Reviewer 1

Some comments to improve this manuscript quality are

Question	Answer
1. Tittle and Abstract . It would be better to add word of "West Sumatera Province' in the tittle rather than West Sumatera only. While, in abstract. I believed that the authors should add a brief of problem statement to complete all elements of abstract . The sentences in L8-10, actually did not mentioned the problem statement.	Thank you for your suggestion, we have been changed the tittle to be “Energy Audit of Rice Production In West Sumatra Province Indonesia”. We also added problem statement in L20-23.
2. Introduction. I believed this current form of introduction did not clearly specify the actual problem or justification or reasons that make the authors conduct this study. Therefore, I suggest to find the knowledge gap that they willing to fill-in through this study. The author must focus more on the problem in West Sumatra Province for the introduction of this study, since the authors use that region as location of study. The current problem statement seems too general and has no link with the objectives of study.	We have added statistical data to supporting and description our focus problem at West Sumatera Province. It shown in L51-56.
3. Research Methods. Lacking of crucial information regarding energy equivalent (MJ/unit) of inputs. In this section, the authors should show the information or references regarding all the energy equivalent for energy inputs. I suggest the authors to make a special table regarding to the energy equivalent of inputs. Many others important information for energy research are also not presented by the authors. For example, data collection periods, wheatear data, topography areas, rice cropping systems (from tillage to harvesting), technical parameters of machines (specification, machine age, annual use) are also not stated. The quantity and name of inputs (for example. active ingredient of pesticides and herbicides) which are key data for such study are also not showed. I suggest the authors to present all these data and information in respective tables in Research Methods so that the readers understand in what conditions this study conducted. All the information can not be left. It is also necessary to explain how the model be produced. What is	In sub-chapter engine energy, we added information like weight of machinery and economic life machinery (L145-148). Then, in seed energy we explained about seed that used In this research and rice characteristic (L177-180). For pesticides energy described in L189-190. Information about fertilizer which used described in sub-bab fertilizer energy in L202. For energy equivalent we have been written in Table 1 (L229).

statistical analysis that the authors employed to develop the model. Thus, I can summarize that the research methods in this manuscript is not completely stated.	
4. Overall, results and discussions are sufficient to describe the achievement of this study objectives. However, I suggest the authors state deeper discussions regarding the results. For example, deeper discussions why the results obtained in the study are either lower or higher when compared to other regions or countries. These things are important to be highlighted for standing out the specialty or novelty of energy use at the study area with others regions or countries.	It has been described i.e in sub-bab engine energy L249-258, in Fuel energy L266-283, in human energy L303-316, L326-329.
5. Conclusions. In the conclusions section, I suggest the authors to describe their limitations of the study as the results or the findings that they had from this study. I also suggest the authors to state the recommendation for the further study.	As your suggestion, we have been added parameters of limitations in our research as information for reader in L554-558. For further study we are suggesting as like in L563-567

Reviewer 2

: (i) it maybe still needed to proof-read the English	
(ii) there was no scientific justifications in introduction part related to the main problems (reasons), why this study should be conducted?,	It has been described in L51-89.
, (iii) in the study objective, authors stated that there were two analysis were done, i.e.; total energy consumtion (energy inputs analysis) and economic analysis, but we couldn't not find methodology for calculating economic analysis,	We are very sorry for our mistake written economic analysis but in this research is not included. Now, we have been deleted its.
(iv) there was no follow-up discussion or analysis related energy output (EO), maybe authors can use EO for determining energy ratio or energy efficiency. As suggestion, for calcultaing EO, not only just from main product (rice) but we can also calculate its by product,	In this research, we are only using rice as product for calculating EO, it's because only rice in this area that selling by the farmers, while straw of paddy is not selling or making to be product which having economic value (i.e making to be feed or fertilizer to commercializing).
(v) what were the justifications related to linear modelling between crop productivity and EI parameters, is it true?. Finally, what were the recommendations for government.	Yes, it is true. We're recommended to the government for using this model and keep watching any parameters that suggesting can reduced production (in L544-548).

Re: FR-CAFEI-019.R1

Food Research <foodresearch.my@outlook.com>
Sat 9/19/2020 9:45 AM
To: Renny Eka Putri <rennyekaputri@ae.unand.ac.id>

1 attachments (463 KB)
FR-CAFEi-019.docx;

Dear Dr Renny,

Manuscript ID: FR-CAFEI-019.R1
Manuscript Title: Energy consumption and economic analysis of rice production in West Sumatra Indonesia

Before we can proceed with the article production, I would like to clarify a few points that I have commented in the manuscript. Please refer to the attachment. Please address the issues raised in the comments.

Please also check your manuscript again for English language proficiency. There are many incorrect tenses and wrong format of writing.

Please use the attached copy to make your revisions as it has been corrected to the Journal's format. Once you have done, kindly revert the copy to me as soon as possible. Please note the faster you respond, the quicker we will process your manuscript.

Thanks & Regards,
Vivian New
Editor
Food Research

From: Renny Eka Putri <rennyekaputri@ae.unand.ac.id>
Sent: Sunday, 2 August, 2020 1:17 PM
To: Food Research <foodresearch.my@outlook.com>
Subject: Re: FR-CAFEI-019.R1 - Decision on your manuscript

Dear Editor

I submit my second correction (attach file).

Thank you.

Renny Eka Putri, Ph.D

Department of Agricultural Engineering
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From: Food Research <foodresearch.my@outlook.com>
Sent: Friday, July 10, 2020 7:30 PM
To: Renny Eka Putri <rennyekaputri@ae.unand.ac.id>
Subject: FR-CAFEI-019.R1 - Decision on your manuscript

Dear Dr Renny,

Manuscript ID: FR-CAFEI-019.R1
Manuscript Title: Energy consumption and economic analysis of rice production in West Sumatra Indonesia

Your manuscript which you submitted to Food Research journal, has been reviewed. The comments of the reviewers are available at the bottom of this email.

Publication is recommended, subject to some minor revision to your manuscript. Therefore, I invite you to respond to the comments and proceed with revision.

Please submit your revised manuscript within one (1) month of this date of email. Respond to the reviewer(s)' comments by commenting in your revised manuscript and click 'Track Changes'.

I look forward to receiving your revision.

Sincerely,
Dr Vivian New
Editor
Food Research

Reviewers' Comment:
Reviewer 1
Just my suggestions for making clear this manuscript; (i) please state/write the assumption that for determining energy output (EO) just considering from main product i.e. rice (case study in West Sumatera), (ii) please give some references that related to crop productivity trend is linear, because crop productivity similar to crop growth model --> non linear trend.

Reviewer 2
Generally the authors have made efforts in improving this manuscript. However I noted that some parts in the manuscript did not addressed accordingly by the athors and yet need the revisions. My comments are as follow: Firstly, I suggest the authors use the all data of energy equivalent (Table 1) from the previous research articles that are listed in the database SCOPUS or WOS, which are the largest citation database of peer-reviewed literature. By citing the past articles came from recognized citation data bases like SCOPUS and WOS, it guarantees the high validity of the study. But, in this manuscript, I found many references in Table 1 are not taken from papers in SCOPUS or WOS databases. Secondly, the authors still did not include the amount inputs that the farmer used in a hectare in the study area. I did not find these data in Table 1. Actually, the structure standard of writing the table for energy (Table 1) should be in the form : Column 1 (Input). Column 2 (Unit), Column 3 (Amount of input used per ha in the study area), Column 4 (energy equivalent in MJ/unit), Column 5 (Energy equivalent in MJ/ha). And, the athors should mention amount of each input per hectare (for example: how many labor was used in

the study area, how much NPK fertilizer used by the farmers in the study area as well as pesticide or verbicides, fuel of tractor). These should be listed in the table 1. But in the manuscript, The authors did not state the items clearly. In Table 1, Column 2 (Value) mentioned the energy equivalent, not the amount of input per ha applied by the farmers during rice cultivation.

Reviewer	Suggestions	Answers
Reviewer 1	1. Please state/write the assumption that for determining energy output (EO) just considering from main product i.e. rice (case study in West Sumatera), 2. Please give some references that related to crop productivity trend is linear, because crop productivity similar to crop growth model --> nonlinear trend.	1. The total output energy is only fill based on mass of rice production in hectare. The output energy shall increase by the mass rice production (linear correlation). 2. We have added the state that crop productivity trend is linier in line 500 to 502.
Reviewer 2	1. I suggest the authors use the all data of energy equivalent (Table 1) from the previous research articles that are listed in the database SCOPUS or WOS, which are the largest citation database of peer-reviewed literature. By citing the past articles came from recognized citation data bases like SCOPUS and WOS, it guarantees the high validity of the study. But, in this manuscript, I found many references in Table 1 are not taken from papers in SCOPUS or WOS databases. 2. The authors still did not include the amount inputs that the farmer used in a hectare in the study area. I did not find these data in Table 1. Actually, the structure standard of writing the table for energy (Table 1) should be in the form: Column 1 (Input). Column 2 (Unit), Column 3 (Amount of input used per ha in the study area), Column 4 (energy equivalent in MJ/unit), Column 5 (Energy equivalent in MJ/ha). And, the athors should mention amount of each input per hectare (for example: how many labor was used in the study area, how much NPK fertilizer used by the farmers in the study area as well as pesticide or herbicides, fuel of tractor). These should be listed in the table 1. But in	1. We had change our citation in Table 1 to any literature which are indexed by SCOPUS

	the manuscript, The authors did not state the items clearly. In Table 1, Column 2 (Value) mentioned the energy equivalent, not the amount of input per ha applied by the farmers during rice cultivation.	

Energy Audit of Rice Production in West Sumatra Province Indonesia

[1]Renny, E.P., [2]Lubis, M.I.A., [1]Andasuryani, [1]Hasan, A., [1]Santosa and [1]Arlius, F.

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Audit energy is an appropriate method to determine the energy consumption expended in each agricultural cultivation activity, thereby reducing the wasteful use of energy. Energy consumption in rice cultivations consists of humans, fuel, machinery, seed, fertilizer, and pesticides. The objective of the study was to analyze the total energy consumptions in the form of an energy audit activity on lowland rice cultivation in West Sumatera Indonesia. It is important to do, because of much energy input excessed, but less on productivity. So, by using analysis energy expenditure, productivity can be optimized with fixed input energy the costs could be minimized. Energy inputs were measured during all operating activities in rice cultivation (seeding, tillage, planting, fertilizing, spraying, weeding, and harvesting). Energy input analysis based on energy sources used was divided into six parameters, namely: engine energy, fuel, humans, seeds, chemicals (pesticides), and fertilizer energy. The result showed the average of the total energy inputs in this study was 16,816,612 MJ/ha distributed to human, fuel, machinery, seeds, fertilizers, and pesticides energy respectively 216.39; 890.75; 60.02; 983.29; 14,207.54; and 458.60 MJ/ha. Production costs incurred in rice cultivation activities in this study were IDR 13,107,562/ha. Finally, the rice yield prediction model based on the input energy are $Y_1 = 4786.560 - 28.286X_1 + 36.226X_2 - 24.727X_3 - 8.426X_4 + 0.057X_5 - 0.803X_6$ and $Y_2 = 3605.110 + 5.443X_2$. The data of total energy were needed as a recommendation for the government to balance energy input and output on rice cultivations.

Keywords: Audit Energy; Energy Input-Output; Energy Analysis; Rice Cultivations

INTRODUCTION

Rice is a cereal crop grown and consumed on every continent of the world because of its adaptive capabilities which enable it to grow in areas with different soil types and climatic conditions. According to the Central Statistics Agency Indonesia (BPS, 2018), nthe number of Indonesians aged 15 years old and over who work in the agricultural sector in 2017 is 35,923,886 people, equivalent to 29.68% of the total population of Indonesia. This indicates that agriculture is the highest source of livelihood in Indonesia.

