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Energy Consumption on Tillage Operation in Low Land Paddy Cultivation

Energy Consumption on Tillage Operation in Low Land Paddy Cultivation

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Abstract. Energy consumption is important to know for efficient on using energy. This study is determined using energy for tillage operation in low land paddy cultivation in Padang Pariaman, West Sumatera Province. The aims of this study is to identify any energy expenditure which used for tillage operation. The data were collected in five paddy field which was located at $0°40'41.63'' - 0°40'37.15''$ latitude and $100°16'39.64'' - 100°16'46.38''$ longitude and average areas is 792.4 meters-square. The energy expenditure were collected on tillage operation which are machinery, fuel, and human energy. All of the energy expenditure will be calculating by manual calculation (conversion factor of energy), exception human energy it also calculating by realtime measurement equipment (*Garmin Forerunner 35*). The biggest consumption energy occured at fuel energy and the lowest one is machinery energy. The fuel energy were 270.6195 and 314.6556 MJ/ha for the average of fuel energy on first and secondary tillage operation, respectively. For first and secondary tillage operation, the average energy of machine were 6.6683 and 9.2414 MJ/ha, respectively. Human energy shown the average energy expenditure on first and secondary tillage operation were 19.4979 and 24.5826 MJ/ha by equipment, while the energy calculation uses conversion factor were 14.8358 and 19.4979 MJ/ha.

Keywords: Energy Consumption; Tillage Operations; Low Land Paddy Cultivation

1. Introduction

Tillage is an important operation which doing in agricultural cultivation, for example in paddy cultivation. Tillage is an operation to prepare the land, which the output of the operation is soil puddled in minimum depth 25 cm [1]. The other functionn of this operation is weeding area, water leveling, restructure soil, and to increase soil fertility for the plant. Tillage operation usually done by the farmer at least twice in one planting season [2]. Tillage is an operation that include in paddy cultivation to maintaining the soil fertility, like: to make soil surface roughness, aerate the soil, increasing porosity, and to stimulate decompositioning [3]. Which is this operation concluded taht tillage operation as one factor to optimizing the plant's growth [4].

Talking about tillage as one of the agricultural process, it can not be merged of energy. Agricultural process is one of the most consumer in terms of input energy, such as machinery, human power, fertilizer, electrical and others [5]. Recent dtudy was summarized which is on tillage operation at least need three inputs energy (machinery, fuel, and labour) [6].

The aims of this study are to reported energy distribution on every energy resources, to identify the most energy expenditure, and to compare the human energy which solved beetwen by conversion factor calculation and realtime measurement (by using garmin forerunner 35 and HRM-strap).

2. Methods

This study has done for 2 months, started on August to September. This study has done at five paddy fields area is 792,4 m.sq, where located at $100°16'39.64'' - 100°16'46.38''$ longitude and $0°40'41.63'' - 0°40'37.15''$ latitude (Figure 1). This study used experimental methods. The tools that used in this study are hand tractor-Yanmar TF 75, garmin *forerunner* 35, heart rate monitor strap (HRM-strap), stopwatch, measuring glass, GPS, and laptop. While the materials used are paddy fields and fuel.

Figure 1. Paddy Fields

Tillage operation has been done for two times. The intervals between first and secondary tillage is 13 days. Some parameter that analyzed are machinery energy, fuel energy, and labour energy. Several formula that used are:

2.1 Machinery Energy

In agricultural practices, any several machines that used. Those are hand tractor, tractor 4WD, transplanter, sprayer, rotary tiller, and eachothers. The machine that used in tillage operation on paddy field is hand tractor. Every working of machine will be give energy expenditure. To know how much the machinery energy, it can be used this formula [6]:

$$ME = \frac{Cf_m \, x \, m}{FC \times E_t} \quad (1)$$

Where ME is machinery energy ($MJ.ha^{-1}$), Cf_m is conversion factor for machine ($MJ.kg^{-1}$), m is mass of the machine (kg), FC is field capacity that should be gotten by dividing paddy field areas with working time ($ha.h^{-1}$), and E_t is economic life time of machine (h).

