Comparison of Performance and Total Energy Requirement for Several Harvesting Method of Indonesian Farmers

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Abstract. Rice harvesting is carried out by farmers both conventional and machinery. The evaluation of energy consumption in this study was conducted to determine the total energy uses during harvesting for three harvesting method (conventional, semi-machinery, and combine harvester). The result shows, detail of harvesting energy requirement using combine harvester are 151.64 MJ/ha of engine energy, 1381.53 MJ/ha of fuel energy, and 18.95 MJ/ha of human energy. However, manual harvesting only human energy (104.4 MJ/ha). Harvesting with semi machinery (a sickle and power thresher) consist of engine energy (7.92 MJ/ha), fuel energy (752.73 MJ/ha), human energy (95.81 MJ/ha). The highest energy requirement for harvesting method of Indonesian farmers is using combine harvester, meanwhile combine harvester have highest capacity and efficiency.

Keywords: Energy Requirement, Combination Harvesting, Rice Harvesting

1. Introduction

Agriculture is an activity of utilizing biological resources carried out by humans which aims to produce food. To produce food security, one must have considered is maintaining rice quality from processing to distribution. Based on the Badan Pusat Statistik (Central Statistics Agency) of West Sumatra Province, in 2016 West Sumatra had a harvested area of rice productivity of 491,875.70 ha [1].

Rice is a food crop that produces rice, the need for rice consumption increases from year to year as population increases. During the harvesting process, there is a loss of yield that is affected by factors such a handling and use of harvesting tools. Handling of harvests using traditional tools such as sickle, threshing by being slammed caused a yield shrinkage of 21.09% [2]. Harvest handling using modern tools can reduce yield losses to 13%. The critical point of yield loss occurs in rice cutting, collection and threshing [3].

Rice harvesting which has been done manually in several regions has weaknesses, one of which is limited labor, late harvest time so that the quality and quantity of rice is reduced. As food needs increase, human resource skills must be further improved. The government is trying to facilitate farmers, one of which is combining harvester, the aim is to reduce limited labor and support rice self-sufficiency and reduce rice harvest losses [4]. By using a combine harvester, yield losses can be reduced by 2.5% because by using it all processes are combined into one activity from harvesting to threshing. The combine harvester is capable of working on an area of 4 ha/day, while using a power thresher is only able to work 1.5 ha/day, so that the use of a combined harvester is more efficient when harvesting rice [5]. The use of combine harvester since 2012 has reached 13,315 units in all regions in
Indonesia, in 2017 the Kementrian Pertanian (Ministry of Agriculture) also increased the number of combine harvesters to 3,984 units, making it easier for farmers to harvest rice [4].

Energy is one of needed input in agricultural activities. The input consists of fuel, machinery, electricity, seeds, fertilizers, and medicines which have an important role in the supply of energy in agricultural systems both conventional and modern. Energy is a form of analysis that is commonly used to calculate the efficiency of energy use of a production system and also its impact on the environment. The existence of an energy audit so that it can calculate the input and output ratios and energy use patterns. The energy consumption while harvesting rice in Malaysia using a holland type combine harvester requires energy of 1,289 MJ/ha. The rice energy consumption analysis in 6 provinces in Northern Thailand when harvesting with three types of manual rice harvesting. First type requires energy of 341.68 MJ/ha, while harvesting using a machine requires energy of the second type is 3569.5 MJ/ha and type three amounted to 5435.5 MJ/ha [6].

2. Methods

Harvesting using a combine harvester is carried out in Koto Panjang Village, Koto Tangah District, Padang City at the coordinate point 00 51’13.59 "S. Harvesting using sickle and threshing manually is located in Nagari Solok, X Koto Singkarak District, Solok Regency which is at the coordinate point 00 41’24.52 "S. Manual rice harvesting and threshing using power thresher are located in Nagari Maek, Bukik Barisan District, Lima Puluh Kota Regency, located at coordinates 00 51’13.59 "S. Research on the analysis of energy consumption in the process of manually harvesting rice and combine harvester was carried out with 15 paddy plots.