BPS (2017) informed that the area of paddy land in Indonesia in 2015 was 8,087,393 ha with production and productivity in 2015 were 75,397,841 tons and 5.34 tons/ha, respectively. This proves that rice has become a priority, especially in Indonesia. One of the provinces that contribute to rice production and rice production as a staple food for the people in West Sumatera. BPS of West Sumatera (2018) reported that yield areas (507,545 to be 491,875.7 hectares), production (2,550,609 to be, 503,452 tons), and productivity (50.25 to

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be 50.09 tons/hectares) for paddy decreased in 2015 to 2016. Based on this case, important to do an effort to solving decreased rice production. An effort to increase rice production by implementing sustainable agriculture is a solution that must be implemented so that food imports do not increase as well as a means of achieving self-sufficiency, sovereignty, and food security. The real effort that can be implemented is to overcome the problem of land conversion by adding, maintaining, and establishing sustainable agricultural land. Sustainable agricultural land itself is divided into areas (agriculture and agricultural allotment), the stretch of land (irrigated, reclaimed, and non-irrigated), and land for sustainable agricultural reserves (Suswono, 2012). Efforts to achieve sustainable agriculture are implemented by implementing management of increased production that can reduce production costs, labor efficiency, and other input factors, and protect the environment (Piringer and Steinberg, 2006). Input factors are energy sources that have a sale value (cost) that is used both during the production, drying, packaging, storage, and transportation processes (Zangeneh, Omid and Akram, 2010).

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Purwantana (2011) said that the effort to increase energy efficiency in rice production is by carrying out calculations or studies of energy needs. This effort includes scheduling activities, estimating the time of each activity, the number of labor, the number of agricultural tools and machinery, as well as all facilities used (seeds, fertilizers, medicines, etc.). Energy analysis can be done by recording all activities, starting from fuel consumption and time spent on each activity.

Energy audits have been applied to previous studies on several agricultural commodities, including potatoes in Hamadan-Iran Province (Zangeneh *et al*., 2010), cucumbers in Iran (Mohammadi and Omid, 2010), tomatoes in Turkey (Ozkan, Ceylan and Kizilay, 2011), rice in Malaysia (Bockari-Gevao *et al*., 2005 and Muazu *et al*., 2015), rice in low land paddy cultivation (Lubis *et al*., 2019), rice planting using rice transplanter (Putri, 2020a), and combine harvester (2020b). Research on the efficiency of energy use and economic analysis of several agricultural crops has been carried out (Muazu et al., 2015). Economic analysis is expected to be able to calculate the costs incurred during rice cultivation activities. So that in the future it can be known technical rice cultivation with the production of energy inputs (power sources incurred costs) and optimum costs. Rahmat (2015) explained that energy audits are evaluation activities of energy utilization and analysis of savings opportunities on energy use as well as recommendations to improve the efficiency of energy use itself.

The objective of the study is to analyze total energy consumptions in the form of an energy audit activity on lowland rice cultivation in West Sumatera Indonesia and to explore the prediction model of yield on rice cultivation based on the energy input. Energy inputs are measured during all operating activities in rice cultivation (seeding, tillage, planting, fertilizing, spraying, weeding, and harvesting).

Materials and methods

This research was conducted in 15 paddy fields from farmers and different implementation times. This research was carried out on paddy fields in Nagari Sungai Abang, Lubuk Alung Subdistrict located at coordinates $0°40'43{,}80'' - 0°40'36{,}45''$ latitude and $100°16'37{,}11'' - 100°16'46{,}57''$ longitude. Diagram of the process flow, equipment, and energy input for rice cultivation can be seen in Figure 1.

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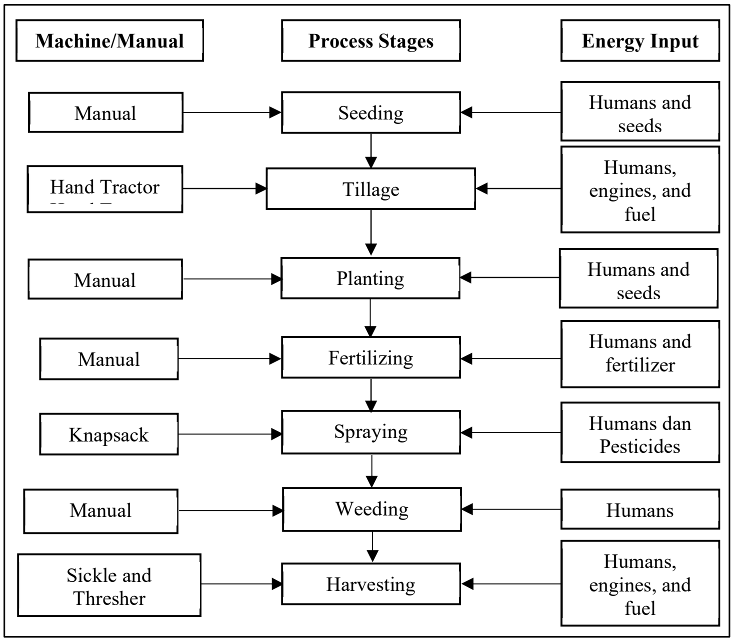

Figure 1. Flow Chart of Process, Equipment and Energy Input of Rice Cultivation

ENERGY ANALYSIS

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a. Engine Energy

The agricultural machinery used in rice cultivation in this research included hand tractors and threshers. Every machine that works certainly releases energy. Energy calculation for each machine is done by completing some data obtained in the field and can be calculated using the following equation (Muazu *et al.*, 2015):

$$ME = \frac{C_{f.m}\ x\ w}{F_c\ x\ N} \quad \text{.......} \quad (1)$$

For Fc, it can be solved by using the following equation (Santosa, 2008):

$$F_c = \frac{A}{t} \quad \text{.......} \quad (2)$$

where:

ME = engine energy (MJ/ha)

$C_{f.m}$ = energy conversion factor for machinery used (MJ/kg), show in Table 1

w = weight of machinery (kg), about 355,8 kg for hand-tractor and 48 kg for thresher

N = economic life of machinery (h), assumed 12,000 hours for hand-tractor and 4,000 hours for thresher

F_c = effective field capacity (ha/h)

A = size of the farm (ha)

t = effective working time (h)

During the rice cultivation activity takes place, the machine working time in the field is an effective time. Effective time is the difference between the total time total to the time lost (when turning, due to slipping, due to rest, due to the adjustment of tools, etc.). Furthermore, effective working time can be formulated as follows:

$$t = t_s - t_h \quad (3)$$

where:

t_s = total total time (h)

t_h = time lost (h)

b. Fuel Energy

Fuel energy can be calculated using the following calculations (Muazu *et al*., 2015):

$$FE = \frac{F_{con} \times C_{f.f}}{A} \quad (4)$$

where:

FE = fuel energy (MJ/ha)

F_{con} = fuel consumed (L)

$C_{f.f}$ = fuel energy conversion factor (MJ/L), shown in table 1

A = size of the farm (ha)

c. Human Energy

Measurement of the amount of energy expended by energy farmers is measured directly (real-time) using Garmin Forerunner 35 and heart rate monitor (HRM) (Figure 2).

Figure 2. Garmin *Forerunner* 35 (left) and *Heart Rate Monitor* (right)

d. Seed Energy

Paddy seed which used in this research is "Anak Daro" variety. It used because of this variety usually cultivated by the farmers at West Sumatera and all of the people at that Province only consumed rice with characteristic "Badarai/Scattered" after cooked. In general, rice seed energy can be calculated using the following equation (Muazu *et al*., 2015):

Commented [G7]: Please edit. The sentence is incomplete.

$$SE = \frac{S_w \times C_{f.s}}{A} \quad (6)$$

where:

SE = seed energy (MJ/ha)

S_w = weight of seeds used (kg)

$C_{f.s}$ = seed energy conversion factor (MJ/kg), shown in table 1

A = size of the farm (ha)

e. Pesticides Energy

The pesticides that used in this research is liquid pesticides by Syngenta's product, with types are insecticides and fungicides. Pesticides energy used can be calculated using the following equation (Muazu *et al*., 2015):

$PE = \frac{P_w \times C_{f.p}}{A}$ .... (7)

where:

PE = pesticides energy (MJ/ha)
P_w = weight of pesticides used (kg)
$C_{f.p}$ = pesticides energy conversion factor (MJ/kg), shown in table 1
A = size of the farm (ha)

f. Fertilizer Energy

The fertilizer that used with branding name is Urea, Phonska, and SP36. The amount of fertilizer energy given to plants can be calculated using the following equation (Muazu *et al*., 2015):

$FTE = \frac{FT_w \times (\sum_{i=1}^{n} FT_i \times C_{f.ft})}{A}$ .... (8)

where:

FTE = fertilizer energy (MJ/ha)
FT_w = weight of fertilizer used (kg)
FT_i = percent composition of i^{th} element (decimal)
$C_{f.ft}$ = fertilizer energy conversion factor (MJ/kg), shown in Table 1
A = size of the farm (ha)

g. Total Input Energy

The total input energy is the total amount of energy used. The general form of the equation used to calculate the total input energy is as follows (Muazu, 2015):

$TE_i = ME + FE + HE + SE + PE + FTE$ .... (9)

where:

TE_i = total input energy (MJ/ha)
ME, FE, HE, SE, PE, and FTE are following the previous explanation above.

h. Total Output Energy

The total energy produced from rice cultivation can be seen from the rice production produced. The total output energy is only fill based on mass of rice production in a hectare. The output energy shall increase by the mass rice production (linear correlation). The equation used to calculate the total output energy produced is as follows (Muazu, 2015):

$TE_o = Y_p \times C_f$ .... (10)

where:

TE_o = total output energy produced (MJ/ha)
Y_p = harvested rice production (kg/ha)
C_f = conversion factor used (MJ/kg)

Table 1. Energy Equivalent (MJ/Unit)

Type of Energy	Value	Unit	References
Machinery	93.61	kg	Muazu (2015)
Fuel (Diesel)	47.8	Liter	Cherati *et al*. (2011)
Paddy Seed	16.74	Kg	Muazu (2015)
Pesticides:			
Herbicides	238	kg	Cherati *et al*. (2011)
Fungicides	216	kg	Cherati *et al*. (2011)

Insecticides	101.2	kg	Zangeneh *et al*. (2010)
Fertilizer:			
Nitrogen (N)	60.6	kg	Cherati *et al*. (2011)
Phosphorus (P)	11.93	kg	Cherati *et al*. (2011)
Potassium (K)	11.15	kg	Zangeneh *et al*. (2010)
Sulfur (S)	9.23	kg	FAO (2001)
Zincum (Zn)	5.3	kg	FAO (2001)

RESULT AND DISCUSSION

ENERGY ANALYSIS

a. Engine Energy

The engine energy is distributed inland processing and harvesting activities. The total average energy of the machine was 60,020 MJ/ha, based on the operation was 56,347 MJ/ha in tillage activities and 3,673 MJ/ha in harvesting activities. The distribution of the level of use of the machine in this study was 0.661 kg/ha. This is different from research in Malaysia, where mechanical energy is distributed in every operational activity, namely tillage, seeding, fertilizing, spraying, harvesting, and weeding with a total energy of 477,780 MJ/ha (Muazu, 2015). In contrast to the use of engines in China 14.62 kg/ha (Dazhong dan Pimentel, 1984), India 4,33 kg/ha (Chauhan *et al*., 2006), USA 38 kg/ha (Pimentel, 2009), Philipina 4,03 kg/ha (Mendoza, 2015), and Malaysia 5,74 kg/ha (Muazu, 2015). Respectively 22, 6, 57, 6, and 9 times, compared with the level of machine used in this study. This is due to differences in the types of agricultural equipment and machinery used and in each cultivation activity between this study and previous research.

The value of machine energy spent on land management and harvesting activities is influenced by working time and land area. The mechanical energy in soil processing activities has a greater value than machine energy at harvest. This is influenced by working time, conversion factors, and the mass of agricultural equipment and machinery used, where energy is directly proportional to the three parameters. Apart from these three factors in the tillage, there are two times the use of agricultural machinery (tractors). This is due to the condition of the soil being harder and drier and more weeds, so it requires longer time, as Muazu's (2015) statement explained that the energy expended during tillage is influenced by soil type, moisture content, and protective vegetation.

b. Fuel Energy

The analysis of fuel energy used by farmers in this study was recorded in two activities, similar to the analysis of engine energy. The average of total fuel energy input released in this study was 890,757 MJ/ha. This shows that the energy input in this study was 79.43% lower than the research in Northern Thailand (Chaichana *et al.*, 2008), 67,22% (Bockari-gevao *et al.*, 2005) and 68,51% (Muazu *et al.*, 2015) lower than rice research in Malaysia, 66,94% (Chauhan *et al.*, 2006) and 59,85% (Mendoza, 2015) lower than research in India and the Philippines. Some things that can cause differences in the value of this energy input are the type of soil, the area of land cultivated, and the machine used. As explained by Muazu (2015), the texture and condition of the cultivated land are one of the determinants of the time spent, where the greater the work time spent, the amount of fuel used will increase. In addition, another factor is the area of land, where the greater the area of land cultivated will result in a decrease in the value of fuel energy (according to equation 4). Each engine has different specifications so that the consumption of spent fuel will also be different. Apart from the type/specification of the engine, the other determining factors for fuel consumption are engine life and maintenance.

