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Energy Analysis of Rice Production in Banten Province, Indonesia

Tian Mulyaqin[1], Muchamad Yusron[1] and Viktor Siagian[1]
Institute forAssessmentand development of Agricultural Technology
Jalan Ciptayasa KM 01, Ciruas, SerangBanten, Indonesia
**Corresponding author : tian.mulyaqin@gmail.com*

ABSTRACT

Rice is the most important food crop for Indonesian people. Rice production process need the amount of energy intensively. The purpose of this study is to analyze the energy requirement of rice production under different farm levels. Data were collected from 133 farmers using structural questioner. The research result showed that rice production consumed a total energy of 18525 MJha^{-1} which chemical fertilizer energy using was 61.99% followed by pesticide (19.87%), human labour (7.71%), fuel energy (3.10%), and machinery (4.96%), respectively. The share of direct, indirect, renewable and non-renewable energies was 10.81%, 89.19%, 10.08%, and 89.92%, respectively. The energy use efficiency and energy productivity were found at 4.13 and 0.28 kg/MJ, respectively. The farm (>5 ha) show had better energy use than a small farm (<5 ha).

Keywords : *rice, the energy ratio*

INTRODUCTION

Energy is absolutely needed to run various economic activities in human life. We need the amount of energy in production or consumption activities (Elinur et al. 2010). Agriculture could become a producer and consumer of energy. As a producer, the agricultural sector produces a huge of biomass as a potential for the amount of energy and as a consumer agriculture use a commercial and non-commercial energy such as solar energy for photosynthesis, labour, animal, seed, fertilizer, chemicals, and fuel (Chaicana et al. 2014).

Rice is a strategic and important cereal crop commodity in Indonesia. Rice is a staple food for more than 95% of the population, with consumption of rice of approximately 97.40 kg/capita/year. In addition, rice is a source of income for more than 21 million people in Indonesia (Ministry of Agriculture of Indonesia 2014a). In order to ensure national food security, the policy is focused on the increase of rice production.

Rice production process needs amount of energy. The energy use in rice production has become more intensive due to the use of fossil fuel, chemical fertilizer, pesticide, machinery etc. It could be causing health and environmental

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problems, therefore there is a need to efficient use of input to produce rice through sustainable agriculture. The purpose of this study is to analysis the energy requirement and technical efficiency of rice production under different farm levels.

MATERIALS AND METHODS

Study and location

The study was conducted at four districts (Pandeglang, Lebak, Serangand Tangerang Districts) of Banten Province (5º7′50′′ and 7º1′1′′ South latitude and 105º1′11′′ and 106º7′12′′East longitude). Banten is located at the most western part of Java Island. The altitude ranging from 0 to 1000 m, generally topography of Banten is low land. The range is from 0 to 200 m above sea level (Tangerang, Pandeglang, and Serang District). The central part of Lebak and Pandeglang District has a height of more than 200 m-2000 m above sea level (BPS Banten 2016). The research sites were selected based on the top producer area of rice in Banten Province (95% of rice production in Banten) (BPS Banten, 2016).

Data Collection

The data of 133 farms were collected by interviewing the farmers using structured questionnaire. The farmer was randomly selected from different districts of the top rice producer area. Data of energy input and energy output were evaluated using the process analysis methodology (Afshar RK et al. 2015). This study is limited for energy used in rice production only. Data of all inputs including seed, fertilizer, pesticide, human labour, machinery, fuel were evaluated. The others source of energy such as environmental energy (sun radiation, wind, etc.) were not included in this study. The output was dry paddy. To analyze the input and output of energy the standard energy coefficient (Table 1) was used, input and outputs were calculated using their energy equivalents from the table.

The classification of energy in this study was categorized into direct (human-labour, diesel fuel) and indirect (chemical fertilizer and pesticides, machinery, and seed) energies. We also categorized the input into renewable (human labour and seed) and non-renewable (diesel fuel, chemical, and machinery) inputs (Komleh SHP, et al. 2011) and (Fazeli M 2017).