The tools used in this research are the meter, combine harvester, sickle, power thresher, Garmin GPS, Geographic Information System (GIS), digital stopwatch, Garmin Forerunner 35, hanging ballance, Heart Rate Monitor (HRM), Garmin Express Software. The materials used in this research are fuel and grain. Rice harvesting is carried out by farmers whose ages range from 30-45 years. Rice harvesting in this research was carried out by 15 paddy field demonstration plots, 10 demonstration plots were used for manual harvesting where 5 plots were threshed by slamming and 5 plots with power thresher. Five demonstration plots used a combine harvester. The size of rice fields for each demonstration plot is 10 m x 20 m.

This research was conducted by farmers both manually and using a combine harvester. The test is carried out with several stages which include literature study, primary and secondary data collection, processing, data analysis and data presentation.

Primary data is data obtained directly from the field. Primary data in this research are the number of labor (N), time during harvest (hours), time lost (hours), the amount of fuel consumption (L), grain yield obtained (kg), grain moisture content (%), level grain cleanliness (%), and overall total land area (kg). Data collection for research carried out directly in the field when harvesting rice both manually and using a combine harvester. Data collection carried out by taking two data from harvesting manually and using a combine harvester machine. Data with manual harvesting is taken by how much human energy is used by using the Garmin Forunner 35. While harvesting using combine harvester, the observed data are fuel (liters), fuel before and after the harvesting process in the tank (L), the area of land used (ha), human labor needed, time needed to harvest rice (hours) and also the type of machine used. After the data in the field is obtained the energy calculation for each energy is based on the energy conversion table shown in Table 1.

| Material          | Energy Coefficient | Source |
|-------------------|--------------------|--------|
| Combine harvester  | 87,63 MJ/kg        | [7]    |
| Thresher          | 7,524 MJ/h         | [8]    |
| Solar             | 43,3 MJ/L          | [6]    |
| Gasoline          | 39,7 MJ/L          | [6]    |
| Male power        | 1,96 MJ/h          | [7]    |
| Woman Power       | 1,57 MJ/h          | [7]    |

Table 1. Energy Conversion
Based on Table 1, the energy conversion obtained the amount of energy expended during the process of harvesting rice manually and using a combine harvester. In the calculation the input of human energy is divided into two parts, the first is the Garmin Forerunner 35 method and the conversion/approach method. After this method is finished, the two methods are compared and processed using ANOVA test, then the harvesting energy comparison will be obtained manually and using a combine harvester.

2.1 Data Processing and Analysis

The data that has been obtained will be processed, analyzed and presented. The data referred to technical analysis, energy analysis, economic analysis and using one-way t-test to see the comparison of harvesting energy manually and combine harvester.

a. Grain Moisture Content

Measurement of water content can be calculated using the formula:

$$KA = \frac{B_b - B_k}{B_r} \times 100\%$$  \hspace{1cm} (1)

b. Working Speed

The working speed of the machine is obtained from the advanced speed of the harvesting machine using the formula [9]:

$$V = \frac{z}{t}$$  \hspace{1cm} (2)

c. Effective Work Capacity

Effective work capacity of a combine harvester calculated with the formula [9]:

$$KKe = \frac{A}{T}$$  \hspace{1cm} (3)

The effective work capacity using a sickle (manual) can be calculated on the formula [10]:

$$KKE = A : T total : n$$  \hspace{1cm} (4)

d. Theoretical Work Capacity

The theoretical work capacity can be calculated by [9]:

$$KKe = 0,36 \times L \times V$$  \hspace{1cm} (5)

The theoretical work capacity using a sickle (manual) can be calculated on the formula [10]:

$$KKE = A : T efektif : n$$  \hspace{1cm} (6)

e. Harvesting Work Efficiency

Harvesting work efficiency can be calculated using the formula:

$$E = \frac{KKe}{KKe} \times 100\%$$  \hspace{1cm} (7)

f. Lost Turn Time

Lost time can be calculated using a formula [9]:

$$Lo_b = \frac{w_b}{w_1 + w_b} \times 100\%$$  \hspace{1cm} (8)

g. Level Cleanliness

Level cleanliness can be calculated with:

$$Tb = \frac{w_a}{w_t} \times 100\%$$  \hspace{1cm} (9)

