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Realtime measurement of human labor energy for primary tillage operation in paddy cultivation

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Abstract. Human labor energy still provides a large and dominant contribution in rice cultivation in Indonesia. This study is specified to determine human energy needed for primary tillage operation in paddy cultivation practices in Padang Pariaman, West Sumatera Indonesia. The objectives of this research are to analyze human energy expenditure for primary tillage operation and to compare between real-time measurement and conversion factor of energy. The data were collected with three different plot areas with average size 30 m × 25 m. The analysis of human energy consumption conducted by two methods (predicted energy using conversion factor value of energy and real-time energy using *Garmin Forerunner 35*). The result shows that the real-time measurements of labor energy expenditure for primary tillage operation were 17.7291, 19.2857, and 12.2483 MJ/ha, respectively. However, the labor energy defined by the conversion factor were 13.3568, 14.0141 and 12.7498 MJ/ha, respectively. Thus, tillage operation with average heart beat rate was 127 bpm, it could be categorized as heavy work. This information is needed as a basis to improve and recommend designing of agricultural equipment and machinery, and also tools to reduce the use of labor energy.

Keywords: Human Labor Energy; Rice Cultivation; Energy Expenditure

1. Introduction

Paddy as a primary crop in the world which is important and as primary food, especially in Asia [1], [2]. Paddy as cereal crop commonly can grow up in different climate, so that it was cultivated mostly other than wheat [3], [4], and world population depends on it [5], [6]. *Statistics of Indonesia* reported that population in Indonesia which work in agricultural sector in 2017 was 29.68 %, or equals 35,923,886 people [7].

The highest source of livelihood as a farmer shown that many potential lands to be cultivated. But, it was not indicated good yield. Reported by *BPS* of West Sumatera (2018) that only 287,046 tons production of paddy (11.47 %) from total paddy yield in West Sumatera [8]. The low productivity can be affected by incorrect handling, one of them is tillage. For best handling we can use analysis study of input energy, especially on tillage activities [9].

Recent studies has done it, for example is conservation-tillage agriculture [10], analysis of energy consumption in lowland rice [2], [11], alternative tillage and crop in wheat after rice [12], evaluation of alternative tillage in rotation of rice-wheat [13], effect of different tillage of wheat [14], and energy audit in wetland paddy in Malaysia [115].

Tillage plays important rule to prepare seedbeds, mix soil material and fertilizer, push down weeds, control insect pests and some diseases, and decomposition organic material [10]. Traditional cultivation use man or animal power. In modern cultivation, tillage activities uses tractor or hand tractor that handling by a labor and even using robotic tractor. Indonesia, especially West Sumatera use hand tractor that handled by a labor for tillaging. Even though, study which concern to know how much energy input in tillage activities still yet done in West Sumatera. The objectives of this research are to analyze human energy expenditure for primary tillage operation and to compare between real-time measurement and predicted energy using conversion factor of energy.

2. Methodology

2.1. Studies of field and time

The field study was conducted at paddy field (0º40'42.47"S and 100º16'39.42"E and elevation 82 ft), Lubuk Alung Subdistrict, Padang Pariaman District, West Sumatera, Indonesia. The study has done in August 2018 at the same time for every paddy field. The study was conducted with three plot areas with the average size was 30 m × 25 m, respectively paddy field number 1, 2, and 3 (Figure 1).

Figure 1. Location of Paddy Field

2.2. Studies of materials and tools

The materials used on this studies were hand tractor and work sheet. The tools used were stopwatch to measure time ellapsed for tillage operation, garmin *forerunner* 35 and heart beat rate monitor strap to detect heart beat and Calories, GPS to mark the place, and laptop (Acer, Aspire V3-471) which has been installed some features like Garmin Express v6.6.0.0 (to convert the data from garmin *forerunner* 35), ArcMAP v10.3 (to convert marking place and export the data to kmz file), and Google Earth Pro v7.3.2.5491 (positioning marking point in map, built polygon as paddy field, and measuring polygon area).

