ANALYSIS OF ENERGY CONSUMPTION AND PERFORMANCE TEST ON RICE PLANTING USING RICE TRANSPLANTER : A CASE STUDY IN WEST SUMATERA PROVINCE, INDONESIA

Renny Eka Putri *, Rizka Fadhilah, Dinah Cherie, Azkiya Wahyu Novianda

Department of Agricultural Engineering, Andalas University, Padang Indonesia

*Corresponding author:
Email: rennyekaputri@ae.unand.ac.id

Abstract. *Energy Consumption in the agricultural sector consists of diesel, gasoline, and kerosene for fuel of agricultural machinery (rice transplanter, tractor, rice milling unit, motor sprayer, and water pump) in the sector. The objectives of this study are to determine the total energy consumption of rice planting and to analyse the performance of rice transplanter during rice planting in West Sumatra, Indonesia. This research was conducted on farmer's rice fields in west Sumatera Indonesia. The results obtained from the performance of a rice transplanter machine include working speed of 0.633 m/s, a theoretical work capacity of 0.274 ha/hour, effective work capacity of 0.222 ha/hour and work efficiency of 80.967%. The detail of energy consumption using a rice transplanter are human energy (9.225 MJ/ha), seed energy (255.413 MJ/ha), fuel energy (93.463 MJ/ha) and engine energy (0.821 MJ/ha), so that the total energy consumption is 358.952 MJ/ha.*
Keywords: *energy consumption, panting activity, rice transplanter, garminforerunner 35*

1. Introduction

Rice is a cereal crop that is consumed almost all over the world, this is because rice is adaptive so it is possible to grow in various types of soil dan different climatic conditions (Ferrero &Tinarelli, 2008). Asia countries consume around 90% of rice which can meet the energy needs of 50% -80% calories. For the people of Indonesia, rice is a food source that has economic potential (Negalur et al., 2016). Half of the world's population depends on rice as the main food crops (Lim et al, 2012).

National rice production data in 2016 amounted to 81,382,451 tons. Rice production in West Sumatera in 2016 amounted to 2,503,452 tons, but each city/regency in West Sumatra has different statistical data on rice production. Padang Pariaman Regency, is ranked third in producing rice for the West Sumatera Province, rice production data in Padang Pariaman Regency in 2016 amounted to 287,046 tons (BPS, 2016).

Rice planting activities are generally still done manually, the constraints in the activities of manual rice planting are requires time and a lot of labour, in the rice production area now it is getting hard to finding labour especially for seed planting activities (Sutedjo&Kartaspoetra, 1988). The growth of labour for the process of planting seedlings continues to decrease by 2.2% (BPS, 2016). The decrease in the number of labor in the agricultural sector is caused by the wage of labour which is not comparable with the energy

https://doi.org/10.32530/ jaast.v4i1.152

expended (Sutedjo&Kartaspoetra, 1988). Nagari Aie Tajun has Transplanter Tanikaya TK RW 2W - 800N produced by PT. Tanikaya Multi Sarana. However, until now the rice transplanter machine is still rarely used because farmers think the rice transplanter machine is still less efficient, because the rice transplanter machine uses gasoline as its main fuel. Gasoline is one type of fuel which is quite expensive, this causes the rice planting activities to require a large enough cost (Smaradhana et. al., 2019).

The working capacity of a rice transplanter is 25-30 man-day/ha with working time of 5-6 hours/ha depending on the expertise of the operator with 1-2 labor/ha. Based on the specifications of rice transplanter machine, it is already very feasible to use and is expected to help the farmers (Balitbangtan, 2016). Rice planting in Indonesia especially in Padang Pariaman Regency is generally still done manually with human energy. The work capacity of the process of planting rice manually is equal to 100-120 man-day/ha with a working time capacity of 200-240 hours/ha and requires of 10-15 labor/ha (Wahyuni, 2016). This shows that rice cultivation manually requires a lot of energy, labor and working time compared to planting using a rice transplanter machine.