2.2 Energy Analysis

a. Engine Energy
A machine that works will release energy. To calculate the energy of an engine it can be calculated with:

\[ EM = \frac{f_{\text{exh}}V}{K_{\text{FE}} \times L} \]  

(10)

b. Fuel Energy
Fuel energy can be calculated using the formula:

\[ FE = \frac{f_{\text{con}} x {p_f}}{A} \]  

(11)

c. Human Energy
Human energy can be calculated using the formula:

\[ HE = \frac{n_s T_{\text{FE}}}{A} \]  

(12)

2.3 Economic Analysis
The value of economic analysis is carried out to determine how much the basic costs of the equipment used include fixed costs and variable costs as well as the work capacity.

a. Basic Cost
Basic costs can be calculated by the formula [11]:

\[ BP = \frac{BT_x + ETT}{KP} \]  

(13)

b. Fixed Cost
The fixed cost can be calculated by the formula [9]:

\[ BT = D + 1 \]  

(14)

The cost of depreciation can be calculated with the formula [9]:

\[ D = \frac{P - S}{N} \]  

(15)

Capital interest can be calculated using the formula [9]:

\[ I = i \left( \frac{P + S}{2} \right) \]  

(16)

c. Variable Cost
Variable costs are also called operating costs. Operating costs are being affected by hours of use in the fields, the cost of repairing and maintaining the equipment. The variable costs can be calculated using the formula [9]:

\[ BTT = PP + Bo + BB + OL \]  

(17)

To get maintenance and repair costs calculated using [9]:

\[ PP = 2\% \frac{(P - S)}{100 \ h} \]  

(18)

Operator costs can be calculated by the formula [9]:

\[ BO = \frac{W_{OF}}{W_{T}} \]  

(19)

Fuel costs can be calculated using the formula [9]:

\[ BB = Q \times H_{bb} \]  

(20)

The cost of oil can be calculated using the formula [9]:

\[ OL = \frac{V_p X H_o}{J_p} \]  

(21)
d. Break-even Point
The break-even point can be calculated by the formula:

\[
BEP = \frac{BT}{(1.1XBP) - \frac{BT}{XP}}
\]  
(22)

2.4 Data Analysis
Data analysis and making conclusion in this research used the SPSS application with ANOVA test consisting of three treatments, each treatment consisting of five replications. The test uses a significance level of 0.05 which is default used in SPSS applications. The statistical test in this analysis consists of two hypotheses:

H₀: The total energy expended in the rice harvesting process for the three treatments has the same variant.
H₁: The total energy expended in the rice harvesting process for the three treatments has different variants.

The conclusion from the analysis of data taken from rejected or accepted H₀ and H₁ in the ANOVA table, with determination if a significant value >0.05 then H₀ is accepted, if a significant value <0.05 then H₀ is rejected.

3. Results and Discussion
The process of harvesting rice in this research was done by using three treatments, the first was harvesting rice using a combine harvester, the second was harvesting using a sickle (manual) then threshing rice in a traditional or known as gebot, the third was harvesting rice sickle (manually) threshing rice using a power thresher.

3.1 Harvesting Rice by Combine Harvesting
Harvesting using a combine harvester is carried out in Koto Panjang Village, Koto Tangah District, Padang City at the coordinate point 00 51'13.59 "S. The land used for research using a combine harvester is five rice fields. The average area of rice fields used for harvesting using a combined harvester is 467 m². The type of soil in paddy fields in the city of Padang is latosol. Rice varieties planted are PB42 with plant spacing of about 30 cm per clump, there are around 16 rice stems, and rice harvesting is done when the rice is 130-140 days old.