2.3. Energy analysis

The labor energy was collected for primary tillage operation. Time consumption is recorded using stopwatch. Human energy is computed using two methods, there are by using equation of conversion

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factor of energy and collecting by real-time measurement using Garmin F*orerunner* 35. To compute human energy using conversion factor value is described in Table 1. The Garmin F*orerunner* 35 recorded human energy in Calories, and then the value would be multiplied by 4.1868×10^{-3} and divided by field area (ha).

Figure 2. Garmin *Forerunner* 35 (Left) and *Heart Rate Monitor* (Right)

Garmin forerunner 35 will be mounted on the hand, while HRM is installed on the chest of the farmer. Garmin forerunner 35 and HRM will be connected / connected (Figure 2). The work system rather than Garmin Forerunner 35 relies on the optical heart rate (OHR) sensor located on the back of the device. This sensor uses LED lights to read the flow rate of blood vessels. While HRM will be connected with Garmin Forerunner 35 to help read heartbeat. Both of these tools are able to read speed and heart rate in the form of graphs, as well as work time, distance and total calories spent during work (Figure 14). In addition, this tool is also able to display the track (route) taken.

The value of human energy based on conversion factor is calculated using the following formula:

$$HE = \frac{n \times T \times C_f}{A} \text{HE} = \frac{nxTxCf}{A}$$

where HE HE is human energy (MJ/ha), nn is number of workers (decimal), TT is duration of working time (h), C_f Cf is the conversion factor of human energy (MJ/kg), and A A is field area used (ha).

Table 1. Conversion Factor of Energy in Paddy Cultivation

Item	Unit	Energi Ekivalen (MJ) unit^{-1}	Referensi
Human, tillage operation	hours	1,57	Abdullah *et al*. (1985)
Human, non tillage operation	hours	0,79	Abdullah *et al*. (1985)
Draft Animals	hours	2,78	Abdullah *et al*. (1985)

Source: Purwanta (2011)

2.4. Data analysis
Data analysis was performed using Microsoft Office Excel 2007 software to process descriptive data from observation parameters. In addition, SPSS 17 software used to measure the level of accuracy of sensors with measurement predicted energy (MJ/ha) and instantaneous energy (MJ/ha).

3. Results and discussion
Human energy for every plot areas shown in Table 2. The lowest human energy shown at plot 3 are 12.2483 MJ/ha and 12.7498 MJ/ha, respectively for realtime measurement and for computing

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equation. The data were collected in this study from three plot size area 30 m × 25 m. The lowest energy influenced by heart beat and working time.

Table 2. Human Energy of associated paddy lot

LOT	Predicted Energy (MJ/ha)	Real time Energy (MJ/ha)
1	13.3568	17.7291
2	14.0141	19.2857
3	12.7498	12.2483
Average	**13.3736**	**16.4210**

Figure 3 show that there is strong relationship between predicted energy using conversion factor value of energy and real time energy using *Garmin Forerunner 35,* due to the R^2 value is about 0.89. It means measuring energy using *Garmin Forerunner 35* can be used as a tool for real time measurement of human energy.