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Table 1. Energy coefficient of inputs and output in rice production

Energy Source (unit)	Energy Equivalent (MJ unit-1)	References
A. Inputs		
Human Labor	1.96	Singh S, et al., 1992
Diesel fuel (L)	47.8	Kitani O, 1999
Machinery		
Tractor and self -propelled (kg yr[a])	9-10	Kitani O, 1999
Stationary equipment (kg yr[a])	8-10	Kitani O, 1999
Implement and machinery (kg yr[a])	6-10	Kitani O, 1999
Chemical Fertilizer		
N (kg)	78.1	Kitani O, 1999
P_2O_5 (kg)	17.4	Kitani O, 1999
K_2O (kg)	13.7	Kitani O, 1999
Pesticide		
Insecticide (kg)	229	Kitani O, 1999
Herbicide (kg)	85	Kitani O, 1999
Fungicide (kg)	115	Kitani O, 1999
Seed (kg)	14.7	Singh S, Mittal JP, 1992
B. Output		
Paddy (kg)	14.7	Singh S, Mittal JP, 1992

a Economic life of machine (year)

The energy ratio (energy use efficiency), energy productivity, specific energy and net energy were calculated using the equation below (Komleh, et al. 2011) and (Fazeli, 2017).

Energy ration/Efficiency = Energy output (MJ/ha)/Energy input (MJ/ha) …….(1)

Energy Productivity = Paddy yield (kg/ha)/Energy input (MJ/ha)…………..…(2)

Specific Energy = Energy input (MJ/ha)/Paddy yield (kg/ha) …………… …...(3)

Net Energy Yield = Energy output (MJ/ha) – Energy input (MJ/ha)………. ….(4)

RESULTS AND DISCUSSION

The Agriculture and Respondent Characteristics

The research site was the rice production centre in Banten Province. Pandeglang and Lebak Districts are located in the southern part of Banten, while Tangerang and Serang Districts are located in the northern part of Banten. The contribution of rice production in these four districts is 96% of the total rice production in Banten. The share of Pandeglang, Lebak, Serang, and Tangerang

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Districts was 33%, 27%, 23%, and 13%, respectively (BPS Banten 2016). The dominant cropping pattern in the research site was rice – rice – fallow with Cropping Index between 1.5 until 2, as the result, most of them could grow rice twice a year. The first season is around September or October when the rain beginning rainfall and the second season begins around January, until March or April. After the second season, there was no crop because of the lack of water in the dry season. However, in addition to rice, there are other non-rice crops in the research site, such as cassava, chilli,beans, eggplant, and cucumber, although these are smaller in terms of production. The rice variety planted by respondent farmer is Ciherang, Mekongga and IR 64, few of them already using Inpari (1, 2, 10, 32, 33) as the new varieties.

As shown in Table 2, the respondent farmers were 21 to 81 years old with the average about 48 years old. This means that the ages of respondent are in their peak age of productivity. The average of formal education of respondents is about 8 years, showing most farmers have a formal education until the elementary school or junior high school. However, there is also respondent gained their formal education from university. As we know that education could have a positive influence on their farming practices.

The average of a family member of respondent about 4 persons, this family member is dependent on the farming, but also as the resource for a family labour. More family member would be more expenses for their family.

The average of rice farming experience in the research site shows that most respondents have sufficient experience to run their rice farm. Then the average farm size is 1.06 ha with the most of farmer used sharing system with the owner of the farm. It means that most of the farmer is not the owner of the farm but just as a labour.