3.2 Harvesting with Sickles and Threshing manually
Harvesting using sickle and threshing manually is located in the Nagari area of Solok District X Koto Singkarak Solok Regency which is at the coordinate point 00 41'24.52 "S. The land used for research manually is 5 rice fields, data collection is done in June. The land used for harvesting has an average area of 254 m². Planting distance between clumps is about 30 cm. The average number of stems per grass is 15 stems. The rice variety used is Cisokan. The age of harvesting rice is 100 days, the type of soil in this area is humus.

3.3 Harvesting with Sickles and Threshing with Power Thresher
Manual rice harvesting and threshing using power thresher are located in Nagari Maek area, Bukik Barisan District, Lima Puluh Kota, located at coordinates 00 51'13.59 "S, harvesting is done in July. The average area of rice harvesting is 353 m². Data was collected in July, the rice varieties used were Junjung with a spacing of about 30 cm per stem per rice grove consisting of 17 rice stems. The harvest age for this variety is 120-125 days depending on the weather conditions at the time of harvest, the type of soil in this area is humus.

3.4 Performance Analysis
3.4.1 Grain Moisture Content
Moisture content measurements were carried out for three treatments of rice harvesting. Grain measured is grain that is ready to be harvested 7.96%, manually averaging 20.46%, manual harvesting threshing with power threshers average moisture content is 17.05%. Based on the Indonesian National Standard (SNI) of good grain quality from I-III quality, the maximum moisture content is 14% so that it can be stored for a period of 6 months, called milled dry grain [12]. Harvesting rice uses a combine harvester and manual harvesting that is shed with a power threshers, which has a lower moisture content due to heat from the machine during harvesting. In a combine harvester machine there is a fan that separates rice and straw so that the hot wind generated from the fan will make the value of the moisture content decrease [13]. To get a good storing quality from the grain, drying must be carried out in order to become rice. Significant value of grain moisture content with three small rice harvesting treatments value compared with 0.05 that is equal to $13 \times 10^{-17}$ so that $H_0$ is rejected and $H_1$ is accepted. This shows that the grain moisture content with three harvesting treatments has different variance.

### 3.4.2 Working Speed

Working speed of combine harvester for 5 paddy fields obtained an average of 0.31 m/s or equivalent to 1.116 km/h. The working speed of harvesting using a sickle for treatment B and C has a working speed with an average value of 0.02 m/s. Based on the three treatments that have been carried out the working speed using a combine harvester is higher than the speed of harvesting with a sickle, this is due to the time required for one track is less than manual harvesting. Working speed is affected by the length of the track, the length of time required for one track, the agility of the operator and farmer equipment and the state of the land [9]. Based on ANOVA analysis the working speed with three harvesting treatments obtained a small significant value compared with 0.05 which is $4.07 \times 10^{-8}$ so that $H_0$ is rejected and $H_1$ is accepted. This shows the value of working speed of grain harvesting with three treatments have different variants.

### 3.4.3 Effective field capacity

The effective work capacity is obtained from the actual work of each repetition in the field [9]. The results obtained from the research when compared with the literature the results are almost same because the specifics of the DC 35 combined harvester work capacity is 0.1-0.3 ha/h (PT. Kubota Indonesia). The value of the effective work capacity of manual harvest both threshing with gebot and with power threshers obtained an average of 0.02 ha/h. This value is greater when compared with the research that has been done by Ikhsan, where the effective work capacity is 0.01 ha/h [14]. Effective work capacity is effected by the area of land and the length of time spent during harvesting. Asymmetrical land shape and large land size as a result the time spent on operating is also increasing and the value of effective work capacity will be higher. The effective capacity loss is caused by lost time, time out of operation and operate the machine less than the working width of the machine [15]. The cause of the value of effective working speed is different is time (turning time, running time). Significant value of effective working speed with three treatments of small rice harvesting compared with 0.05 that is equal to $5.08 \times 10^{-7}$ so that $H_0$ is rejected and $H_1$ is accepted.