2.2 Fuel Energy

Hand tractor is not be able separate from fuel. It's because the power source of engine came from fuel. Fuel that used by machine also having energy. The fuel energy could be know by using this formula [6]:

$$FuE = \frac{Fu_c \times Cf_{fu}}{A} \quad (2)$$

Where FuE is fuel energy ($MJ.ha^{-1}$), Fu_c is total of fuel consumption (L), Cf_{fu} is conversion factor for fuel ($MJ.L^{-1}$), and A is total areas (ha).

2.3 Labour Energy

Machines as tool which can not separate from agricultural process, certainly need labour to operate them. This study using two manner for calculating the labour energy. Those are manual calculating (equation 3) and realtime calculating (equation 4). For manual calculating it can be solved by using this formula [6]:

$$LE_m = \frac{n \times t \times Cf_l}{A} \quad (3)$$

Where LE_m is labour energy by manual calculation ($MJ.ha^{-1}$), n is number of labour (no dimensional), t is working time (h), Cf_l is conversion factor for labour ($MJ.h^{-1}$), and A is total areas (ha).

Manual calculating is different with realtime calculating. Realtime calculating do by wearing the realtime equipments to labour (Figure 2). Where is the tools on left side (HRM-strap) is use on the chest of operator and the other side is use on operator's hand as like as watch (garmin *forerunner* 35). This tools should be connected to each other, where the HRM-strap should be recorded the operator's heart rate that should be read on garmin *forerunner* 35. The results of garmin *forerunner* are heart rate, total working time, distance, and calories (Figure 3). By this results we can used to calculate the labour energy with this formula:

$$LE_r = \frac{Cal \times (4{,}1868 \times 10^{-3})}{A} \quad (4)$$

Where LE_r is labour energy by realtime calculation ($MJ.ha^{-1}$), Cal is total calorie of labour (Calories), $4{,}1868 \times 10^{-3}$ is conversion factor of calorie (MJ/Calories), and A is total areas (ha).

Figure 2. Realtime Equipments

Figure 3. Results of The Equipment

3. Results and Discussion

3.1 Energy Distribution

This study discussed about tillage operation which had been conducted on August to September on 5 paddy fields (Figure 1). Tillage operation shown in this study at least need three input energy. Energy of this study was distributed as first and secondary tillage operation that shown in Figure 4a and 4b, respectively.

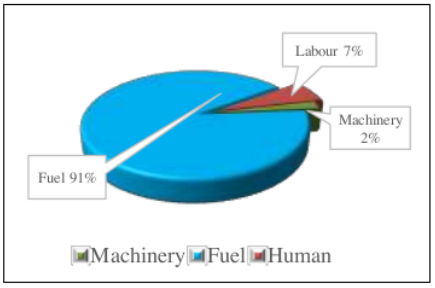

Figure 4. (a) Distribution Energy: First Tillage

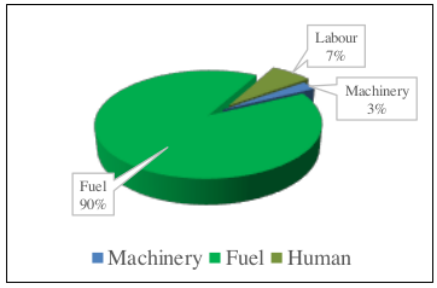

Figure 5. (b) Distribution Energy: Secondary Tillage

First and secondary tillage operation were described that labour energy both of them is equals, but in machinery and fuel have differences. In machinery energy, first tillage shown lower 1% than the secondary tillage. It caused by working time in secondary tillage more length than primary tillage. It seems like recent study that reported pudling activity (secondary tillage) is longer than first tillage [7]. It's because in secondary tillage need levelling paddy field area, which the levelling activity is not enough in one operation and at least two until four operation until the levelling land and soil puddling is good and ready for planting. For fuel energy, the highest is also on secondary tillage operation. It was affected by working time.

3.2 The Most Energy Expenditure

On tillage operation the most energy expenditure occured in fuel energy, exactly in the secondary tillage (1573.2779 MJ.ha-1). The smallest energy expenditure occured in machinery energy on first tillage operation (33.3414 MJ.ha-1). If we analyzed in each of input energy resources, both of the first and secondary tillage the highest is fuel energy, then human, and the smallest one is machinery. But, between first and secondary tillage operation, the highest energy occured in the secondary tillage operation for each input energy resources. Completely displayed in Table 1.