The highest value of fuel energy is found in soil processing activities. This is due to the distribution of fuel energy in tillage there are two activities, namely first and second tillage. Tillage activities on land 10 emit the largest fuel energy, which is 753,035 MJ/ha and the lowest is found in land 8 of 419,522 MJ/ha. A big or small amount of energy spent on land treatment activities is influenced by the volume of fuel used and the area of land worked on. The volume of fuel used is identic to the soil water content and compactness/soil density (Muazu, 2015) which will affect the length of work, where the longer the tillage time, the greater the fuel spent.

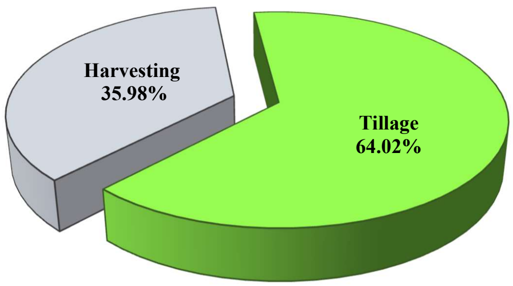

Figure 3. Fuel Energy Analysis

The fuel energy recorded in the land processing activities was 64.02% (570,223 MJ/ha) of the total fuel energy, as well as being the largest energy in the distribution of fuel energy. Furthermore, the distribution of fuel energy is found in the harvesting activities of 35.98% or equivalent to 320,534 MJ/ha (Figure 3). Cherati, Bahrami, and Asakereh (2011) and Khan *et al.*, (2010) explained the same thing in rice research in Iran and Australia, which obtained the largest distribution of fuel energy in tillage and subsequently in harvesting activities. In a row is 45,89% (3.378,600 MJ/ha) and 31,85% (867,676 MJ/ha), 23,08% (1.698,900 MJ/ha) and 28,97% (789,216 MJ/ha). Other than that, Safa, Samarasinghe, dan Mohssen (2010) also noted in wheat research in New Zealand that the largest fuel energy was spent in two operational activities namely tillage and harvesting, respectively 46,15% (1.419 MJ/ha) and 27,69% (851,400 MJ/ha).

c. Human Energy

Analysis of human energy during rice cultivation activities in this study was distributed in seven operations, which amounted to 216,390 MJ/ha. The value of human energy released in this study was 5.19 times out of 41,700 MJ/ha (Muazu, 2015) and 11,96 times out of 18,084 MJ/ha (Khan *et al*., 2010). This is due to the fact that in this study some activities were still carried out manually, except for the tillage activities that had been carried out mechanically and the harvesting activities applied a semi-mechanical system. As in agricultural activities in Malaysia which still tends to some operating systems (such as seeding, spraying, and fertilizing) done manually, resulting in an increase in human energy consumption (Muazu, 2015).

The greatest consumption of human energy is found in planting activities and the smallest is in fertilizing activities. The high or low value of the distribution of human energy is influenced by the length of work time (Table 1) and or intensity. As in spraying activities showed a greater distribution of human energy caused by the intensification of spraying in this study as much as five times, while in fertilizing activities only three times with an average processing time of 13,225 h/ha (0.705 times smaller than spraying time).

Table 2. Human Energy Analysis

Activities	Energy Average (MJ/ha)	Time Average (h/ha)
Seeding	37,805	1,373
Tillage	40,402	26,688
Planting	42,446	28,673
Fertilizing	18,579	13,225
Spraying	21,729	18,761
Weeding	27,268	24,704
Harvesting	28,160	62,223
Total	**216,388**	**175,647**

The percentage distribution of human energy can be seen in detail in Figure 4. Umar dan Noorginayuwati (2004) explained that the greatest human energy is in planting activities without including postharvest activities and maintenance pumps, which is 1,33 times greater than this research and planting activities 1,32 times from this research. Another case with research in Malaysia (Muazu *et al*., 2015), which reported that human energy is greatest in spraying activities, which is 40,48% of the total energy used and fertilizing activity 0,59 times less than this study. The low value of human energy in the study is because the agricultural system applied has used a mechanical system in each of its activities, so it can be stated based on the research that the application of mechanical agriculture is able to reduce the use of human energy.

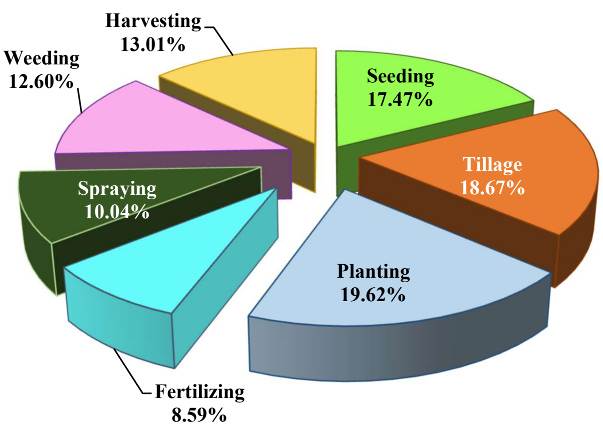

Figure 4. Percentage of Human Energy Distribution

d. Seed Energy

Seed energy distributed during this research was in planting activities. The average energy used is 983,295 MJ/ha, with an average use of seedling mass per hectare is 58,739 kg. Research in Northern Thailand, where the seed energy in succession in transplanting and broadcasting (sowing) systems was only 0,25 times (250,187 MJ/ha) and 1,001 times (984,625 MJ/ha) of this study. Another case with research by Muazu *et al*., (2015) who explained that the average seed energy used was 2.493 MJ/ha (148,925 kg/ha). That is, the average seed energy expenditure in this study was 2,53 times lower compared to research in Malaysia.

e. Fertilizer Energy

Fertilizer energy released in this study as a whole comes from inorganic fertilizers. The average fertilizer energy released in this study was 14.207,547 kg/ha When compared with some previous studies, the fertilizer energy used in this study was 1,43 times out of 9.931 MJ/ha (Muazu *et al*., 2015), 1,37 times out of 10,355,634 MJ/ha (Khan *et al*., 2010), 2,38 times out of 5,956 MJ/ha (Chaichana *et al*., 2008), and 1,31 times (Dazhong and Pimentel, 1984). The average use of inorganic fertilizers by farmers in this study was 917,547 kg/ha, with an average nitrogen, phosphorus, potassium, sulfur, and zinc content used, respectively, 171,344; 165,045; 50,497; 49,071; and 0,101 kg / ha.

Figure 5 illustrates the percentage of fertilizer use based on the elements contained in it. The level of nitrogen usage has the highest percentage of 39,29% (171,334 kg/ha) and this value indicates a figure greater than 130 kg/ha and 116,90 kg/ha which is the average of the level of nitrogen in the Muazu *et al*. (2015) and Dobermann *et al*. (2002) study, but about 4,81% lower than the level of nitrogen in Central-China 180 kg/ha (Yuan and Peng, 2017) and 10,29% of the level of nitrogen in China 191 kg/ha (Dazhong and Pimentel, 1984).

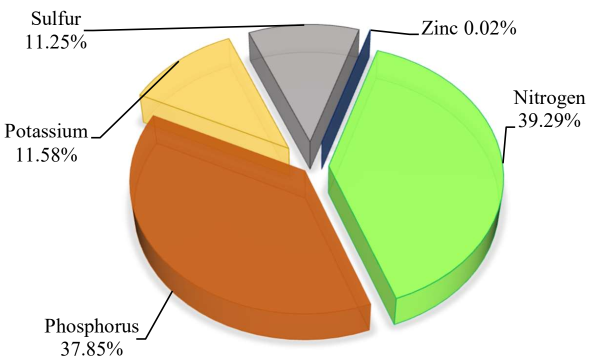

Figure 5. Percentage of Level of Use of Mineral Fertilizer Elements

The level of use of phosphorus, potassium, sulfur, and zinc in this study were 37,85% (165,045 kg/ha), 11,58% (50,497 kg/ha), 11,25% (49,071 kg/ha), and 0,02% (0,101 kg/ha). When compared with the level of fertilizer use in Central-China in 2015 which was 180 kg/ha nitrogen, 91,6 kg/ha phosphorus, 120,5 kg/ha potassium, and 5 kg/ha zinc (Yuan and Peng, 2017), phosphorus by farmers in this study was 1,8 times larger, but smaller in nitrogen, potassium, and zinc each by 0,55; 0,41; and 0,02 times.

Good fertilizer management is an activity that takes into economic, social, and environmental factors in order to achieve a sustainable agriculture system. The concept of good fertilizer management and has been widely adopted by the fertilizer industry in the world is by applying the 4R system (Right source, Right dose, Right time, and Right place) (IPNI, 2017). Strengthening the Kitchen, Goulding, and Shanahan (2008), that in agricultural practices farmers need to improve the efficiency of fertilizer use by not redundant fertilizer and apply the right time interval for fertilizer application, then Aguilar and Borjas (2005) state that it is not justified giving water to the rice fields when fertilizer time is taking place and over the next few days to avoid soil salinity problems that will have an impact on production.

f. Chemicals Energy (Pesticides)

The chemicals (pesticides) used in this study consisted of two types, namely insecticides and fungicides. The average pesticide energy expenditure is 458,603 MJ/ha. The size of the energy of pesticides depends on the amount of pesticide (kg/ha) used. The more amount of pesticides used will increase the amount of energy expended.

The average pesticide use in this study was 2,269 kg/ha (Table 2). This shows that in this study the use of pesticides 49,13; 59.19; and 67.86% lower than 4,46; 5,56; and 7,06 kg/ha for each use of pesticides in rice cultivation in Yangliangyou6-China in 2015, Malaysia, and Northern Thailand (Yuan dan Peng (2017), Muazu *et al*. (2015), and Chaichana *et al.* (2008)).

Table 3. Analysis of Average Level of Pesticide Use

Input	Average	
	Use (kg/ha)	Energy (MJ/ha)
Insecticides	0,339	80,268
Fungicides	1,930	378,334
Total	**2,269**	**458,602**

However, the use of pesticides in this study was higher compared to the use of pesticides in South Kalimantan Province 1,11 kg/ha (Umar and Noorginayuwati, 2004), Phatthalung-Thailand Province 1,260 kg/ha (Chaicana *et al*., 2014). Based on research that has been carried out on lowland rice cultivation in the Mekong Delta-Vietnam, that the use of pesticides that are good for the health of farmers and optimal in achieving yield production (6,700 tons/ha) is 0,743 kg/ha (Dung and Dung, 1999). Thus, the application of pesticides in the future needs to be considered so as not to harm the health of farmers and minimize wasteful energy on energy sources, in this case pesticide energy. The percentage of pesticide use can be seen in Figure 6.

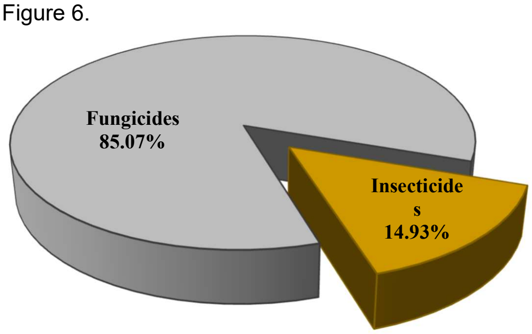

Figure 6. Percentage of distribution of pesticide use

Average Energy Input Based on Energy Source

Based on the six energy sources used during rice cultivation activities that have been carried out, a total average energy value of 16.816,612 MJ/ha was obtained, 25% lower than 22.425 MJ/ha (Chaichana *et al*., 2008). However, 2,24% greater than 16.440 MJ/ha (Muazu *et al*., 2015). Fertilizer energy is the biggest energy source used in this study, which is 84,49% (Figure 7) of 100% of the total energy expended. Chaichana *et al*. (2008) and Muazu (2015) explained in a study conducted in the Northern part of Thailand and Malaysia that fertilizer energy was the holder of the biggest role of energy sources, namely 39,25% and 60,41%; So, farmers in this study used a much larger fertilizer, which is 24,08 – 45,24%.