### 3.4.4 Theoretical field capacity

The working speed is greater than the theoretical capacity will also be greater [16]. The theoretical work capacity average using a combine harvester is 0.17 ha/h. The theoretical work capacity of combining harvester is higher than the others because it is effected by the working speed and harvesting width. Treatment B and C have a theoretical work capacity of 0.02 ha/h. The results of his research for an average theoretical work capacity is 0.017 ha/h [17]. Manual harvesting and threshing with power threshers have a similar time span to manual harvesting. In terms of labor also consists of three people to harvest in treatments B and C. Significant value of the theoretical work capacity with three treatments of harvesting rice small compared with 0.05 that is equal to $8.96 \times 10^{-8}$ so that $H_0$ is rejected and $H_1$ is accepted. This shows the value of theoretical work speed with three treatments of harvesting that have different variants.
3.4.5 Harvesting Efficiency

Efficiency of rice harvesting is obtained from the ratio of effective work speed and theoretical work speed. Theoretical work speed is affected by the length of the land side, the longer the land side, the higher the work efficiency will be [10]. The average efficiency for harvesting using a combine harvester is 91.13%. Research of harvesting that using a combine harvester obtained 61.91% - 79.90% [10]. The difference in value that has been done is due to the operator's expertise, the area of land used and the time during harvesting. The efficiency of manual rice harvesting is low at 70.65% due to the time needed to harvest one rice field longer than combine harvester, then the labor required is also more. The value of manual efficiency is due to the total time and effective time of harvest, the ineffective time is obtained from the farmer’s rest time and sickle sharpening time [10]. Efficiency rice threshing with power thresher is 79.97%, the value is higher than manual harvesting because when threshing rice takes less time and energy compared to manual. Significant value of efficiency with three treatments harvesting rice small compared with 0.05 that is equal to 1.3×10^{-13} so that H_0 is rejected and H_1 is accepted. This shows the value of harvest efficiency with the three harvest treatments have different variants.

3.4.6 Lost Turn Time

The total time lost when turning is obtained from the turn time when using the combine harvester at each lane, the time for refueling, the equipment setting, the time to adjust the tool, and the time for the farmer to rest. The time lost when harvesting rice with three treatments has values respectively 16.31%, 1.17%, 0.73%. The lost turn time using a combine harvester is higher than the other treatments. When operating the combine harvester it takes about 10-15 seconds to turn to the next track, while manually it only takes 3-5 seconds to turn to the next track. The percentage of turning time is caused by the operator's expertise in operating the equipment, land conditions and the weight of the equipment used [9]. Significant value of harvest efficiency with three treatments harvesting rice small compared with 0.05 that is equal to 3.02×10^{-9} so that H_0 is rejected and H_1 is accepted. This shows the value of harvest efficiency with the three harvest treatments have different variants.

3.4.7 Level Cleanliness

Grain that tested is one kg that is cleaned by aerated. Besides removing post-harvesting dirt, it also separates empty grain. After aerating the grain, it will be weighed again so that it can be known the total net harvesting results. The level of cleanliness by combine harvester averaged 97.20% in other words the level of cleanliness was above 95%, so there was no need to clean the grain after that. The low rate of yield loss using a combine harvester is caused by the entire harvesting process being carried out one-time process starting from cutting to one stage combining [18]. Manual harvesting obtained an average of 89.4%, at the time of manual harvesting there are still some such as rice stalks or empty grain that is still mixed together with the grain so that the grain must be cleaned again in order to get quality grain results. Threshing using power thresher on average is 94.4% because the power thresher machine has been separated directly between grain and dirt, a significant value of cleanliness level of harvesting with three treatments of harvesting small rice compared with 0.05 that is equal to 2.96×10^{-8} so H_0 is rejected and H_1 is accepted. This shows the value of the level of cleanliness of harvesting with three harvesting treatments have different variants.