Table 2. Characteristics of respondents

Variable	Mean	Minimum	Median	Maximum
Age (year)	47.96	21.00	46.00	81.00
Formal Education (year)	7.73	0.00	6.00	16.00
FarmingExperience (year)	21.29	0.00	20.00	50.00
Family member (persons)	3.80	0.00	4.00	8.00
Farmsize (ha)	1.06	0.10	1.00	6.50

Input-output Energy Analysis

The result of input-output energy analysis of rice production at different farm levels is shown in Table 3. The total energy input of rice production in Banten Province is about 18.525 MJ/ha which is the most energy input sharing

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from fertilizer. It is about 61.99% of total input energy (11,848 MJ/ha). This result is in line with the other researchers in which the chemical fertilizer (N, P_2O_5 and K_2O) utilization had high consumption of rice production (Komleh, et al. 2011; Fazeli, 2017; Bockari-Gevao, et al. 2005; Khan, et al. 2009; Gajaseni, 1995; Bautista and Minowa, 2010; Pathak, Bining,1985; Freedman, 1980).There are some reasons that chemical fertilizer had high consumption in rice production. Firstly, it is caused by price subsidized fertilizer and secondly, it is caused by farmer knowledge of fertilizer application. Because the price of fertilizer is subsidized by government, the farmerused excessive fertilizer (more than the plant need) and many farmers still think that more chemical fertilizer applied the more yield will be achieved.

The sharing of energy input followed by pesticide, it is about 19.87% (3,681 MJ/ha). Also the same just like fertilizer the poor knowledge of pesticide application, many farmers used pesticide are not on proper time, target, and dose. Then the sharing of energy input followed by human labor input, it is about 7.71% (1,428 MJ/ha). The sharing of human labor input in this research was divided into human labor energy for land preparation, planting, maintenance, and harvesting which is 0.64% (118 MJ/ha), 1.84% (341 MJ/ha), 2% (370 MJ/ha), and 3.23% (598 MJ/ha), respectively.

The share of machinery/tractor and fuel energy consumption was calculated 4.96% (918 MJ/ha) and 3.10% (574 MJ/ha), respectively (Table 3). Due to low mechanization operation in rice production, most respondent farmers only used tractor for rice production. For harvesting, farmers are still using human labour (Table 3). The energy of human labor for harvesting is bigger than another activities (land preparation, planting, maintenance).

The share of seed energy consumption was about only 2.37%, most respondents already used the certified seed for their rice production. The knowledge of farmers about the seed already at a good level, they already used the new high yield variety and usually monitor the quality of the seed from the label showing the expiration date of the seed packaging.

Table 3 also shows the comparison between different energy inputs for farm size in which farmers with less than 0.5 ha cultivated area, generally used more amount of total energy input (seed, fertilizer, pesticide, human labor) than the farmer who run the rice production with the farm size more than 0.5 ha. This result shows that the farm more than 0.5 ha and more than 1 ha had better management and were more successful in energy use. This result agrees well with the previous study by Komleh et al. (2011).

The energy of output for each farm size was 82,757.63 MJ/ha, 75,084.05 MJ/ha, and 67,261.99 MJ/ha for farm size level less than 0.5 ha, 0.5 ha until 1 ha, and more than 1 ha, respectively. The average of different farm levels is about

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75,034.56 MJ/ha. We can see that the energy of farm size with less than 0.5 ha has a higher energy output than the other farm size level. However, due to the higher energy input for the farm size less than 0.5 ha compared to the farm size more than 0.5 ha, the energy ratio of this farm level (<0.5 ha) is lower than the others. It is about 3.52. However, the other farm level has the energy ratio about 4.55 and 4.31 for the farm size that more than 0.5 ha until 1 ha, and more than 1 ha respectively (Table 4.). The energy ratio reflecting the efficiency of input of energy for rice production, the high the value of energy ratio, the more efficient the energy input.