Marzuki, Murniati, and Ardian (2013) explained that the use of fertilizer in large amounts (excess) can cause a decrease in plant growth and inefficient plants in absorbing nutrients actually so that it will result in a decrease in rice production. Therefore, it is necessary to apply the right fertilizer by following the 4R rules, so that there is no redundant fertilizer (IPNI, 2017) which has an impact on the waste of energy and production costs (Uhlin, 1998).

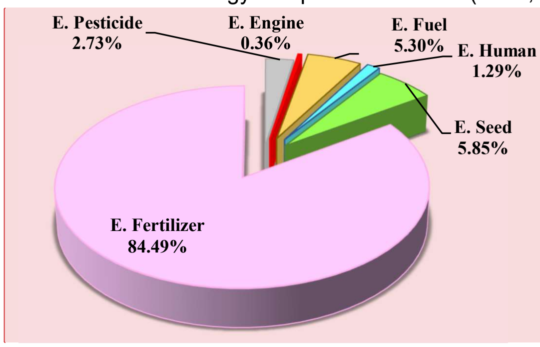

Figure 7. Percentage of Energy according to Energy Input Sources

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The seed energy, fuel, pesticides, and engine used in this study were lower than 15,16%; 17,21%; 4,06%; and 2,91% of each use of energy sources applied in Malaysia. However, human energy input in this study is 1,04% higher than 0.25% of human energy use in research conducted in Malaysia (Muazu, 2015). This is different from the research conducted in the District of South Kalimantan, where there was no fertilizer, engine, and fuel energy (traditional cultivation systems), so it can be concluded that in this study the energy of fertilizer, engine and fuel was greater. However, the percentage of seed, pesticide, and human energy expenditure in this study was smaller compared to 10,40%; 55,58%; and 34,02% of each percentage of the energy distribution of rice cultivation that occurred (Umar and Noorginayuwati 2004).

Average Energy Input Based on Operating Activities

Based on research that has been carried out on average, the total value of energy input based on operations is 16,816,612 MJ/ha. The biggest energy expended is in fertilizing activities is 84,60%, then planting (6,10%), tillage (3,97%), spraying (2,86%), harvesting (2,10%), seeding (0,22%), and finally weeding is 0,16%. More can be seen in Figure 8.

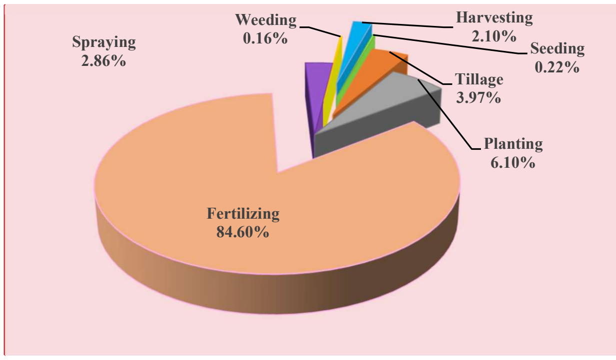

Figure 8. Percentage of Energy in Each Operating Activity

The energy in fertilizing activities as the biggest energy in this study, according to several previous studies. Muazu *et al*. (2015) explained the same thing that energy in fertilizing activities in rice cultivation in Malaysia was the largest, about 61,33% (10.082 MJ/ha). Furthermore, the same thing was reported by Chaicana *et al*. (2014), Khan *et al*. (2010), Chaichana *et al*. (2008), and Chauhan *et al*. (2006) that the energy in fertilizing activities as the largest energy in rice cultivation activities, respectively 13,22% (2414,687 MJ/ha) in Phatthalung Province-Thailand, 38,32% (9.247,388 MJ/ha) in Australia, in North Thailand about 26,61% (5.967,063 MJ/ha), and 33% (3.114,144 MJ/ha) in India.

The average value of energy consumption in fertilizing activities in this study showed a percentage of 84,60% or equivalent to 14.207,547 MJ/ha. This indicates that the figure obtained is greater than the expenditure of fertilizing energy on rice cultivation in the Province of Phatthalung-Thailand, Malaysia, Australia, Northern Thailand, and India. More simply can be described that the energy in fertilizing activities in this study 5,88 times greater than research in the Province of Phatthalung-Thailand, 1,41 times from research in Malaysia, 1,54 times from research in Australia, 2,38 times that of research in northern Thailand, and 4,56 times bigger than research in India. The imbalance of energy distribution that occurs in this study needs to be addressed. One alternative that can be applied in overcoming the imbalance of energy distribution that occurs is to apply precision agriculture, this is useful to minimize wasteful (wasteful) energy.

Energy Analysis

Based on research that has been carried out obtained an average production yield of 6.029,466 kg/ha (6,029 tons/ha). This shows that production results are 1,13 times greater than 5,34 tons/ha of national production (BPS, 2017), 1,18 times of 5,09 tons/ha of West Sumatra rice production (BPS West Sumatra, 2018), and 1,32 out of 4,57 tons/ha of rice production in Lubuk Alung District (BPS Padang Pariaman Regency, 2018b).

Table 4. Energy Analysis

Parameter	Value
Production result (kg/ha)	6,029.466
Energy intensity (MJ/kg)	2.747
Productivity (kg/MJ)	0.362
Clean energy (MJ/ha)	83,529.630

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Parameter	Value
Output energy (MJ/ha)	**100,933.259**

When compared with some previous studies that applied mechanical systems in Malaysia (Muazu *et al*., 2015), Australia (Khan *et al*., 2010), and the United States (Pimentel, 2009), the production results in this study were smaller respectively by 20,93%; 39,07%; and 20,83%. The value of energy intensity in this study indicates that to produce 1 kg of grain requires 2,747 MJ of energy, or it can be interpreted that with 1 MJ of energy released can produce 362 grams of grain. Potential production of unhulled rice with 1 MJ energy input in this study was greater than 255 grams (Dazhong and Pimentel, 1984), 225 grams (Chamsing *et al*., 2006), 226 grams (Purwantana, 2011), 352 grams (Eskandari and Attar, 2015), 86 grams (Aghaalikhani, Kazemi-poshtmasari, and Habibzadeh, 2013), and 266 grams (Yuan and Peng, 2017). However, lower than 460 grams (Muazu *et al*., 2015). Productivity of a plant should be greater by the energy that input in sample farm and between yield production and energy have linier correlation (Ozkan *et al*., 2011).

The yield prediction model built in this study is adapted to six aspects of energy input, including engine energy, fuel, humans, seeds, fertilizers, and pesticides. This is in accordance with the research of Muazu *et al*. (2015) which limits the development of yield prediction models in rice cultivation in Malaysia by using six sources of energy input. All energy inputs carried out in this study were formulated based on seven activities, like: seeding, tillage, planting, fertilizing, spraying, splashing, and harvesting. This is different in terms of aspects of the activity when compared to research that has been conducted in Malaysia. The prediction model of the results released in this study as described in equation 19.

Based on Table 4, the F-count value is obtained at a significant level of 0,01 which illustrates that the F-count is large from the F-table at a 99% confidence level, so it can be interpreted that the independent variables (energy input source or X) have an effect significant to the dependent variable (yield of rice or Y) and then the coefficient of determination can be used to predict the effect of variable X simultaneously on the variable Y. The T-value of the fuel is significant at the 0,01 level which describes that this variable is good for estimating of rice yields.

Table 5. Analysis of Data Parameter Prediction Model Results

Variable	Coefficient	Standard Error	T-count
Intercept [m]	4786.560	4230.635	1.131**
Engine energy [X1]	-28.286	28.676	-0.986ns
Fuel energy [X2]	36.226	11.160	3.246*
Human energy [X3]	-24.727	19.282	-1.282ns
Seed energy [X4]	-8.426	3.698	-2.278ns
Fertilize energy [X5]	0.057	0.141	0.405ns
Pesticide energy [X6)	-0.803	7.299	-0.110ns
R^2	0.811		
Multiple-R	0.901		
F-count	82.260*		
F-table	15.207		

Information: * Significant at the level 0.01; ** Significant at the level 0.5; ns Not significant at the level 0.01

The coefficient of determination (R^2) model from the input energy is 0.811. This means that 81.1% of the variables X simultaneously affect the Y variable, the remaining 18.9% is influenced by other factors outside the equation of the variable under study. According to Junaidi (2014), the value of R^2 gets better if the value approaches 1. Therefore, we can state that the input energy has a good level of suitability. Next, if we look at the Multiple-R value which shows the level of closeness (correlation) of the dependent variable and the independent variables. That is, the level of closeness of the value of production results to the independent variables is very strong that is equal to 90,10%. The prediction model of the first results produced is as follows:

$$Y_1 = 4786.560 - 28.286X_1 + 36.226X_2 - 24.727X_3 - 8.426X_4 + 0.057X_5 - 0.803X_6$$

$$Y_2 = 3605.110 + 5.443X_2$$

where:

Y_1 = prediction of results with all variables (ton/ha)
Y_2 = prediction results using significant variables (ton/ha)
X_1 = engine energy input (MJ/ha)
X_2 = fuel energy input (MJ/ha)
X_3 = human energy input (MJ/ha)
X_4 = seed energy input (MJ/ha)
X_5 = fertilizer energy input (MJ/ha)
X_6 = pesticide energy input (MJ/ha)

Fuel energy has the most influence on the prediction of rice production, followed by the energy of fertilizers, pesticides, seeds, humans, and the smallest is engine energy. Fertilizer is one of the factors needed and influencing rice growth needs to be considered the pattern of administration and dosage, because these factors will influence the yield (Muazu, 2015). One way is to implement a 4R system (IPNI, 2017). Steps that can be taken to implement the 4R system is to test the type of soil so that it can be seen what elements are lacking in the soil. In addition to fertilizer as a factor that has a positive influence on the prediction of yield is fuel energy.

Another thing is if we examine the energy coefficient values of pesticides, seeds, humans, and engines that have negative predictive coefficient values. That is, if there is an increase in energy at the four sources, rice production will decrease according to the prediction model that is built. One way to reduce this reduction is by reducing the operator and machine's working time (Muazu, 2015), and regulating the use of seeds and pesticides as efficiently as possible.

CONCLUSION

The conclusions of this study are the average of the total energy inputs of 16,816,612 MJ/ha distributed to human energy, fuel, engine, seeds, fertilizers, and pesticides respectively 216.390; 890.757; 60.020; 983.295; 14,207.547; and 458.602 MJ/ha. As a limitation in this research, every parameter made uniform as like as land's characteristics, seed variety, labor in all activities is same for each field area, hand-tractor and thresher that used with the same type for all field area and also for fuel is same (diesel), and weight of fertilizer and doses of pesticides in every broadcasting is same for every field area. Human energy that is measured in real-time and using a conversion table has a difference in the value of 7.525 MJ/ha, where human energy is calculated using a smaller conversion table (21.997 MJ/ha). The final result of the research is the determination of a prediction model of rice yield, with a mathematical model $Y_1 = 4786.560 - 28.286X_1 + 36.226X_2 - 24.727X_3 - 8.426X_4 + 0.057X_5 - 0.803X_6$ dan $Y_2 = 3605.110 + 5.443X_2$. For further research, it can be conducted by using comparing both of two until three seed variety in the same land characteristics or comparing energy expenditure with any parameters equals except land characteristic (low-land and high-land cultivation).

ACKNOWLEDGMENT
The authors would like to thank Andalas University Grant number 95/ UN.16.17/PP.PGB/LPPM/2018 for providing financial support or this project.

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Renny Eka Putri, Ph.D

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Subject: Re: FR-CAFEI-019.R1

Dear Dr Renny,

Kindly be informed that your manuscript has been assigned to Food Research 2020, Vol. 4, Supplementary Issue 5. Your manuscript is currently available online and in press on our website https://www.myfoodresearch.com. Alternatively, you can download a copy of the manuscript by clicking on the following link:
https://doi.org/10.26656/fr.2017.4(S6).019

We encourage you to share your published work with your colleagues. Thank you for your fine contribution. We hope that you continue to submit other articles to the Journal.