Energy is an important factor in rice cultivation activity, starting from the land cultivation, planting, maintenance, harvesting, to post-harvest activities. Analysis of energy consumptions have been applied to previous studies on several agricultural commodities, such as: potatoes in Hamadan-Iran Province (Zangeneh et al., 2010), cucumbers in Iran (Mohammadi and Omid, 2010), tomatoes in Turkey (Ozkan, et.al., 2011), and rice in Malaysia (Bockari-Gevao et al., 2005 and Muazu et al., 2015). Rahmat (2015) mention 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. Planting activities require about 15% of the total energy in rice cultivation (Muazu et al, 2015). Imprecise rice planting activities such as mistakes in determining the planting system, mistakes in determining the clumps in each planting hole and other errors can lead to a greater energy input effect than expected and it can also increase the cost of rice production. Energy input when planting rice manually comes from human energy and seeds, while when planting rice using rice transplanter energy input comes from humans, seed energy, fuel, and machinery (Muazu et al., 2015).

Analysis of human energy released in the process of planting rice in this study was using *Garmin Forerunner* 35 as a tool to measure human energy released, measurement of human energy in real time which is used to improve the accuracy of data in calculating human energy. Devices that are equipped with optical heart rate sensors are expected to produce more accurate calculations. The objectives of this study are to determine the total energy consumption of rice planting and to analyse the performance of rice transplanter during rice planting in West Sumatra, Indonesia.

2. Methods

This research was carried out in the rice cultivation area in NagariAieTajun, Padang Pariaman Regency which is located at 0°11'- 0°49' South Latitude and 98°36'-100°28' East Longitude. Rice planting activities in this study were done manually and using a rice transplanter machine. This research was conducted on four demonstration plots owned by farmers in Nagari AieTajun, Padang Pariaman Regency (Figure 1). Average dame plot size is 0.01ha/plot. The equipment used in this study were Rice Transplanter / TK RT 2W-800N (with the specification working width 1227 mm, working depth 38,0 mm), digital stopwatch (Anytime-A023), Garmin Forerunner 35, Heart Rate Monitor (HRM), Garmin Connect Software, Garmin GPS (GPSmap62sc), digital scale 180 kg, application of Geographic Information System 10.5, measuring cup 1000 ml. The materials used in this study were variety rice seeds IR42.

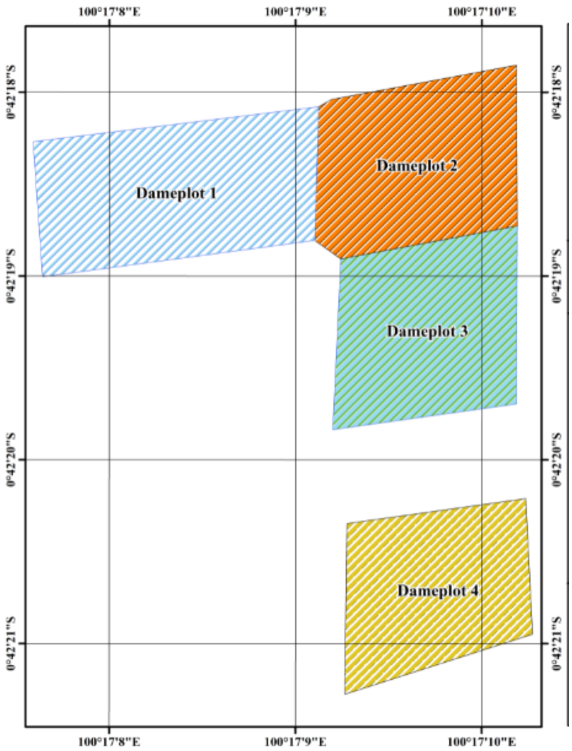

Figure 1. Description demonstration plot

The data are the performance of rice transplanter machines and the use of energy in the rice planting process using a rice transplanter. The performance data of the rice transplanter machine is obtained from several parameters such as the working speed, theoretical work capacity, effective work capacity, the number of holes are not embedded and the number of falling plants. Processing and analysis of energy data in the planting process using a rice transplanter machine such as human energy in real time using the Garmin Forerunner 35 and using a conversion table.

Rice Transplanter Performance Test

Working speed

The working speed is calculated from the forward speed of the planting machine which can be calculated by the following equation (Santosa et al., 2017):

$$V= \frac{S}{t} \text{ [m/s]} \quad (1)$$

where: S – distance travelled of rice transplanter, m; t – planting time of rice transplanter, s.