3.5 Energy Analysis

3.5.1 Engine Energy

The type of machine used for harvesting is two different treatments that is harvesting using combine harvester and power thresher. The engine energy obtained using a combine harvester is on average 151.64 MJ/ha. Manual threshing harvesting with power thresher is 7.92 MJ/ha. The difference in value is due to the size of the combine harvester machine used is greater than the power thresher. Energy consumption of rice harvesting machines in Mazandaran Province, Iran for three methododative cultivars, high yield cultivars and hybrid cultivars respectively is 347,985 MJ/ha, 390,621 MJ/ha,
432,003 MJ/ha [19]. A rice harvesting by combine harvester type 195HP machine consumes engine energy during harvesting of 4431 MJ/ha [20].

3.5.2 Fuel Energy
The process of harvesting rice using a combine harvester and threshing with power thresher requires fuel to drive the device. The fuel that combine harvester needed is diesel, while power thresher is gasoline. The fuel consumption is obtained by knowing the amount of fuel spent during the harvesting process. Fuel consumption during the harvesting process is effected by several factors such as soil type and structure, land conditions, land shape and size, varieties of plants harvested, and the ability of operators [21]. When the weather is good the fuel consumption is less than the bad weather. The fuel consumption using a combine harvester is higher compared to the power thresher. The average value for 5 plots of paddy fields using combine harvester is 1381.53 MJ/ha. The area of paddy fields for harvesting uses a combined harvester of 467 m². Thresher with power thresher fuel consumed an average of 752.73 MJ/ha. The difference of fuel consumption with the two treatments is caused by the area of paddy fields being harvested, the more extensive the paddy fields, the higher the fuel consumption will be, causing the energy value to be higher. If the area of land harvested is small, it will cause energy consumption in the fuel will be less.

The amount or the amount of fuel energy consumption depends on the amount of fuel used [22]. The fuel energy consumption in rice harvesting in Thailand is 400.06 MJ/ha [20]. The fuel consumption is effected by several factors including vehicles, environment, drivers and road conditions [23]. Vehicle factors can be seen from the cylinder volume, weight, size and type of tire. Factors of the environment are on the road slope, direction, hardness, wind speed, roughness and type of land. Traffic conditions can be seen from the speed of work, slip times and changes in speed. The greater the power of an engine, the greater the fuel consumption.

3.5.3 Human Energy
Analysis of energy consumption in humans is done in two ways through table conversion and using Garmin Forerunner 35. Conversion tables obtained from the literature published in the literature, human energy calculations with Garmin Forerunner 35 obtained directly from the device provided with the Heart Rate Monitor. Human energy consumption for triples in a row with the conversion table obtained 12.94 MJ/ha, 92.10 MJ/ha, 87.76 MJ/ha. The tool used when research was the Garmin Forerunner 35 for the three value human energy at 18.9 9 MJ/ha, 104.40 MJ/ha, 95.81 MJ/ha. Based on these three preparations, the lowest consumption in harvesting is required by combine harvester because of the time required and the amount of labor required.

According to a research in Iran, energy consumption in rice harvesting uses traditional energy for three native cultivar methods, high yield cultivar and hybrid cultivars respectively are 236.73 MJ/ha, 284.87 MJ/ha, 296.33 MJ/ha, while harvesting uses three engines this method consumes human energy as a whole 20.58 MJ/ha, 24.22 MJ/ha, 27.30 MJ/ha [19]. Rice harvesting in Thailand using a combine harvester machine consumes human energy of 16 MJ/ha [20].

Harvesting uses a combine harvester need the less time, labor needed by two people, one carrier as an operator and another as a helper makes the use of combining harvesters more efficient to do rice harvesting. The value of energy consumption in the manual is greater because the time spent more and the labor needed is three people. When threshing, farmers need more to move threshing tools from one place to another in the fields. While manual harvesting uses thresher power, it consumes the second least energy combining harvesters. The process of threshing rice is carried out at one point, farmers transporting rice harvested from rice fields in the sense that farmers do not need to move threshing tools such as manual threshing. However, the energy required is also very large requires energy and time to plant rice in the threshing power.