Thanks & Regards,
Dr Vivian New
Editor
Food Research

From: Food Research <foodresearch.my@outlook.com>
Sent: Monday, 5 October, 2020 9:14 PM
To: Renny Eka Putri <rennyekaputri@ae.unand.ac.id>
Subject: Re: FR-CAFEI-019.R1

Dear Dr Renny,

Noted with thanks.

Thanks & Regards,
Vivian New
Editor
Food Research

From: Renny Eka Putri <rennyekaputri@ae.unand.ac.id>
Sent: Monday, 5 October, 2020 10:22 AM
To: Food Research <foodresearch.my@outlook.com>
Subject: Re: FR-CAFEI-019.R1

I approve this paper for publish.

Thank you Dr. Vivian

Renny Eka Putri, Ph.D

Department of Agricultural Engineering
Faculty of Agricultural Technology
Andalas University

Jl. Universitas Andalas, Limau Manis, Kec. Pauh,
Kota Padang, Sumatera Barat 25163
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From: Food Research <foodresearch.my@outlook.com>
Sent: Thursday, October 1, 2020 8:31 PM
To: Renny Eka Putri <rennyekaputri@ae.unand.ac.id>
Subject: Re: FR-CAFEI-019.R1

Dear Renny,

Noted. Please refer to the attachment for the revised galley proof. If the galley proof is fine, please approve the galley proof.

Thanks & Regards,
Vivian New
Editor
Food Research

From: Renny Eka Putri <rennyekaputri@ae.unand.ac.id>
Sent: Wednesday, 30 September, 2020 8:35 AM
To: Food Research <foodresearch.my@outlook.com>
Subject: Re: FR-CAFEI-019.R1

Thank you Dr. Vivian
I have mention table 4 in the text.

Renny Eka Putri, Ph.D

Department of Agricultural Engineering
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Andalas University

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From: Food Research <foodresearch.my@outlook.com>
Sent: Tuesday, September 29, 2020 10:31 AM
To: Renny Eka Putri <rennyekaputri@ae.unand.ac.id>
Subject: Re: FR-CAFEI-019.R1

Table 4 is not cited in the text. Please cite table 4 in text.
Please re-check your table numbering.

From: Renny Eka Putri <rennyekaputri@ae.unand.ac.id>
Sent: Tuesday, 29 September, 2020 10:44 AM
To: Food Research <foodresearch.my@outlook.com>
Subject: Re: FR-CAFEI-019.R1

I have done the correction, based on the latest correction.

Thank you

Renny Eka Putri, Ph.D

Department of Agricultural Engineering
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From: Food Research <foodresearch.my@outlook.com>
Sent: Tuesday, September 29, 2020 9:27 AM
To: Renny Eka Putri <rennyekaputri@ae.unand.ac.id>
Subject: Re: FR-CAFEI-019.R1

Dear Renny,

Please refer to the attachment. Kindly highlight the corrections.

Thanks & Regards,
Vivian New
Editor
Food Research

From: Renny Eka Putri <rennyekaputri@ae.unand.ac.id>
Sent: Tuesday, 29 September, 2020 10:25 AM
To: Food Research <foodresearch.my@outlook.com>
Subject: Re: FR-CAFEI-019.R1

Dear Dr. Vivian

Please, send me the ms word file.

I will make correction soon.

Renny Eka Putri, Ph.D

Department of Agricultural Engineering
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From: Food Research <foodresearch.my@outlook.com>
Sent: Monday, September 28, 2020 4:02 PM
To: Renny Eka Putri <rennyekaputri@ae.unand.ac.id>
Subject: Re: FR-CAFEI-019.R1

Dear Dr Renny,

Apparently, it was the same attachment as before. Nevertheless, I have proceeded with the article production.

Please refer to the attachment for the galley proof of your manuscript FR-CAFEI-019 entitled 'Energy audit of rice production in West Sumatra province, Indonesia' . Please check the content of the galley proof. If there are any mistakes, please comment and highlight in the PDF itself and revert to us within two (2) days of receipt. Once we have finalized the PDF version, your manuscript will be published online for early viewing.

There are some comments that I have highlighted in the galley proof that require your attention. Please address them.

Thanks & Regards,
Vivian New
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Food Research

From: Renny Eka Putri <rennyekaputri@ae.unand.ac.id>
Sent: Friday, 25 September, 2020 12:56 PM
To: Food Research <foodresearch.my@outlook.com>
Subject: Re: FR-CAFEI-019.R1

sorry... it 'my mistake

I have done correction

Thank you
Renny Eka Putri, Ph.D

Department of Agricultural Engineering
Faculty of Agricultural Technology
Andalas University

Jl. Universitas Andalas, Limau Manis, Kec. Pauh,
Kota Padang, Sumatera Barat 25163
Telp : +62 81266407961

From: Food Research <foodresearch.my@outlook.com>
Sent: Thursday, September 24, 2020 7:59 PM
To: Renny Eka Putri <rennyekaputri@ae.unand.ac.id>
Subject: Re: FR-CAFEI-019.R1

Dear Dr Renny,

Please edit the references again.

Thanks & Regards,
Vivian New
Editor
Food Research

From: Renny Eka Putri <rennyekaputri@ae.unand.ac.id>
Sent: Thursday, 24 September, 2020 10:16 AM
To: Food Research <foodresearch.my@outlook.com>
Subject: Re: FR-CAFEI-019.R1

Dear Dr. Vivian

I have done correction based on the comment (attached file).
Please, proceed my paper soon

Renny Eka Putri, Ph.D

Department of Agricultural Engineering
Faculty of Agricultural Technology
Andalas University

Jl. Universitas Andalas, Limau Manis, Kec. Pauh,
Kota Padang, Sumatera Barat 25163
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From: Food Research <foodresearch.my@outlook.com>
Sent: Saturday, September 19, 2020 9:45 AM
To: Renny Eka Putri <rennyekaputri@ae.unand.ac.id>
Subject: Re: FR-CAFEI-019.R1

Dear Dr Renny,

Manuscript ID: FR-CAFEI-019.R1
Manuscript Title: Energy consumption and economic analysis of rice production in West Sumatra Indonesia

Before we can proceed with the article production, I would like to clarify a few points that I have commented in the manuscript. Please refer to the attachment. Please address the issues raised in the comments.

Please also check your manuscript again for English language proficiency. There are many incorrect tenses and wrong format of writing.

Please use the attached copy to make your revisions as it has been corrected to the Journal's format. Once you have done, kindly revert the copy to me as soon as possible. Please note the faster you respond, the quicker we will process your manuscript.

Thanks & Regards,
Vivian New
Editor
Food Research

From: Renny Eka Putri <rennyekaputri@ae.unand.ac.id>
Sent: Sunday, 2 August, 2020 1:17 PM
To: Food Research <foodresearch.my@outlook.com>
Subject: Re: FR-CAFEI-019.R1 - Decision on your manuscript

Dear Editor

I submit my second correction (attach file).

Thank you.

Renny Eka Putri, Ph.D

Department of Agricultural Engineering
Faculty of Agricultural Technology
Andalas University

Jl. Universitas Andalas, Limau Manis, Kec. Pauh,
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Telp : +62 81266407961

From: Food Research <foodresearch.my@outlook.com>
Sent: Friday, July 10, 2020 7:30 PM
To: Renny Eka Putri <rennyekaputri@ae.unand.ac.id>
Subject: FR-CAFEI-019.R1 - Decision on your manuscript

Dear Dr Renny,

Manuscript ID: FR-CAFEI-019.R1
Manuscript Title: Energy consumption and economic analysis of rice production in West Sumatra Indonesia

Your manuscript which you submitted to Food Research journal, has been reviewed. The comments of the reviewers are available at the bottom of this email.

Publication is recommended, subject to some minor revision to your manuscript. Therefore, I invite you to respond to the comments and proceed with revision.

Please submit your revised manuscript within one (1) month of this date of email. Respond to the reviewer(s)' comments by commenting in your revised manuscript and click 'Track Changes'.

I look forward to receiving your revision.

Sincerely,
Dr Vivian New
Editor
Food Research

Reviewers' Comment:
Reviewer 1
Just my suggestions for making clear this manuscript; (i) please state/write the assumption that for determining energy output (EO) just considering from main product i.e. rice (case study in West Sumatera), (ii) please give some references that related to crop productivity trend is linear, because crop productivity similar to crop growth model --> non linear trend.

Reviewer 2
Generally the authors have made efforts in improving this manuscript. However I noted that some parts in the manuscript did not addressed accordingly by the athors and yet need the revisions. My comments are as follow: Firstly, I suggest the authors use the all data of energy equivalent (Table 1) from the previous research articles that are listed in the database SCOPUS or WOS, which are the largest citation database of peer-reviewed literature. By citing the past articles came from recognized citation data bases like SCOPUS and WOS, it guarantees the high validity of the study. But, in this manuscript, I found many references in Table 1 are not taken from papers in SCOPUS or WOS databases. Secondly, the authors still did not include the amount inputs that the farmer used in a hectare in the study area. I did not find these data in Table 1. Actually, the structure standard of writing the table for energy (Table 1) should be in the form : Column 1 (Input). Column 2 (Unit), Column 3 (Amount of input used per ha in the study area), Column 4 (energy equivalent in MJ/unit), Column 5 (Energy equivalent in MJ/ha). And, the athors should mention amount of each input per hectare (for example: how many labor was used in the study area, how much NPK fertilizer used by the farmers in the study area as well as pesticide or verbicides, fuel of tractor). These should be listed in the table 1. But in the manuscript, The authors did not state the items clearly. In Table 1, Column 2 (Value) mentioned the energy equivalent, not the amount of input per ha applied by the farmers during rice cultivation.

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Energy Audit of Rice Production in West Sumatra Province Indonesia

[1]Putri, R.E. [2]Lubis, M.I.A., [1]Andasuryani, [1]Hasan, A., [1]Santosa and [1]Arlius, F.

[1]Department of Agricultural Engineering. Andalas University, Padang, Indonesia
[2]Department of Plantation Cultivation. Institute of Agricultural Sciences – Plantation Agribusiness (STIP-AP), Medan, Indonesia

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Audit energy is an appropriate method to determine the energy consumption expended in each agricultural cultivation activity, thereby reducing the wasteful use of energy. Energy consumption in rice cultivations consists of humans, fuel, machinery, seed, fertilizer, and pesticides. The objective of the study was to analyze the total energy consumptions in the form of an energy audit activity on lowland rice cultivation in West Sumatera Indonesia. It is important to do, because of much energy input excessed, but less on productivity. So, by using analysis energy expenditure, productivity can be optimized with fixed input energy the costs could be minimized. Energy inputs were measured during all operating activities in rice cultivation (seeding, tillage, planting, fertilizing, spraying, weeding, and harvesting). Energy input analysis based on energy sources used was divided into six parameters, namely: engine energy, fuel, humans, seeds, chemicals (pesticides), and fertilizer energy. The result showed the average of the total energy inputs in this study was 16,816,612 MJ/ha distributed to human, fuel, machinery, seeds, fertilizers, and pesticides energy respectively 216.39; 890.75; 60.02; 983.29; 14,207.54; and 458.60 MJ/ha. Production costs incurred in rice cultivation activities in this study were IDR 13,107,562/ha. Finally, the rice yield prediction model based on the input energy are $Y_1 = 4786.560 - 28.286X_1 + 36.226X_2 - 24.727X_3 - 8.426X_4 + 0.057X_5 - 0.803X_6$ and $Y_2 = 3605.110 + 5.443X_2$. The data of total energy were needed as a recommendation for the government to balance energy input and output on rice cultivations.

Keywords: Audit Energy; Energy Input-Output; Energy Analysis; Rice Cultivations

INTRODUCTION

Rice is a cereal crop grown and consumed on every continent of the world because of its adaptive capabilities which enable it to grow in areas with different soil types and climatic conditions. According to the Central Statistics Agency Indonesia (BPS, 2018), nthe number of Indonesians aged 15 years old and over who work in the agricultural sector in 2017 is 35,923,886 people, equivalent to 29.68% of the total population of Indonesia. This indicates that agriculture is the highest source of livelihood in Indonesia.

Commented [G1]: There are 3 references with the same author, same publication year. Please indicate which is which.