Effective work capacity

The effective work capacity of a rice transplanter is the average ability of a machine to plant on a land. The effective work capacity of the machine is obtained by calculating the total time to operate the machine includes turning time, seed filling time, seed planting time and adjustment time. Effective work capacity can be calculated by the following equation (Santosa et al., 2017):

$$KKe = \frac{A}{T} \text{ [ha/hours]} (2)$$

where: A – total area planted with rice transplanter, ha; T – total time for planting with rice transplanter, hours.

Theoretical work capacity

Theoretical work capacity is the ability of machine to work in a land. The amount of theoretical work capacity is influenced by the width of the planting, the speed of the machine, environmental conditions and operator expertise. The theoretical work capacity can be calculated using the following equation (Santosa et al., 2017):

$$KKt = 0.36 \text{ x } L \text{ x } V \text{ [ha/hours]} (3)$$

where: L – width of the planting of rice transplanter, m; V – working speed of rice transplanter, m/minute.

Work efficiency

The work efficiency is obtained from a comparison between effective work capacity and theoretical work capacity. The work efficiency can be calculated with the following equation (Santosa et al., 2017):

$$E = \frac{KKe}{KKt} X100\% \text{ [\%]} \quad (4)$$

where: KKe effective work capacity, ha/hours; KKt – theoretical work capacity, ha/hours.

Percentage of falling plants

Percentage of fallen plants is calculated from plants that have a very tilted position and almost hit the soil after being planted by a rice transplanter machine. Percentage of falling plants is obtained by comparing the number of fallen clumps to the number of main clumps, it can be calculated with the following equation (Santosa et al., 2017):

$$PTR = \frac{TR}{TP} X100\% \text{ [\%]} \quad (5)$$

where: TR – the number of fallen plants, clumps; TP – the number of main clumps, clumps.

Percentage of Holes Not Embedded

The percentage of holes that are not embedded can be calculated using the following formula (Lia, et al., 2016):

$$PLT= \frac{LTT}{TP} X100\% \text{ [\%]}(6)$$

where: LTT – number of holes that are not embedded, holes; TP – the number of main clumps, clumps.

Energy Data Analysis

Human Energy. Calculation of the amount of energy expended by farmers when planting is obtained in two ways, real-time energy measurement using the Garmin Forerunner 35 and Heart Rate Monitor (HRM) and energy measurement by calculating using a conversion table value.

The energy readings displayed by Garmin Forerunner 35 are in calories. The data is then multiplied by 4.1868×10−3 as the conversion factor calories into MJ. Then, the human energy data will be divided by the total land worked out so that human energy is obtained in units of MJ/ha. Meanwhile, the calculation of human energy by the conversion method is calculated using the equation below (Muazu et al., 2015).

$$HE = \frac{n \text{ x } T \text{ x } fk}{A} \text{ [MJ/ha]}(7)$$

where: N – number of labor; T – total working time, hours; fk – energy conversion factor, 1.96 MJ/hour; A – area of cultivated land, ha.

Seeds energy

The energy of rice seeds planted in a rice field can be calculated based on the weight of the seeds used when planting. Rice seed energy can be calculated using the following equation (Muazu et al., 2015):

$SE = \frac{Sw \text{ x } fk}{A}$ [MJ/ha](8)

where: Sw – mass of seed used, kg; fk – seed energy conversion factor, 13.22 MJ/hour; A – area of cultivated land, ha.

Engine energy

The agricultural machine commonly used in rice planting is a rice transplanter. The calculation of engine energy can be calculated using the following equation (Muazu et al., 2015):

$EM = \frac{fk \text{ x } W}{Fc \text{ x } t}$ [MJ/ha](9)

The value of Fc is obtained from the area of land divided by the effective working time, for the effective working time is obtained from the total time spent working subtracted by the time lost which includes turning time and time when filling seeds, which can be completed using the following equations:

$Fc = \frac{A}{T}$ [MJ/ha](10)

where: fk – engine energy conversion factor, 62.70 MJ/hour; W – machine mass, 175 kg; economic life of the machine, 62320 hour; effective capacity of the machine, ha/hour; A – area of cultivated land, ha; T – effective working time, hours.

During the rice cultivation activities will be obtained the effective time of the machine working in the field. The effective time is obtained from the difference between the total time total to the lost time (turn time, operator rest time, machine tuning and so on). Then the effective working time can be calculated with the following formula:

$T = Ts - Th$ [hours](11)

where: Ts – total working time, hours; Th – lost time, hours.

