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Power Tiller Requirement for Cassava Cultivation at Estate Scale

Rufiani Nadzirah[1], Agus Dharmawan[2], Siswoyo Soekarno[1]✉, Indarto[1], Tasliman[1]

[1] Department of Agricultural Engineering, Faculty of Agricultural Technology, University of Jember, INDONESIA
[2] Department of Agricultural and Biosystem Engineering, Faculty of Agricultural Technology, Universitas Gadjah Mada

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✉Corresponding Author:
siswoyo.s@unej.ac.id

ABSTRACT

Indonesia's food needs continue to increase along with population growth. Land development for supporting the cassava food estate is one of the priority programs of the central and regional governments. The purpose of this study was aimed at determining the need for power tiller for land management based on land area. This research was carried out at the planned location of the cassava plantation in Gunung Mas Regency, Central Kalimantan in 2020. The data on the land area planned was determined from a topographic map, while the tractor needs were obtained from the calculation of field capacity. The area of land suitable for cassava cultivation is 1227.57 ha which is divided into 25 blocks. The basis for the number of tractors as power tiller needed is determined from the time of tillage work so that it requires working capacity variables, including data on land area, work speed, and width of the plow implement. The plow studied in this study used 2, 3, 4, and 5 blades of disc plows. The need for a tractor with a 5-blade disc plow is 2 tractors that work fully and take turns cultivating an area of 1227.57 ha in the span of one cassava cultivation period (7-8 months). If the disc plow used is less than five blades, it will affect the working width of tillage, so the work time will be longer and the need for power tiller will increase.

1. INTRODUCTION

Food reserves are a deterrent effect factor for national defense, because the strength of food reserves determines the country's survival in facing prolonged threats (war, disease outbreaks and natural disasters) as well as the threat of embargoes from other countries. At the end of the 20th century, about one in four of the world's population did not have food reserves to meet their daily needs, and about one billion people in the world were in danger of starvation each year, and about 800 million people were malnourished (Kogan, 2019).

Food security is controlled by financial, economic, political, and environmental factors as well as the number of people who consume it, so it needs attention from global and regional aspects (Zakky *et al*., 2021). From a regional aspect, developed countries with strong political systems do not have a major problem with food shortages, although there are some indicators of malnourished households. Developing countries have been affected by shortages of food to feed their populations in the last 30 years. Since many developing countries are currently experiencing this problem, food security has become a global problem, especially in the twenty-first century (Godfray *et al*., 2010; Gottlieb & Joshi, 2010).

The need for food in Indonesia has increased along with the increase in population which has reached 270 million, and this will continue to increase. In Indonesia, food is associated with the need for nine basic foodstuffs and especially rice, corn, and sugar which can be met by producing independently or by importing from other countries. Independent food production (called food sovereignty) is the main vision in the agricultural development of a country (Lasminingrat & Efriza, 2020; Ma'ruf & Safruddin, 2017).

In addition, the consumption pattern of the community has also changed which leads to the consumption of non-rice as a source of carbohydrates, namely flours derived from cassava, corn, potatoes, and sago. Most of the flour raw materials are imported, so they are very vulnerable to embargo policies or export cessation from producing countries. This will interfere with a country to meet national food needs.

In order to support food sovereignty, the government aspires to achieve food security with a program to increase food production (Yestati & Noor, 2021). The government needs to develop sources of carbohydrates (food) that are fully produced domestically to strengthen national food reserves. National food reserves in sufficient quantities are needed in both normal and extraordinary situations. Exceptional situations include, for example, a prolonged disease outbreak, a prolonged war or a natural disaster. With this condition, it is necessary to shift from rice and wheat to other food commodities. The alternative option is to increase and develop cassava commodities as national food reserves. Cassava has gluten free properties, so it is good for ensuring health. Cassava and its derivatives have wide applications as a food source, energy source and staple in several cosmetic industries (Wulandani & Anggraini, 2020).

Cassava has advantages in ease of cultivation compared to rice commodities, because cassava can grow well on marginal land and does not require complex irrigation systems. This increase in production can be made available through increasing land productivity and expanding marginal land. The development of land for food reserves is carried out by utilizing sub-optimal land outside Java. Clearing and developing sub-optimal land for massive cassava cultivation is expected to be one of the solutions to overcome the problem of national food reserves. This type of land is mostly found in Kalimantan and is rarely used so that cassava cultivation is very possible in Kalimantan and maintains the supply of food needs for Indonesia.