BPS (2017) informed that the area of paddy land in Indonesia in 2015 was 8,087,393 ha with production and productivity in 2015 were 75,397,841 tons and 5.34 tons/ha, respectively. This proves that rice has become a priority, especially in Indonesia. One of the provinces that contribute to rice production and rice production as a staple food for the people in West Sumatera. BPS of West Sumatera (2018) reported that yield areas (507,545 to be 491,875.7 hectares), production (2,550,609 to be, 503,452 tons), and productivity (50.25 to

Commented [G2]: There are 3 references with the same author, same publication year. Please indicate which is which.

be 50.09 tons/hectares) for paddy decreased in 2015 to 2016. Based on this case, important to do an effort to solving decreased rice production. An effort to increase rice production by implementing sustainable agriculture is a solution that must be implemented so that food imports do not increase as well as a means of achieving self-sufficiency, sovereignty, and food security. The real effort that can be implemented is to overcome the problem of land conversion by adding, maintaining, and establishing sustainable agricultural land. Sustainable agricultural land itself is divided into areas (agriculture and agricultural allotment), the stretch of land (irrigated, reclaimed, and non-irrigated), and land for sustainable agricultural reserves (Suswono, 2012). Efforts to achieve sustainable agriculture are implemented by implementing management of increased production that can reduce production costs, labor efficiency, and other input factors, and protect the environment (Piringer and Steinberg, 2006). Input factors are energy sources that have a sale value (cost) that is used both during the production, drying, packaging, storage, and transportation processes (Zangeneh, Omid and Akram, 2010).

Commented [G3]: Please edit the references following the journal's format.

Purwantana (2011) said that the effort to increase energy efficiency in rice production is by carrying out calculations or studies of energy needs. This effort includes scheduling activities, estimating the time of each activity, the number of labor, the number of agricultural tools and machinery, as well as all facilities used (seeds, fertilizers, medicines, etc.). Energy analysis can be done by recording all activities, starting from fuel consumption and time spent on each activity.

Energy audits have been applied to previous studies on several agricultural commodities, including potatoes in Hamadan-Iran Province (Zangeneh *et al*., 2010), cucumbers in Iran (Mohammadi and Omid, 2010), tomatoes in Turkey (Ozkan, Ceylan and Kizilay, 2011), rice in Malaysia (Bockari-Gevao *et al*., 2005 and Muazu *et al*., 2015), rice in low land paddy cultivation (Lubis *et al*., 2019), rice planting using rice transplanter (Putri, 2020a), and combine harvester (2020b). Research on the efficiency of energy use and economic analysis of several agricultural crops has been carried out (Muazu et al., 2015). Economic analysis is expected to be able to calculate the costs incurred during rice cultivation activities. So that in the future it can be known technical rice cultivation with the production of energy inputs (power sources incurred costs) and optimum costs. Rahmat (2015) explained that energy audits are evaluation activities of energy utilization and analysis of savings opportunities on energy use as well as recommendations to improve the efficiency of energy use itself.

The objective of the study is to analyze total energy consumptions in the form of an energy audit activity on lowland rice cultivation in West Sumatera Indonesia and to explore the prediction model of yield on rice cultivation based on the energy input. Energy inputs are measured during all operating activities in rice cultivation (seeding, tillage, planting, fertilizing, spraying, weeding, and harvesting).

Materials and methods

This research was conducted in 15 paddy fields from farmers and different implementation times. This research was carried out on paddy fields in Nagari Sungai Abang, Lubuk Alung Subdistrict located at coordinates $0°40'43{,}80'' - 0°40'36{,}45''$ latitude and $100°16'37{,}11'' - 100°16'46{,}57''$ longitude. Diagram of the process flow, equipment, and energy input for rice cultivation can be seen in Figure 1.

Commented [G4]: Delete

Commented [G5]: Please type the latitude and longitude in normal text, avoid using the equation.

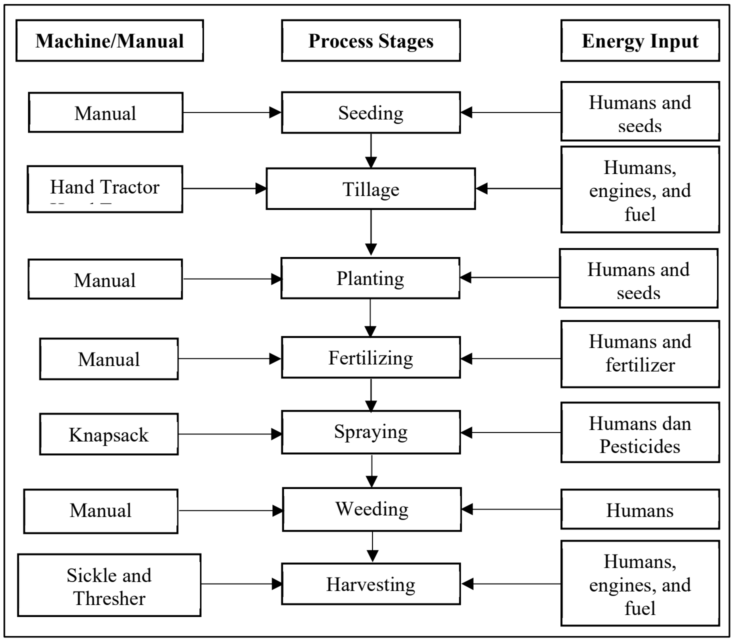

Figure 1. Flow Chart of Process, Equipment and Energy Input of Rice Cultivation

ENERGY ANALYSIS

Commented [G6]: Materials and methods should be written in past tense.

a. Engine Energy

The agricultural machinery used in rice cultivation in this research included hand tractors and threshers. Every machine that works certainly releases energy. Energy calculation for each machine is done by completing some data obtained in the field and can be calculated using the following equation (Muazu *et al.*, 2015):

$$ME = \frac{C_{f.m}\ x\ w}{F_c\ x\ N} \quad \text{......} \quad (1)$$

For Fc, it can be solved by using the following equation (Santosa, 2008):

$$F_c = \frac{A}{t} \quad \text{......} \quad (2)$$

where:

ME = engine energy (MJ/ha)
$C_{f.m}$ = energy conversion factor for machinery used (MJ/kg), show in Table 1
w = weight of machinery (kg), about 355,8 kg for hand-tractor and 48 kg for thresher
N = economic life of machinery (h), assumed 12,000 hours for hand-tractor and 4,000 hours for thresher
F_c = effective field capacity (ha/h)
A = size of the farm (ha)
t = effective working time (h)

During the rice cultivation activity takes place, the machine working time in the field is an effective time. Effective time is the difference between the total time total to the time lost (when turning, due to slipping, due to rest, due to the adjustment of tools, etc.). Furthermore, effective working time can be formulated as follows:

$$t = t_s - t_h \quad (3)$$

where:

t_s = total total time (h)
t_h = time lost (h)

b. Fuel Energy

Fuel energy can be calculated using the following calculations (Muazu *et al*., 2015):

$$FE = \frac{F_{con} \times C_{f.f}}{A} \quad (4)$$

where:

FE = fuel energy (MJ/ha)
F_{con} = fuel consumed (L)
$C_{f.f}$ = fuel energy conversion factor (MJ/L), shown in table 1
A = size of the farm (ha)

c. Human Energy

Measurement of the amount of energy expended by energy farmers is measured directly (real-time) using Garmin Forerunner 35 and heart rate monitor (HRM) (Figure 2).

Figure 2. Garmin *Forerunner* 35 (left) and *Heart Rate Monitor* (right)

d. Seed Energy

Paddy seed which used in this research is “Anak Daro” variety. It used because of this variety usually cultivated by the farmers at West Sumatera and all of the people at that Province only consumed rice with characteristic “Badarai/Scattered” after cooked. In general, rice seed energy can be calculated using the following equation (Muazu *et al*., 2015):

Commented [G7]: Please edit. The sentence is incomplete.

$$SE = \frac{S_w \times C_{f.s}}{A} \quad (6)$$

where:

SE = seed energy (MJ/ha)
S_w = weight of seeds used (kg)
$C_{f.s}$ = seed energy conversion factor (MJ/kg), shown in table 1
A = size of the farm (ha)

e. Pesticides Energy

The pesticides that used in this research is liquid pesticides by Syngenta’s product, with types are insecticides and fungicides. Pesticides energy used can be calculated using the following equation (Muazu *et al*., 2015):

$$PE = \frac{P_w \times C_{f.p}}{A} \quad (7)$$

where:

PE = pesticides energy (MJ/ha)
P_w = weight of pesticides used (kg)
$C_{f.p}$ = pesticides energy conversion factor (MJ/kg), shown in table 1
A = size of the farm (ha)

f. Fertilizer Energy

The fertilizer that used with branding name is Urea, Phonska, and SP36. The amount of fertilizer energy given to plants can be calculated using the following equation (Muazu *et al.*, 2015):

$$FTE = \frac{FT_w \times (\sum_{i=1}^{n} FT_i \times C_{f.ft})}{A} \quad (8)$$

where:

FTE = fertilizer energy (MJ/ha)
FT_w = weight of fertilizer used (kg)
FT_i = percent composition of i^{th} element (decimal)
$C_{f.ft}$ = fertilizer energy conversion factor (MJ/kg), shown in Table 1
A = size of the farm (ha)

g. Total Input Energy

The total input energy is the total amount of energy used. The general form of the equation used to calculate the total input energy is as follows (Muazu, 2015):

$$TE_i = ME + FE + HE + SE + PE + FTE \quad (9)$$

where:

TE_i = total input energy (MJ/ha)
ME, FE, HE, SE, PE, and FTE are following the previous explanation above.

h. Total Output Energy

The total energy produced from rice cultivation can be seen from the rice production produced. The total output energy is only fill based on mass of rice production in a hectare. The output energy shall increase by the mass rice production (linear correlation). The equation used to calculate the total output energy produced is as follows (Muazu, 2015):

$$TE_o = Y_p \times C_f \quad (10)$$

where:

TE_o = total output energy produced (MJ/ha)
Y_p = harvested rice production (kg/ha)
C_f = conversion factor used (MJ/kg)

Table 1. Energy Equivalent (MJ/Unit)

Type of Energy	Value	Unit	References
Machinery	93.61	kg	Muazu (2015)
Fuel (Diesel)	47.8	Liter	Cherati *et al*. (2011)
Paddy Seed	16.74	Kg	Muazu (2015)
Pesticides:			
Herbicides	238	kg	Cherati *et al*. (2011)
Fungicides	216	kg	Cherati *et al*. (2011)

Insecticides	101.2	kg	Zangeneh *et al*. (2010)
Fertilizer:			
Nitrogen (N)	60.6	kg	Cherati *et al*. (2011)
Phosphorus (P)	11.93	kg	Cherati *et al*. (2011)
Potassium (K)	11.15	kg	Zangeneh *et al*. (2010)
Sulfur (S)	9.23	kg	FAO (2001)
Zincum (Zn)	5.3	kg	FAO (2001)

RESULT AND DISCUSSION

ENERGY ANALYSIS

a. Engine Energy

The engine energy is distributed inland processing and harvesting activities. The total average energy of the machine was 60,020 MJ/ha, based on the operation was 56,347 MJ/ha in tillage activities and 3,673 MJ/ha in harvesting activities. The distribution of the level of use of the machine in this study was 0.661 kg/ha. This is different from research in Malaysia, where mechanical energy is distributed in every operational activity, namely tillage, seeding, fertilizing, spraying, harvesting, and weeding with a total energy of 477,780 MJ/ha (Muazu, 2015). In contrast to the use of engines in China 14.62 kg/ha (Dazhong dan Pimentel, 1984), India 4,33 kg/ha (Chauhan *et al*., 2006), USA 38 kg/ha (Pimentel, 2009), Philipina 4,03 kg/ha (Mendoza, 2015), and Malaysia 5,74 kg/ha (Muazu, 2015). Respectively 22, 6, 57, 6, and 9 times, compared with the level of machine used in this study. This is due to differences in the types of agricultural equipment and machinery used and in each cultivation activity between this study and previous research.