Fuel energy

Every use of the engine will definitely need fuel as a source of driving energy. The rice transplanter machine uses gasoline as fuel. Consumption of fuel used is obtained from the difference between the initial fuels before the engine operates to the remaining fuel after the engine operates. Fuel energy can be calculated using the following equation (Muazu et al, 2015):

$FE = \frac{fkons \text{ x } \rho \text{ x } fk}{A}$ [MJ/ha](12)

where: fkons – fuel consumption, liters; ρ – density of gasoline, 42,30 kg/l; fk – fuel energy conversion factor. MJ/kg; A – area of cultivated land, ha.

3. Results and Discussion

Field Performance Test

Performance test on the rice planting process in NagariAieTajun, Padang Pariaman Regency, were carried out on eight rice field demonstration plots.

Working Speed

The working speed produced in the process of planting seedlings is obtained from the result of the distance travelled divided by the travel time of planting. The working speed of planting in one demonstration plots is taken as 4 repetitions, the average speed of a rice transplanter machine on each demonstration plots can be seen in Table 1.

Table1. Working speed of rice transplanter

Demonstration Plot	Working Speed (m/s)
1	0.638
2	0.652
3	0.581
4	0.662
Average	0.633
Standard Deviation	0.036

The average of the speed of planting rice using a rice transplanter is 0.633 m/s or 2.27 km/hour. Based on the specifications of the rice transplanterTanikaya model TK RT2W-800N, the working speed is 2.0 km/hour. The engine speed obtained in this study is greater than the engine speed based on engine specifications by the factory. A rice transplanter rice planting machine is capable of driving at speeds of 1.5 to 2.5 km/hour (Widayati, 2013). Working speed from research are in the range of working speed values from the literature. This is because the land used for planting in conditions suitable to the machine so that farmers do not have difficulty in operating the machine.

Effective Work Capacity

Effective work capacity is the actual work of a rice transplanter machine from the speed of each demonstration plots. The smaller the total planting time, the greater the resulting capacity and vice versa. The effective work capacity of the rice transplanter machine during the rice planting process at each demonstration plots can be seen in Table 2.

Table2.Effective work of rice transplanter

Plots	Effective Work Capacity (ha/hour)
1	0.185
2	0.211
3	0.212
4	0.279
Average	0.222

Plots	Effective Work Capacity (ha/hour)
Standard Deviation	0.040

The average of effective working capacity is 0.222 ha/hour. Based on the specifications of the rice transplanterTanikaya model TK RT2W-800N by the factory, the effective field capacity is 0.17 ha/hour. The effective work capacity of the machine obtained in this study slightly exceeds the value of the machine specification. This means the machine works very well in the field. The effective work capacity of rice planting using a rice transplanter machine is greater than the value of the manually which is 0.222 ha/hour and 0.065 ha/hour. The difference is caused by the time used in the process of planting rice manually is greater than using a rice transplanter machine. This is because limited labor in the planting process. Effective work capacity is also influenced by various things, including work speed, work time and operator skills. The working capacity of the machine will depend on the type of engine, available power sources, working conditions and operator skills.

Theoretical Work Capacity

The theoretical work capacity of a rice transplanter machine is carried out by measuring the working speed and width of the planting of rice transplanter. The width of the planting (L) on each demonstration plots are set to the same size, 1.2 meters. The theoretical work capacity of the rice transplanter machine during the planting process on each demonstration plots can be seen in Table 3.

Table 3. Theoriticalwork capacityofricetransplanter

Plots	Theoretical Work Capacity (ha/hour)
1	0.276
2	0.282
3	0.251
4	0.289
Average	0.274
Standard Deviation	0.016

The average theoretical work capacity of the rice transplanter machine is 0.274 ha/hour with an average working speed (Table 1) of 0.633 m / sec. The greater the speed of planting, the greater the value of the terrorist work capacity obtained (Santosa et al, 2017). The highest of engine speed (Table 1) when planting rice is in demonstration plot 4 which is 0.662 m/s, the largest theoretical working capacity is in demonstration plot 4 which is 0.286 ha/hour. Then the theoretical work speed data from this study is in line with the literature that is the greater the speed, the greater the value of the theoretical work capacity.

The average of theoretical work capacity of rice cultivation manually from this study is equal to 0.053 ha/hour. Compared to planting with a machine, the manual value is lower.