The application of technology in the agricultural sector, one of which is the use of agricultural tools and machinery, needs to be developed to make work easier and more efficient (Yadav & Ghosh, 2019). One effort to increase efficiency in farming is the use of mechanical power, such as the use of tractors for tillage. Soil cultivation means changing agricultural land by using an agricultural tool in such a way that the best soil structure can be obtained, in terms of soil structure and porosity. Tillage aims to ensure a balance between water, air, and temperature in the soil. Soil cultivation is absolutely necessary to create an optimal environment for plant growth (Saraswati & Husen, 2007).

In this study, it is necessary to calculate the number of tractors needed based on technical characteristics and land area (Bulgakov et al., 2019). The use of tractors is needed to increase efficiency in cassava farming activities. The optimal arrangement of tractor requirements will calculate the number of tractors that should be needed with the existing land area. The purpose of this study was to determine the number of tractors needed based on the existing land area in Gunung Mas, Central Kalimantan and technical calculations of the performance of agricultural tools and machinery for tillage, which consisted of the first tillage (or plowing), the second tillage (or loosening), and bed formation.

2. MATERIALS AND METHOD

2.1. Research Site

The food estate study in this study was located in a cassava plantation, Gunung Mas Regency, Central Kalimantan in 2020 (Figure 1). The area of the study area is 2057 ha with a suitable land area for gardening is 1227.57 ha.

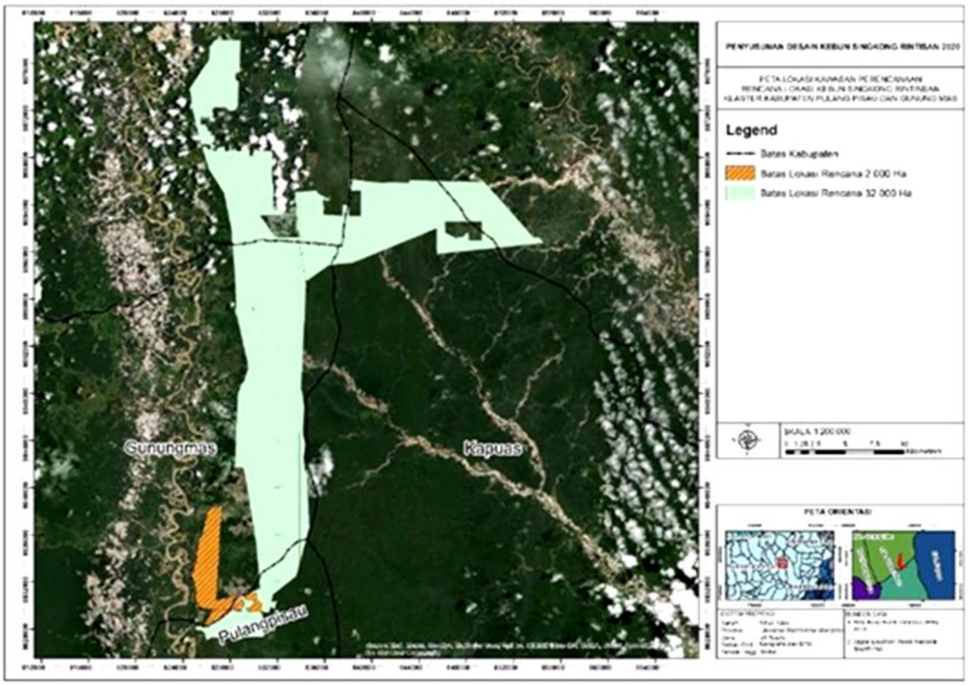

Figure 1. Location of the planned food estate based on cassave in Gunung Mas Regency, Central Kalimantan

2.2. Regional Topographical Data

Topographic data from DEMNAS, IFSAR, and Drones are used as the basis for planning (site-plan). The site-plan also considers the actual conditions of land use and topographical constraints. The site-plan includes determining the design of garden blocks, roads, farm blocks, residential locations, reservoir locations, weir locations, nursery locations, warehouses, factory locations, and office areas.

2.3. Tractor Work Needs

In this food estate program, the type of tractor used is a four-wheel tractor with a double axle. The resulting working capacity of the tractor depends on the power generated, tillage implements, and land conditions. The tractors used are small tractors with a power of 13.4 – 34.5 kW (18 - 46 HP) and medium tractors with a power of 34.6 – 70.9 kW (45.6 – 95.1 HP) equipped with a hydraulic system, 3 coupling point, and PTO shaft. In its operation, tractor needs are also strongly influenced by fuel consumption per unit area which is determined from many factors, such as engine power, type of fuel, maintenance, work width, soil type, time used and engine condition (Ali, 2018).