3.5.4 Total Energy Consumption
The input total energy requirements of each process of harvesting rice are for three treatments in general including engine energy, fuel, and human consumption. The amount of energy expenditure during work activities is effected by several factors including how to carry out work, work attitude,
environmental conditions where we work and working speed [24]. The highest total energy was in treatment A of 1522.16 MJ/ha, treatment B 104.50 MJ/ha, treatment C 856.46 MJ/ha. The highest energy consumption is in the engine fuel combining harvester and power threshing and then followed by engine energy. Total energy in the rice harvesting process is around 32% of the total rice production process [20]. Human energy spent when using a combine harvester is smaller than the other two treatments, because using a combine harvester the harvesting is done in one stage. Human energy consumption using power thresher is smaller than the manual harvesting process, because during the threshing of rice the farmers do not need much power because there is already a power thresher. The excess power thresher from the gebot is to save energy and time during threshing, reduce yield losses, the working capacity of the tool is 75-100 kg/hour [25]. A statement added that the use of a pedal thresher also suppresses loss of results [26]. The cause of human energy consumption is greater in this harvest because all processes ranging from cutting to grain into sacks require the workforce of more than two people who spend quite a long time.

3.6 Data Analysis
Based on ANOVA analysis, shows a small significance compared with 0.05 of 1.7×10⁻¹⁵, then H₀ is rejected and H₁ is accepted. The total energy expended in the rice harvesting process for three treatments has different variants with each other in different subsets.

3.7 Yield
Grain that produced during the harvesting process with three treatments, the average grain productivity obtained ranges from 7000-8000 kg/ha. Big or small rice productivity per land depends on the state and fertility of the rice. The better the quality and management of the land, the grain produced will also be greater, and vice versa if the management of paddy fields is not good, the results obtained will also be less. Manually threshing in this study uses gebot which results in some grain being thrown out when the rice stalks are slammed, this is also in accordance with [25] statement, threshing rice with being stepped on feet causes a yield loss of 7.48% which is lower than being slashed the yield loss rate is 9-13%.

3.8 Economic Analysis
The cost of depreciating of a combined harvester for 5 years is IDR 49,500,000, with an initial price of IDR 275,000,000, capital interest is IDR 9,705,000 with a percentage of 6%. The fixed cost of combine harvester is IDR 58,575,000. Variable costs for 5 plots of rice fields averaged IDR 73,666. The basic cost is IDR 818,967. In the BEP analysis the value is 156,718 ha/year means that the return of capital for all operating costs for one year if the combine harvester can work optimally on an area of 156,718 ha/year.

4. Conclusion
Technical analysis with harvesting using combine harvester for an average land area 467 m² has a working speed 0.31 m/s, moisture content is 17.96%, effective work capacity is 0.16 ha/h, theoretical work capacity is 0.17 ha/h with an efficiency 91.13% the level of cleanliness is 97.20%. Manual harvesting averaged land area of 254 m², working speed of 0.02 m/s, moisture content is 20.46%, effective work capacity of 0.02 ha/h, theoretical work capacity of 0.02 ha/h with efficiency 70.65%, the level of cleanliness is 89.4%. The third harvest is manual harvesting by threshing with power threshing an average land is 467 m², working speed of 0.02 m/s, moisture content 17.05%, effective work capacity is 0.02 ha/h, theoretical work capacity is 0.02 ha/h with an efficiency is 79.97% the level of cleanliness is 94.4%.

The total energy harvesting of rice using combine harvester, energy consumption of engine, fuel, and human respectively is 151.64 MJ/ha, 1381.53 MJ/ha, 18.95 MJ/ha with a total energy consumption is 1552.16 MJ/ha. Manual rice harvesting consumes human energy at 104.40 MJ/ha. Manual harvesting of rice is threshed with power thresher energy consumption of engines, fuels and
humans respectively 7.92 MJ/ha, 752.73 MJ/ha, 95.81 MJ/ha with a total energy consumption of 856.46 MJ/ha.

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