This is caused by the speed of work of farmers in manual planting is much lower compared to speed of work in planting rice using a machine.

Work Efficiency

The work efficiency is used to determine the feasibility of the machine used in the rice planting process. The work efficiency in rice planting activities can be seen in Table 4.

Table 4. Work effisiencyofricetransplanter

Plots	Work efficiency (%)
1	67.029
2	74.823
3	84.462
4	97.552
Average	80.967
Standard Deviation	13.157

The average of work efficiency in rice planting using rice transplanters is 80.967%. Based on the specifications of the rice transplanterTanikaya model TK RT2W-800N by the factory the work efficiency is 84.1%. The work efficiency of rice transplanter machine obtained from research data is not much different from the specifications. So, it can be said the use of a rice transplanter machine in the process of planting rice in NagariAieTajun Padang Pariaman is feasible to use. Comparison of the value of the efficiency of rice planting using a machine and manually obtained far different. The work efficiency value of rice planting using a rice transplanter machine is greater than the manually which is 80.967% and 13.709%. It shows that planting rice using a rice transplanter machine is far more efficient than planting rice manually.

Percentage of Falling Plants

Percentage of Falling Plants is fallen rice seeds (drooping) when the rice transplanter machine operates, the results of which can be seen in Table 5.

Table 5. Percentage of falling plants of rice transplanter

Parameter	Demonstration Plot				Average	Standard Deviation
	1	2	3	4		
Number of Main Clumps (Clumps)	58.824	48.006	49.800	36.252	48.220	9277.57
Number of Fallen Clumps (Clumps)	254	307	298	174	258.25	60.75
Fallen Plants (%)	0.43	0.64	0.60	0.48	0.56	0.1

The average percentage of fallen plants is 0.56%. Percentage value of felling plants depends on the number of plants that crossed the crossing. The largest percentage of transplanting plants came from demonstration plot 2 with a value of 0.64% of fall crops. The reason for the high percentage was when planting activities using rice transplanters the land was still very runny so as to increase the number of clumps that had fallen down. This is in line with the literature on the factors that influence the percentage of fallen crops when planting rice using rice transplanters, one of which is caused by water in the flooded so that the seeds are not embedded in the soil (Santosa et al, 2017).

The smallest percentage of felling plants was in demonstration plot 1 with a percentage 0.43%. This is because the amount of water contained in the demonstration plot is appropriate. The amount of water inside the demonstration plot must be considered before planting. This is a way to minimize the number of fallen plants when the machine is working. The process of planting rice manually does not have a felling percentage value. This is due to the fact that rice clumps are planted directly so that all clumps are planted in an upright position and no one falls.

Percentage of Holes Not Embedded

Percentage of holes not embedded when the rice transplanter machine is operating can be seen in Table 6.

Table 6. Percentage of falling plants of rice transplanter

Parameter	Demonstration Plot				Average	Standard Deviation
	1	2	3	4		
Number of Main Clumps (Clumps)	58.824	48.006	49.800	36.252	48.220	9277.57
Number of Holes That Are Not Embedded (holes)	263	387	329	252	307	62.83
Holes That Are Not Embedded (%)	0.45	0.81	0.66	0.70	0.64	0.15

The largest percentage of not embedded holes came from demonstration plot 2, which was 0.81%. The smallest percentage of not embedded holes was in demonstration plot 1, which was 0.45%. The average percentage of holes that are not embedded is 0.64%. Holes are not planted due at the time of seeding less dense so that during operation of the tweezers to move the seedlings to the field cannot take only the seeds so that only tweezers enter the ground without planting rice seeds.

Energy Analysis

The data obtained include fuel consumption data (l), total labor (n), total time of planting activities (hours), mass of seeds used (kg). This literature study data will be used to analyze and calculate the results of the analysis of total energy analysis in rice cultivation (Table 7).

Table 7. Total energy in rice planting using rice transplanter

Energy Source	Demontration Plot				Average
	1	2	3	4	
Human Energy (MJ/ha)	9.944	9.456	9.192	8.427	9.225
Seed Energy (MJ/ha)	269.392	262.329	250.469	239.460	255.413
Fuel Energy (MJ/ha)	120.067	106.083	73.514	74.188	93.463
Engine Energy (MJ/ha)	0.965	0.846	0.832	0.642	0.821
Total	400.368	378.714	334.007	322.717	358.952

The total energy consumption in rice planting using rice transplanters is obtained from several energy input parameters which include human energy, seed energy, fuel energy and engine energy. Calculation of energy consumption in rice cultivation using rice transplanters in each demonstration plot. The average value of total energy consumption in rice planting activities using rice transplanters is 358.952 MJ/ha.