The value of machine energy spent on land management and harvesting activities is influenced by working time and land area. The mechanical energy in soil processing activities has a greater value than machine energy at harvest. This is influenced by working time, conversion factors, and the mass of agricultural equipment and machinery used, where energy is directly proportional to the three parameters. Apart from these three factors in the tillage, there are two times the use of agricultural machinery (tractors). This is due to the condition of the soil being harder and drier and more weeds, so it requires longer time, as Muazu's (2015) statement explained that the energy expended during tillage is influenced by soil type, moisture content, and protective vegetation.

b. Fuel Energy

The analysis of fuel energy used by farmers in this study was recorded in two activities, similar to the analysis of engine energy. The average of total fuel energy input released in this study was 890,757 MJ/ha. This shows that the energy input in this study was 79.43% lower than the research in Northern Thailand (Chaichana *et al*., 2008), 67,22% (Bockari-gevao *et al*., 2005) and 68,51% (Muazu *et al*., 2015) lower than rice research in Malaysia, 66,94% (Chauhan *et al*., 2006) and 59,85% (Mendoza, 2015) lower than research in India and the Philippines. Some things that can cause differences in the value of this energy input are the type of soil, the area of land cultivated, and the machine used. As explained by Muazu (2015), the texture and condition of the cultivated land are one of the determinants of the time spent, where the greater the work time spent, the amount of fuel used will increase. In addition, another factor is the area of land, where the greater the area of land cultivated will result in a decrease in the value of fuel energy (according to equation 4). Each engine has different specifications so that the consumption of spent fuel will also be different. Apart from the type/specification of the engine, the other determining factors for fuel consumption are engine life and maintenance.

The highest value of fuel energy is found in soil processing activities. This is due to the distribution of fuel energy in tillage there are two activities, namely first and second tillage. Tillage activities on land 10 emit the largest fuel energy, which is 753,035 MJ/ha and the lowest is found in land 8 of 419,522 MJ/ha. A big or small amount of energy spent on land treatment activities is influenced by the volume of fuel used and the area of land worked on. The volume of fuel used is identic to the soil water content and compactness/soil density (Muazu, 2015) which will affect the length of work, where the longer the tillage time, the greater the fuel spent.

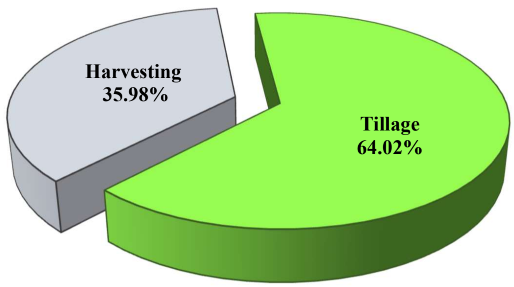

Figure 3. Fuel Energy Analysis

The fuel energy recorded in the land processing activities was 64.02% (570,223 MJ/ha) of the total fuel energy, as well as being the largest energy in the distribution of fuel energy. Furthermore, the distribution of fuel energy is found in the harvesting activities of 35.98% or equivalent to 320,534 MJ/ha (Figure 3). Cherati, Bahrami, and Asakereh (2011) and Khan *et al*., (2010) explained the same thing in rice research in Iran and Australia, which obtained the largest distribution of fuel energy in tillage and subsequently in harvesting activities. In a row is 45,89% (3.378,600 MJ/ha) and 31,85% (867,676 MJ/ha), 23,08% (1.698,900 MJ/ha) and 28,97% (789,216 MJ/ha). Other than that, Safa, Samarasinghe, dan Mohssen (2010) also noted in wheat research in New Zealand that the largest fuel energy was spent in two operational activities namely tillage and harvesting, respectively 46,15% (1.419 MJ/ha) and 27,69% (851,400 MJ/ha).

c. Human Energy

Analysis of human energy during rice cultivation activities in this study was distributed in seven operations, which amounted to 216,390 MJ/ha. The value of human energy released in this study was 5.19 times out of 41,700 MJ/ha (Muazu, 2015) and 11,96 times out of 18,084 MJ/ha (Khan *et al*., 2010). This is due to the fact that in this study some activities were still carried out manually, except for the tillage activities that had been carried out mechanically and the harvesting activities applied a semi-mechanical system. As in agricultural activities in Malaysia which still tends to some operating systems (such as seeding, spraying, and fertilizing) done manually, resulting in an increase in human energy consumption (Muazu, 2015).

The greatest consumption of human energy is found in planting activities and the smallest is in fertilizing activities. The high or low value of the distribution of human energy is influenced by the length of work time (Table 1) and or intensity. As in spraying activities showed a greater distribution of human energy caused by the intensification of spraying in this study as much as five times, while in fertilizing activities only three times with an average processing time of 13,225 h/ha (0.705 times smaller than spraying time).

Table 2. Human Energy Analysis

Activities	Energy Average (MJ/ha)	Time Average (h/ha)
Seeding	37,805	1,373
Tillage	40,402	26,688
Planting	42,446	28,673
Fertilizing	18,579	13,225
Spraying	21,729	18,761
Weeding	27,268	24,704
Harvesting	28,160	62,223
Total	**216,388**	**175,647**

The percentage distribution of human energy can be seen in detail in Figure 4. Umar dan Noorginayuwati (2004) explained that the greatest human energy is in planting activities without including postharvest activities and maintenance pumps, which is 1,33 times greater than this research and planting activities 1,32 times from this research. Another case with research in Malaysia (Muazu *et al.*, 2015), which reported that human energy is greatest in spraying activities, which is 40,48% of the total energy used and fertilizing activity 0,59 times less than this study. The low value of human energy in the study is because the agricultural system applied has used a mechanical system in each of its activities, so it can be stated based on the research that the application of mechanical agriculture is able to reduce the use of human energy.

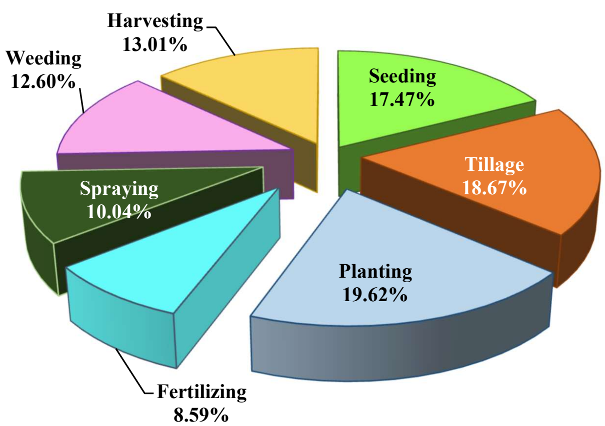

Figure 4. Percentage of Human Energy Distribution

d. Seed Energy

Seed energy distributed during this research was in planting activities. The average energy used is 983,295 MJ/ha, with an average use of seedling mass per hectare is 58,739 kg. Research in Northern Thailand, where the seed energy in succession in transplanting and broadcasting (sowing) systems was only 0,25 times (250,187 MJ/ha) and 1,001 times (984,625 MJ/ha) of this study. Another case with research by Muazu *et al.*, (2015) who explained that the average seed energy used was 2.493 MJ/ha (148,925 kg/ha). That is, the average seed energy expenditure in this study was 2,53 times lower compared to research in Malaysia.

e. Fertilizer Energy

Fertilizer energy released in this study as a whole comes from inorganic fertilizers. The average fertilizer energy released in this study was 14.207,547 kg/ha When compared with some previous studies, the fertilizer energy used in this study was 1,43 times out of 9.931 MJ/ha (Muazu *et al*., 2015), 1,37 times out of 10,355,634 MJ/ha (Khan *et al*., 2010), 2,38 times out of 5,956 MJ/ha (Chaichana *et al*., 2008), and 1,31 times (Dazhong and Pimentel, 1984). The average use of inorganic fertilizers by farmers in this study was 917,547 kg/ha, with an average nitrogen, phosphorus, potassium, sulfur, and zinc content used, respectively, 171,344; 165,045; 50,497; 49,071; and 0,101 kg / ha.

Figure 5 illustrates the percentage of fertilizer use based on the elements contained in it. The level of nitrogen usage has the highest percentage of 39,29% (171,334 kg/ha) and this value indicates a figure greater than 130 kg/ha and 116,90 kg/ha which is the average of the level of nitrogen in the Muazu *et al*. (2015) and Dobermann *et al*. (2002) study, but about 4,81% lower than the level of nitrogen in Central-China 180 kg/ha (Yuan and Peng, 2017) and 10,29% of the level of nitrogen in China 191 kg/ha (Dazhong and Pimentel, 1984).

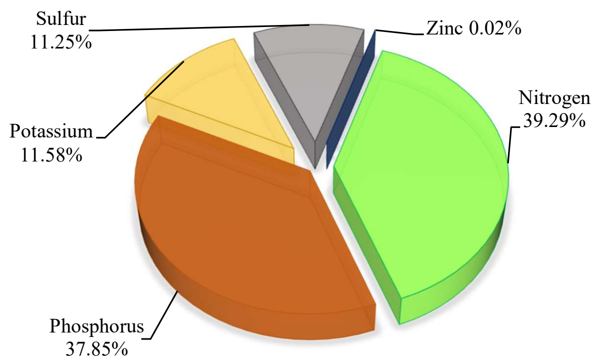

Figure 5. Percentage of Level of Use of Mineral Fertilizer Elements

The level of use of phosphorus, potassium, sulfur, and zinc in this study were 37,85% (165,045 kg/ha), 11,58% (50,497 kg/ha), 11,25% (49,071 kg/ha), and 0,02% (0,101 kg/ha). When compared with the level of fertilizer use in Central-China in 2015 which was 180 kg/ha nitrogen, 91,6 kg/ha phosphorus, 120,5 kg/ha potassium, and 5 kg/ha zinc (Yuan and Peng, 2017), phosphorus by farmers in this study was 1,8 times larger, but smaller in nitrogen, potassium, and zinc each by 0,55; 0,41; and 0,02 times.

Good fertilizer management is an activity that takes into economic, social, and environmental factors in order to achieve a sustainable agriculture system. The concept of good fertilizer management and has been widely adopted by the fertilizer industry in the world is by applying the 4R system (Right source, Right dose, Right time, and Right place) (IPNI, 2017). Strengthening the Kitchen, Goulding, and Shanahan (2008), that in agricultural practices farmers need to improve the efficiency of fertilizer use by not redundant fertilizer and apply the right time interval for fertilizer application, then Aguilar and Borjas (2005) state that it is not justified giving water to the rice fields when fertilizer time is taking place and over the next few days to avoid soil salinity problems that will have an impact on production.

f. Chemicals Energy (Pesticides)

The chemicals (pesticides) used in this study consisted of two types, namely insecticides and fungicides. The average pesticide energy expenditure is 458,603 MJ/ha. The size of the energy of pesticides depends on the amount of pesticide (kg/ha) used. The more amount of pesticides used will increase the amount of energy expended.

The average pesticide use in this study was 2,269 kg/ha (Table 2). This shows that in this study the use of pesticides 49,13; 59.19; and 67.86% lower than 4,46; 5,56; and 7,06 kg/ha for each use of pesticides in rice cultivation in Yangliangyou6-China in 2015, Malaysia, and Northern Thailand (Yuan dan Peng (2017), Muazu *et al*. (2015), and Chaichana *et al.* (2008)).

Table 3. Analysis of Average Level of Pesticide Use

Input	Average	
	Use (kg/ha)	**Energy (MJ/ha)**
Insecticides	0,339	80,268
Fungicides	1,930	378,334
Total	**2,269**	**458,602**

However, the use of pesticides in this study was higher compared to the use of pesticides in South Kalimantan Province 1,11 kg/ha (Umar and Noorginayuwati, 2004), Phatthalung-Thailand Province 1,260 kg/ha (Chaicana *et al*., 2014). Based on research that has been carried out on lowland rice cultivation in the Mekong Delta-Vietnam, that the use of pesticides that are good for the health of farmers and optimal in achieving yield production (6,700 tons/ha) is 0,743 kg/ha (Dung and Dung, 1999). Thus, the application of pesticides in the future needs to be considered so as not to harm the health of farmers and minimize wasteful energy on energy sources, in this case pesticide energy. The percentage of pesticide use can be seen in Figure 6.

