored comprehensively. However, the commercialization of rice production and the quality of the environment are important concerns and research agendas that are being carried out by policy consequences to improve and integrate conventional and modern agricultural technologies.

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