Based on Table 7, an average value of human energy consumption is 9.225 MJ/ha. Human energy consumption in the process of planting rice using a rice transplanter is quite small because the work time of the operator in completing planting on a land is shorter. The value of human energy consumption in the process of rice planting depends on the length of time the work is planted (Safa et al, 2010). Rice planting using a rice transplanter can shorten the operator's work time so that human energy consumption can be minimized. This working time causes the value of human energy in the process of planting rice using a rice transplanter is smaller than the consumption of human energy in the process of planting rice manually.The average value of energy consumption in rice planting activities using rice transplanters can be seen in Fig. 2.

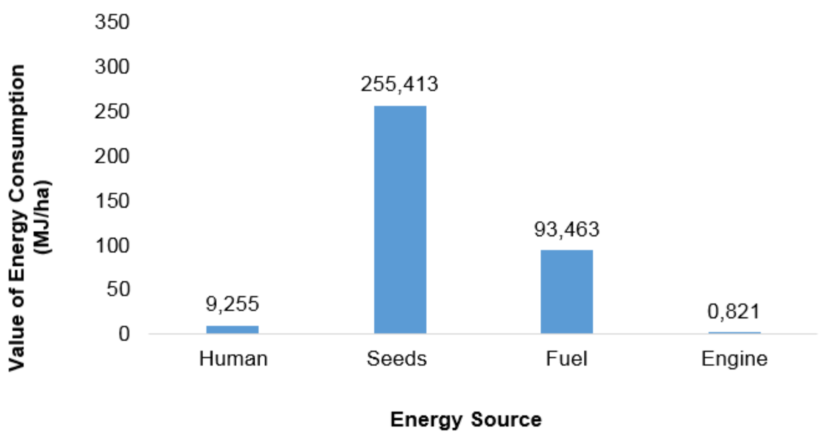

Figure 2. Energy consumption in rice planting using rice transplanter

Based on Fig.1, the average value of the largest energy consumption comes from seed energy input that is equal to 255.413 MJ/ha. The greater the area of land used, the more seeds will be used and the smaller the land, the smaller the number of seeds used. The number of seeds used in the process of planting each demonstration plot will affect the value of seed energy consumption, the greater the seeds used, the greater the seed energy value. The biggest energy consumption comes from seed energy, this is because seeds are a major aspect of the rice planting process.

The smallest energy consumption comes from engine energy that is equal to 0.821 MJ/ha, due to in the rice planting process, operators who operate the machines are already skilful so to do a demonstration plot of land only requires a little time. When working time in completing a demonstration plot of land is getting smaller, then the value of the effective capacity will be obtained which is quite large. This is what causes the machine's energy consumption produced to have a small value. The conversion value for the rice transplanter machine used will also affect the amount of machine energy consumption. The average of fuel energy consumption is 93.463 MJ/ha. Fuel energy consumption for each demonstration plot has a different value depending on the amount of fuel used for each demonstration plot. The more fuel used, the greater the fuel consumption obtained. The total value of fuel energy consumption depends on the fuel used (Soltani, et al., 2013). The process of planting rice using a rice transplanter can be seen in Fig.3.

Figure 3. Rice planting process using rice transplanter

4. Conclusions

It can be concluded that performance test of rice transplanter machines including the average of working speed is 0.63 m/s. The average of effective work capacity is 0.22 ha/hour. The average of theoretical work capacity is 0.27 ha/hour. The average of efficiency of planting work is 80.976%. Percentage of felling plants and the percentage of holes not embedded when the rice transplanter machine works is smaller than 1%. So, it can be said the use of a rice transplanter machine in NagariAieTajun Padang Pariaman is very feasible to use. Analysis of energy input in rice planting activities using rice transplanters which are examined in four aspects of energy including human energy, seed energy, fuel energy and engine energy which have a total energy consumption of 394.534 MJ/ha.

5. Acknowledgement

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

References

Balitbangtan. (2016). Teknologi Persemaian Padi Sistem Depong, Tray No.006/DLS-LPTP/2016. West Sulawesi, Indonesia: Balitbangtan.