Table 3. Energy input and output of rice production at different farm levels

	Unit	Farm size (ha)			Average (MJ/ha)	%
		>0.5	0.5-1	>1		
A. Input						
Seed	MJ ha^{-1}	483.45[a]	414.06[b]	417.40[b]	**438.31**	**2.37**
Fertilizer						
N	MJ ha^{-1}	10,495.41	8,798.59	9,571.08	9,621.69	51.94
P_2O^5	MJ ha^{-1}	1,119.71	1,061.82	908.78	1,030.10	5.56
K_2O	MJ ha^{-1}	1,614.89	578.39	305.85	833.04	4.50
Total Fertilizer	MJ ha^{-1}	13,230.01[a]	10,438.80[b]	10,785.71[b]	**11,484.84**	**61.99**
Pesticide	MJ ha^{-1}	6,234.86[a]	2,758.86[b]	2,050.35[b]	**3,681.36**	**19.87**
Human Labor						
Land preparation	MJ ha^{-1}	173.16	112.82	69.79	118.59	0.64
Planting	MJ ha^{-1}	523.59	291.94	207.52	341.02	1.84
Maintenance	MJ ha^{-1}	500.22	366.69	243.36	370.09	2.00
Harvesting	MJ ha^{-1}	841.85	624.93	329.57	598.78	3.23
Total human labor	MJ ha^{-1}	2,038.83[a]	1,396.37[b]	850.24[b]	**1,428.48**	**7.71**
Tractor	MJ ha^{-1}	918.47	918.47	918.47	**918.47**	**4.96**
Solar fuel	MJ ha^{-1}	575.06	573.60	573.60	**574.09**	**3.10**
Total Energy input	MJ ha^{-1}	23,480.68[a]	16,500.16[b]	15,595.78[b]	18,525.54	100.00
B. Output (paddy)	MJ ha^{-1}	82,757.63	75,084.05	67,261.99	75,034.56	

Note: different letter (a,b,c) within the same column showed a significant difference of means at 5% level.

The energy productivity of farm with more than 0.5 ha is higher than the less than 0.5 ha. The energy is 0.31 (0.5-1 ha farm size), 0.24 (<0.5 ha farm size), and 0.24 (<0.5 ha farm size); reflecting the production of 1 kg rice required 1 MJ of energy. However, the specific energy of < 5 ha farm size is higher than the other farm levels, about 29%, reflecting 29% more energy needed to produce 1 kg of rice than the other farm levels.

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Table 4. Indices and energy form of rice production

Item	Unit	farm size (ha)			Average (MJ/ha)	Percentage (%)
		<0.5	0.5-1	>1		
Energy Ratio	-	3.52	4.55	4.31	4.13	
Energy Productivity	Kg/MJ	0.24	0.31	0.29	0.28	
Specific energy	MJ/kg	4.17	3.23	3.41	3.60	
Net Energy	MJ/ha	59,276.95	58,583.89	51,666.21	56,509.02	
Direct energy[a]	MJ/ha	2,613.89	1,969.97	1,423.84	2,002.56	10.81
Indirect energy[b]	MJ/ha	20,866.80	14,530.19	14,171.94	16,522.98	89.19
Renewable energy[c]	MJ/ha	2,522.28	1,810.43	1,267.64	1,866.78	10.08
Non Renewable energy[d]	MJ/ha	20,958.40	14,689.73	14,328.14	16,658.76	89.92
Total Energy	MJ/ha	23,480.68	16,500.16	15,595.78	18,525.54	

[a]Include human labor and fuel
[b]Include machinery, seed, chemical fertilizer and pesticide
[c]Include seed and human labor
[d]Include machinery, chemical fertilizer, fuel and pesticide

The form of energy was used in rice production also shown in Table 4. On average, the proportion of indirect energy is higher than direct energy in each farm level. It is 89.19% and 10.81% respectively. Further, the use of energy of non-renewable energy is still higher than renewable energy about 89.92% versus 10.08%. The use of non-renewable energy is higher due to the increased use of chemical fertilizer and pesticide, and fuel for machinery utilization.

CONCLUSIONS

Rice production consumed a total energy of 18525 MJ/ha in which chemical fertilizer use energy of 61.99% followed by pesticide (19.87%), human labour (7.71%), machinery (4.96%), and fuel energy (3.10%).The share of direct, indirect, renewable and non-renewable energies was 10.81%, 89.19%, 10.08%, and 89.92%, respectively. The energy use efficiency and energy productivity were found at 4.13 and 0.28 kg/MJ, respectively.The farm (>0.5 ha) showed the better energy use than a small farm (<0.5 ha).

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