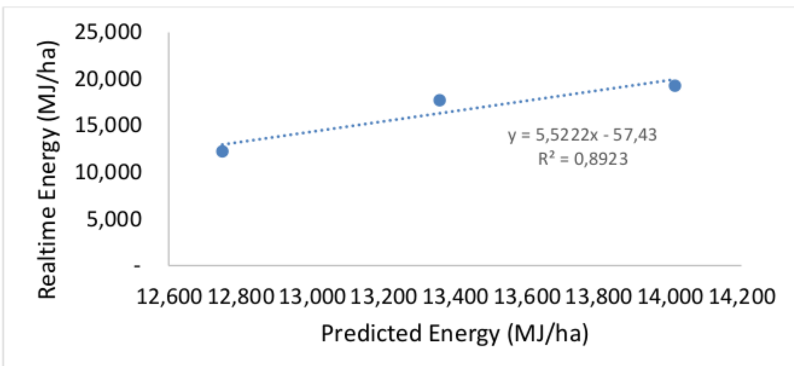

Figure 3. Comparing real time human energy and predicted energy

Whereas lower heart beat indicated that the operation is easier (Figure 4 to 6) and the working time given linear indicating to energy expenditure. The another factor which influenced is climate when tillage operating. For the plot 1 tilled at the morning (09.00 till end), the plot 2 tilled at 10.13 a.m till end when the day was sunny, and the plot 3 tilled at 14.47 p.m till end after rainy and the day was cloudy and rainy again before operation would be end. Physical condition of the operator when working also influenced. It's because the operator smoked before tilling for the second plot and he doesn't smoke when he would work at the plot 1 and 3. The volume of water in field was also dedicated in operation. The volume of water was in correct volume, it means the water is in proper volume based on paddy requirement. It was like reported by Bhushan *et al*. (2007) that existing soil, crop and climate conditions, and the efficiency and skill of operator were components site-spesificity depends [16].

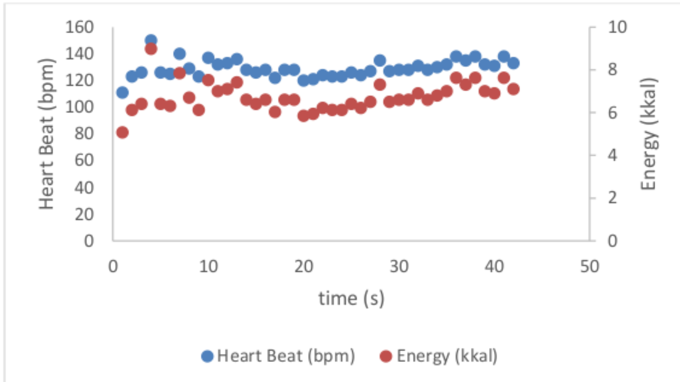

Figure 4. Heart Beat for Plot 1

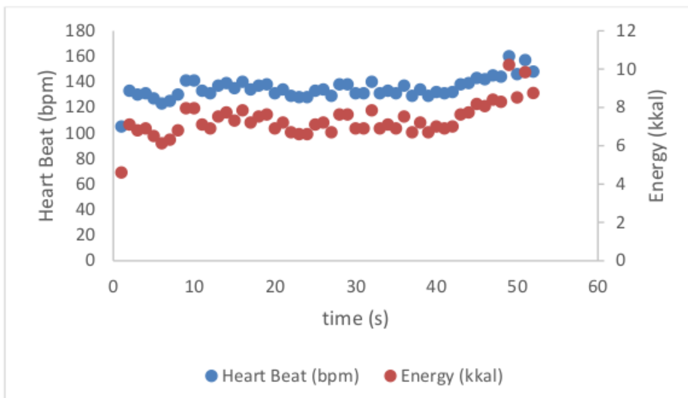

Figure 5. Heart Beat for Plot 2

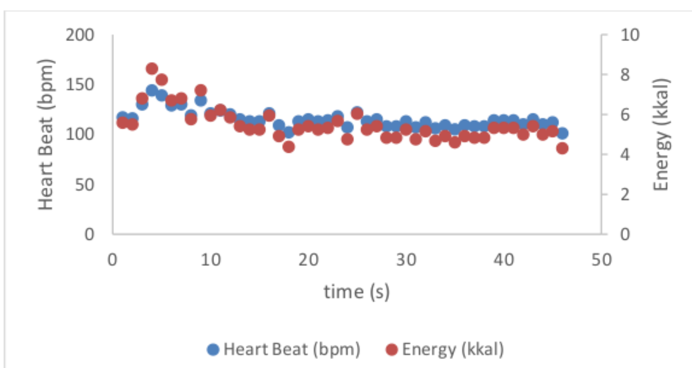

Figure 6. Heart Beat for Plot 3

4. Conclusions

The realtime measurements for energy consumption on tillage operation were 17.7291, 19.2857, and 12.2483 MJ/ha, respectively. However, energy expenditure of labor for tillage operation defined by the conversion factor were 13.3568, 14.0141 and 12.7498 MJ/ha, respectively. The lowest input energy at plot 3, 12.2483 and 12.7498 MJ/ha for realtime measurement and equation, respectively. The other factor which influenced when operating were weather condition, soil texture, water on field, and physical condition of labor. This information is needed as a basis to improve and recommend designing of agricultural equipment and machinery, and also tools to reduce the use of labor energy.

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