BPS. (2018, August 17). Luas Panen (ha), ProduksiPadi (ton), dan Produktivitas Padi di Sumatera Barat. Retrieved from: https://www.sumbar.bps.go.id.

Bockari-gevao, S. M., W. Ishak., and A. Yahya. 2005. Analysis of Energy Consumption in Lowland Rice-Based Cropping System of Malaysia. Songklanakarin J. Science Technology (27): 819–826.

Ferrero, A.&Tinarelli, A. (2008), Rice cultivation in the EU ecological conditions and agronomical practices. Pesticide Risk Assessment in Risk Paddies: Theory and Practice, 1–24.

Sutedjo, M. M. &Kartaspoetra, A.G. (1988). Budidaya Tanaman Padi di Lahan Rawa Pasang Surut. Jakarta, Indonesia: PT Bina Aksara.

Lia, A. (2016). Studi Tekno-ekonomi Mesin Tanam Indo Jarwo Transplanter 2: 1 di Kabupaten Dharmasraya dan Kabupaten Padang Pariaman. Doctoral dissertation, Universitas Andalas.

Lim, J. S., Abdul Manan, Z., Wan Alwi, S. R.&Hashim, H.(2012). A review on utilisation of biomass from rice industry as a source of renewable energy.*Renewableand Sustainable Energy Reviews*, 16(5), 3084-3094.

Mohammadi, A. and Omid, M. 2010. Economical analysis and relation between energy inputs and yield of greenhouse cucumber production in Iran. Applied Energy. Elsevier Ltd, 87 (1): 191–196.

Muazu, A. 2015. Modeling for Energy Optimization in Wetland Paddy Production in Malaysia. [Disertasi]. Universiti Putra Malaysia. Malaysia. 373 hal.

Muazu, A., Yahya, A. and Ishak, W. I. W. 2015. Energy audit for sustainable wetland paddy cultivation in Malaysia. Energy. Elsevier Ltd (87): 182–191.

Negalur, R.B., Halepyati, A. S. & Rao, K. N. (2016), Influence of age and number of seedling on yield and nutrient uptake by machine transplanted rice.*International Journal ofBio-resource and Stress Management*, 7(3), 393-397.

Ozkan, B., Ceylan, R. F., and Kizilay, H. 2011. Comparison of Energy Inputs in Glasshouse Double Crop (Fall and Summer Crops) Tomato Production. Renewable Energy. Elsevier Ltd, 36 (5): 1639–1644.

Rahmat, R. 2015. The Importance of an Energy Audit for Energy Efficiency (Pentingnya Energi Audit untuk Efisiensi Energi). Environment Article. https://environment-indonesia.com/audit-energi-adalah/ [accessed on 16 October 2018].

Soltani, A., Rajabi, M. H., Zeinali, E., &Soltani, E. (2013). Energy inputs and greenhouse gases emissions in wheat production in Gorgan, Iran. Energy, 50, 54-61.

Safa, M., Samarasinghe, S., dan Mohssen, M. 2010. Determination of Fuel Consumption and Indirect Factors Affecting It in Wheat Production in Canterbury, New Zealand. Energy (35): 5400–5405.

Santosa, F. I., &Adiani, L. (2017). Studi Terkno-Ekonomi Mesin Tanam Indo Jarwo Transplanter 2: 1 Di Kabupaten Dharmasraya Dan Padang Pariaman. Teknik Pertanian J. Prosiding Seminar Nasional FKPT-TPI

Smaradhana, L. T., Sandra, S., & Djoyowasito, G. (2019). Financial Analysis of a Rice Transplanter Usage in Farming Activity at the Junrejo District in Batu City. WACANA, Jurnal Sosial dan Humaniora, 22(4).

Wahyuni. (2016).PenanamanPadiKonvensional).Bogor, Indonesia: Bumi Aksara.

Widayati S. Winardi. (2013). Mesin tanam bibit padi jarwo, gantikan 20 tenagakerja. Majalah Sains Indonesia. 23:18– 20.

Zangeneh, M., Omid, M. and Akram, A. 2010. A Comparative Study on Energy Use and Cost Analysis of Potato Production Under Different Farming Technologies in Hamadan Province of Iran. Energy 35 (7): 2927–2933.