Table 1. Energy Expenditure

Paddy Fields	Energy Expenditure (MJ/ha)					
	Machinery		Fuel		Human	
	First Tillage	Secondary Tillage	First Tillage	Secondary Tillage	First Tillage	Secondary Tillage
1	6.0035	8.3228	308.1433	346.6612	17.7291	21.0022
2	3.8823	7.2281	198.9968	255.1241	13.9108	21.9050
3	9.4285	8.5213	276.6347	249.4247	24.4063	20.6329
4	6.2989	9.6869	254.5013	322.7822	19.2857	24.5054
5	7.7282	12.4480	314.8214	399.2857	22.1574	34.8673
Total	**33.3414**	**46.2071**	**1353.0975**	**1573.2779**	**97.4893**	**122.9129**

3.3 Human Energy

In this study, measurement of human energy has been done in two ways. They are realtime measurement (equipment) and conversion factor calculating. The first and secondary tillage operation shown human energy which calculating by conversion factor and equipment were 74.1791 and 97.4893 MJ.ha-1 then 102.8032 and 122.9129 MJ.ha-1, respectively (Table 2).

Table 2. Measurement of Human Energy

Paddy Fields	Energy Activities Measuring			
	First Tillage		Secondary Tillage	
	Conversion Factor	Equipment	Conversion Factor	Equipment
1	13.3567	17.7291	18.5168	21.0022
2	8.6374	13.9108	16.0814	21.9050
3	20.9769	24.4063	18.9585	20.6329
4	14.0140	19.2857	21.5518	24.5054
5	17.1940	22.1574	27.6947	34.8673
Total	**74.1791**	**97.4893**	**102.8032**	**122.9129**

Figure 5 shown R.square for firt and secondary tillage operation 0.9835 and 0.8799, respectively. It means, 98.35% conversion factor calculating affects equipment calculating on first tillage and 87.99% conversion factor calculating affects equipment calculating on secondary tillage. By using formula (CORREL) in Excel apps. we can identified how much relation between calculating by conversion factor and equipment. Correlation between conversion factor and equipment measuring were 99.17 and 93.80%, respectively for first and secondary tillage operation. It means that human energy which calculating by conversion factor and equipment has high correlation.

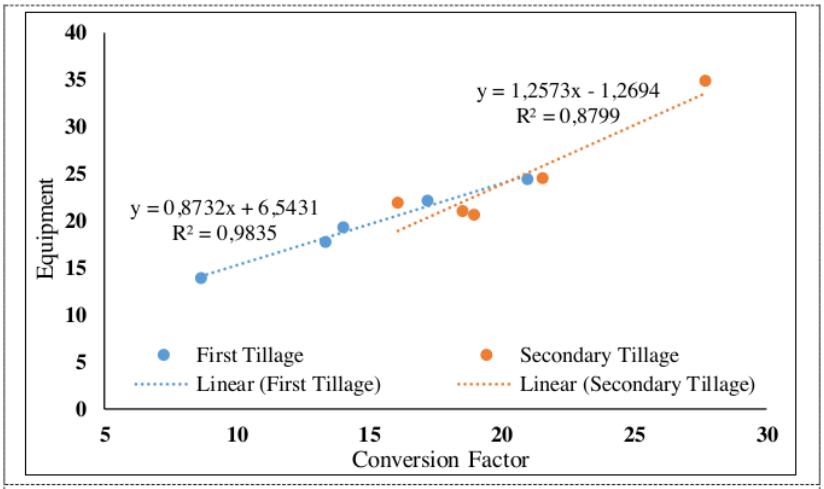

Figure 6. Measurement Relation of Human Energy

4. Conclusion

Tillage is one of important operation that needed to do in paddy cultivation. In this operation thr energy was distribute in three kind of energy, they are fuel, machinery, and human energy. Fuel spent energy as the bigest with 91% and 90%, then human energy with 7% and 7%, and the smallest is

machinery energy as much as 2% and 3 %, they are respectively for first and secondary tillage. Secondary tillage was spent energy expenditure more than primary tillage. The averages of human on first and secondary tillage operation were 19.4979 and 24.5826 MJ/ha by equipment, while the energy calculation uses conversion factor were 14.8358 and 19.4979 MJ/ha.

Acknowledgements
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