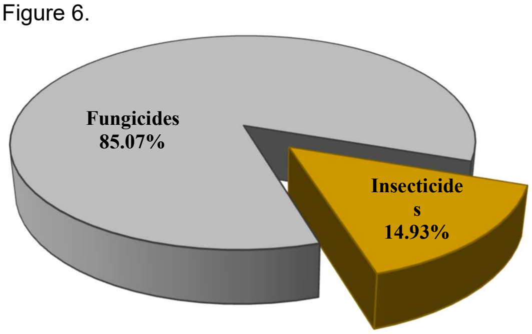

Figure 6. Percentage of distribution of pesticide use

Average Energy Input Based on Energy Source

Based on the six energy sources used during rice cultivation activities that have been carried out, a total average energy value of 16.816,612 MJ/ha was obtained, 25% lower than 22.425 MJ/ha (Chaichana *et al*., 2008). However, 2,24% greater than 16.440 MJ/ha (Muazu *et al*., 2015). Fertilizer energy is the biggest energy source used in this study, which is 84,49% (Figure 7) of 100% of the total energy expended. Chaichana *et al*. (2008) and Muazu (2015) explained in a study conducted in the Northern part of Thailand and Malaysia that fertilizer energy was the holder of the biggest role of energy sources, namely 39,25% and 60,41%; So, farmers in this study used a much larger fertilizer, which is 24,08 – 45,24%.

Marzuki, Murniati, and Ardian (2013) explained that the use of fertilizer in large amounts (excess) can cause a decrease in plant growth and inefficient plants in absorbing nutrients actually so that it will result in a decrease in rice production. Therefore, it is necessary to apply the right fertilizer by following the 4R rules, so that there is no redundant fertilizer (IPNI, 2017) which has an impact on the waste of energy and production costs (Uhlin, 1998).

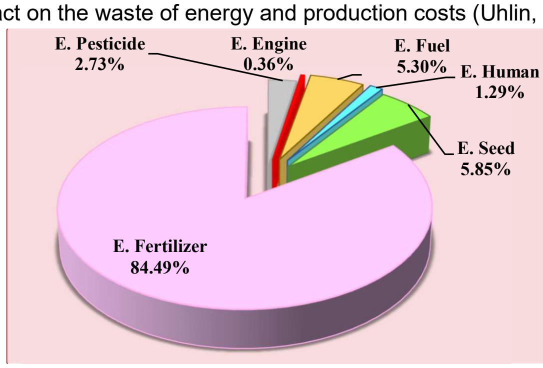

Figure 7. Percentage of Energy according to Energy Input Sources

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The seed energy, fuel, pesticides, and engine used in this study were lower than 15,16%; 17,21%; 4,06%; and 2,91% of each use of energy sources applied in Malaysia. However, human energy input in this study is 1,04% higher than 0.25% of human energy use in research conducted in Malaysia (Muazu, 2015). This is different from the research conducted in the District of South Kalimantan, where there was no fertilizer, engine, and fuel energy (traditional cultivation systems), so it can be concluded that in this study the energy of fertilizer, engine and fuel was greater. However, the percentage of seed, pesticide, and human energy expenditure in this study was smaller compared to 10,40%; 55,58%; and 34,02% of each percentage of the energy distribution of rice cultivation that occurred (Umar and Noorginayuwati 2004).

Average Energy Input Based on Operating Activities

Based on research that has been carried out on average, the total value of energy input based on operations is 16,816,612 MJ/ha. The biggest energy expended is in fertilizing activities is 84,60%, then planting (6,10%), tillage (3,97%), spraying (2,86%), harvesting (2,10%), seeding (0,22%), and finally weeding is 0,16%. More can be seen in Figure 8.

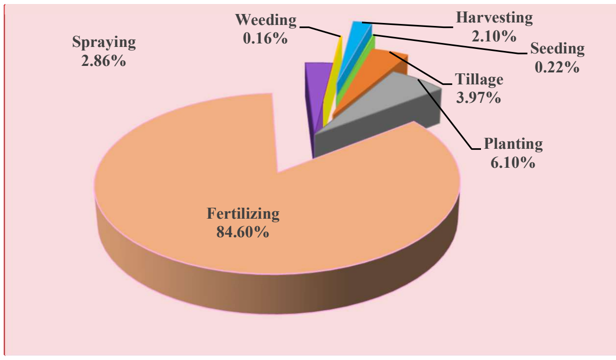

Figure 8. Percentage of Energy in Each Operating Activity

The energy in fertilizing activities as the biggest energy in this study, according to several previous studies. Muazu *et al*. (2015) explained the same thing that energy in fertilizing activities in rice cultivation in Malaysia was the largest, about 61,33% (10.082 MJ/ha). Furthermore, the same thing was reported by Chaicana *et al*. (2014), Khan *et al*. (2010), Chaichana *et al*. (2008), and Chauhan *et al*. (2006) that the energy in fertilizing activities as the largest energy in rice cultivation activities, respectively 13,22% (2414,687 MJ/ha) in Phatthalung Province-Thailand, 38,32% (9.247,388 MJ/ha) in Australia, in North Thailand about 26,61% (5.967,063 MJ/ha), and 33% (3.114,144 MJ/ha) in India.

The average value of energy consumption in fertilizing activities in this study showed a percentage of 84,60% or equivalent to 14.207,547 MJ/ha. This indicates that the figure obtained is greater than the expenditure of fertilizing energy on rice cultivation in the Province of Phatthalung-Thailand, Malaysia, Australia, Northern Thailand, and India. More simply can be described that the energy in fertilizing activities in this study 5,88 times greater than research in the Province of Phatthalung-Thailand, 1,41 times from research in Malaysia, 1,54 times from research in Australia, 2,38 times that of research in northern Thailand, and 4,56 times bigger than research in India. The imbalance of energy distribution that occurs in this study needs to be addressed. One alternative that can be applied in overcoming the imbalance of energy distribution that occurs is to apply precision agriculture, this is useful to minimize wasteful (wasteful) energy.

Energy Analysis

Based on research that has been carried out obtained an average production yield of 6.029,466 kg/ha (6,029 tons/ha). This shows that production results are 1,13 times greater than 5,34 tons/ha of national production (BPS, 2017), 1,18 times of 5,09 tons/ha of West Sumatra rice production (BPS West Sumatra, 2018), and 1,32 out of 4,57 tons/ha of rice production in Lubuk Alung District (BPS Padang Pariaman Regency, 2018b).

Table 4. Energy Analysis

Parameter	Value
Production result (kg/ha)	6,029.466
Energy intensity (MJ/kg)	2.747
Productivity (kg/MJ)	0.362
Clean energy (MJ/ha)	83,529.630

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Parameter	Value
Output energy (MJ/ha)	**100,933.259**

When compared with some previous studies that applied mechanical systems in Malaysia (Muazu *et al*., 2015), Australia (Khan *et al*., 2010), and the United States (Pimentel, 2009), the production results in this study were smaller respectively by 20,93%; 39,07%; and 20,83%. The value of energy intensity in this study indicates that to produce 1 kg of grain requires 2,747 MJ of energy, or it can be interpreted that with 1 MJ of energy released can produce 362 grams of grain. Potential production of unhulled rice with 1 MJ energy input in this study was greater than 255 grams (Dazhong and Pimentel, 1984), 225 grams (Chamsing *et al*., 2006), 226 grams (Purwantana, 2011), 352 grams (Eskandari and Attar, 2015), 86 grams (Aghaalikhani, Kazemi-poshtmasari, and Habibzadeh, 2013), and 266 grams (Yuan and Peng, 2017). However, lower than 460 grams (Muazu *et al*., 2015). Productivity of a plant should be greater by the energy that input in sample farm and between yield production and energy have linier correlation (Ozkan *et al*., 2011).

The yield prediction model built in this study is adapted to six aspects of energy input, including engine energy, fuel, humans, seeds, fertilizers, and pesticides. This is in accordance with the research of Muazu *et al*. (2015) which limits the development of yield prediction models in rice cultivation in Malaysia by using six sources of energy input. All energy inputs carried out in this study were formulated based on seven activities, like: seeding, tillage, planting, fertilizing, spraying, splashing, and harvesting. This is different in terms of aspects of the activity when compared to research that has been conducted in Malaysia. The prediction model of the results released in this study as described in equation 19.

Based on Table 4, the F-count value is obtained at a significant level of 0,01 which illustrates that the F-count is large from the F-table at a 99% confidence level, so it can be interpreted that the independent variables (energy input source or X) have an effect significant to the dependent variable (yield of rice or Y) and then the coefficient of determination can be used to predict the effect of variable X simultaneously on the variable Y. The T-value of the fuel is significant at the 0,01 level which describes that this variable is good for estimating of rice yields.

Table 5. Analysis of Data Parameter Prediction Model Results

Variable	Coefficient	Standard Error	T-count
Intercept [m]	4786.560	4230.635	1.131**
Engine energy [X1]	-28.286	28.676	-0.986ns
Fuel energy [X2]	36.226	11.160	3.246*
Human energy [X3]	-24.727	19.282	-1.282ns
Seed energy [X4]	-8.426	3.698	-2.278ns
Fertilize energy [X5]	0.057	0.141	0.405ns
Pesticide energy [X6)	-0.803	7.299	-0.110ns
R^2	0.811		
Multiple-R	0.901		
F-count	82.260*		
F-table	15.207		

Information: * Significant at the level 0.01; ** Significant at the level 0.5; ns Not significant at the level 0.01

The coefficient of determination (R^2) model from the input energy is 0.811. This means that 81.1% of the variables X simultaneously affect the Y variable, the remaining 18.9% is influenced by other factors outside the equation of the variable under study. According to Junaidi (2014), the value of R^2 gets better if the value approaches 1. Therefore, we can state that the input energy has a good level of suitability. Next, if we look at the Multiple-R value which shows the level of closeness (correlation) of the dependent variable and the independent variables. That is, the level of closeness of the value of production results to the independent variables is very strong that is equal to 90,10%. The prediction model of the first results produced is as follows:

$$Y_1 = 4786.560 - 28.286X_1 + 36.226X_2 - 24.727X_3 - 8.426X_4 + 0.057X_5 - 0.803X_6$$

$$Y_2 = 3605.110 + 5.443X_2$$

where:

Y_1 = prediction of results with all variables (ton/ha)
Y_2 = prediction results using significant variables (ton/ha)
X_1 = engine energy input (MJ/ha)
X_2 = fuel energy input (MJ/ha)
X_3 = human energy input (MJ/ha)
X_4 = seed energy input (MJ/ha)
X_5 = fertilizer energy input (MJ/ha)
X_6 = pesticide energy input (MJ/ha)

Fuel energy has the most influence on the prediction of rice production, followed by the energy of fertilizers, pesticides, seeds, humans, and the smallest is engine energy. Fertilizer is one of the factors needed and influencing rice growth needs to be considered the pattern of administration and dosage, because these factors will influence the yield (Muazu, 2015). One way is to implement a 4R system (IPNI, 2017). Steps that can be taken to implement the 4R system is to test the type of soil so that it can be seen what elements are lacking in the soil. In addition to fertilizer as a factor that has a positive influence on the prediction of yield is fuel energy.

Another thing is if we examine the energy coefficient values of pesticides, seeds, humans, and engines that have negative predictive coefficient values. That is, if there is an increase in energy at the four sources, rice production will decrease according to the prediction model that is built. One way to reduce this reduction is by reducing the operator and machine's working time (Muazu, 2015), and regulating the use of seeds and pesticides as efficiently as possible.

CONCLUSION

The conclusions of this study are the average of the total energy inputs of 16,816,612 MJ/ha distributed to human energy, fuel, engine, seeds, fertilizers, and pesticides respectively 216.390; 890.757; 60.020; 983.295; 14,207.547; and 458.602 MJ/ha. As a limitation in this research, every parameter made uniform as like as land's characteristics, seed variety, labor in all activities is same for each field area, hand-tractor and thresher that used with the same type for all field area and also for fuel is same (diesel), and weight of fertilizer and doses of pesticides in every broadcasting is same for every field area. Human energy that is measured in real-time and using a conversion table has a difference in the value of 7.525 MJ/ha, where human energy is calculated using a smaller conversion table (21.997 MJ/ha). The final result of the research is the determination of a prediction model of rice yield, with a mathematical model $Y_1 = 4786.560 - 28.286X_1 + 36.226X_2 - 24.727X_3 - 8.426X_4 + 0.057X_5 - 0.803X_6$ dan $Y_2 = 3605.110 + 5.443X_2$. For further research, it can be conducted by using comparing both of two until three seed variety in the same land characteristics or comparing energy expenditure with any parameters equals except land characteristic (low-land and high-land cultivation).

ACKNOWLEDGMENT

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