Tractor needs are calculated based on the working time of the tractor in tillage, namely plowing, harrowing, and bed forming. The variables needed are the width of the implement (*L*, m) and working speed (*v*, km/h) to find the value of the theoretical field capacity (C_T, ha/h). C_T is the work ability of an implementer (plow) to complete the work of cultivating a plot of land if the implementer meets the work speed and width of one hundred percent of the available time (Hanif *et al*. 2015). With a specified field efficiency of 60% (SNI 7416 2013), the value of the effective field capacity (C_E) can be determined. C_E is the effective field operation capability of an implement (plow) to complete soil tillage work in an area of test land for total time (Hanif *et al*, 2015). So that the tractor working time (*t*, h) can be calculated using the ratio of the area of the tillage area (*A*, ha) and C_E (ha/h). The formula for the relationship between C_T, C_E, and field efficiency (*Eff*) is as follows.

$$C_T = v \times L \tag{1}$$

$$C_E = \frac{A}{t} \tag{2}$$

$$Eff = \frac{C_E}{C_T} \times 100\% \tag{3}$$

2.5. Determination of Soil Processing Implements

Soil tillage implements used and pulled by tractors include disc plows for plowing, roto-cultivators for harrowing or loosening, and ber forming (ridgers). The disc plow was chosen because of its ability to cut, break, flip, and crush the soil to reduce soil strength, burying weeds, pesticides, and nutrients in the soil surface (ASABE, 2013). A roto-cultivator or rotary tiller is used as a second tillage to loosen the soil, crush and mix litter, pesticides, and nutrients into the soil, level the soil, close the soil pores, and eradicate weeds (ASABE, 2013). The roto-cultivator consists of rotating curved blades, the blades are mounted on a shaft where the source of rotational power is obtained from the PTO axle. Disc plow and roto-cultivator specifications are presented in Tables 1 and 2.

Table 1. Specifications of disc plow

Specification	Unit	Number of *disc plow*		
		3	**4**	**5**
Width of tillage	mm	900	1200	1500
Depth of tillage	mm	150-300	150-300	150-300
Disk diameter	mm	660	660	660
Total weight	kg	400	470	560
Tractor power	HP	60	70	80

Source: Yucheng Liansheng Machinery Co. Ltd

Table 2. Specification of roto-cultivator

Parameter	Unit	Width of tillage (m)		
		3	4	5
Power	HP	12-15	15-18	25-30
Width of tillage	mm	150-300	1200	1500
Number of blade	-	18	22	34

Source: Yucheng Liansheng Machinery Co. Ltd

Ridgers are used to prepare soil beds for planting grafted cassava seedlings. The aim is to facilitate the disposal of rainwater and infiltration of rainwater, and to provide access roads for farmers to plant cassava seeds by grafting, watering, and maintaining plants. The specification of the bed former pulled by a small tractor that is recommended is the 2 row type with a working width of 1.2 m, a bed width of 0.2 - 0.45 m, and a bed height of 0.15 - 0.24 m.

3. RESULTS AND DISCUSSION

3.1. Food Estate Land Analysis

Cassava plants grow well in loose soil. Therefore, tillage activities are needed to prepare optimum conditions for tuber formation and development. In addition to improving soil structure, tillage also aims to suppress weed growth, apply soil conservation to minimize the chance of erosion (Slepenkov *et al.*, 2021). Soil cultivation based on soil type can be grouped into three, namely, (a) light soil (loose) which is enough to be plowed once, then leveled and can be planted immediately; (b) moderately heavy soil where the soil is plowed 1-2 times, then leveled and made beds or mounds, for further planting, (c) heavy and wet soil needs to be processed by plowing or hoeing twice or more (Wargiono, 1979).

The availability of land is one of the determining factors for the need for agricultural tools and machinery, including tractors. Planning for the projection of tractor needs can use the number of planting land areas as the basis for calculations. Soil processing for cassava cultivation is enough to do once and then the stems can be planted immediately (Wargiono, 1979).

The topography of the food estate area is bumpy and hilly with an altitude between 65 - 150 m above sea level (asl). The slope of the land varies from 0 to > 40%. Slope classification produces 6 classes, with details: (1) slope 0 – 5%, covering an area of 1930.44 ha; (2) slope 5 – 8 % covering 567.17 ha; (3) slope 8 – 15% covering an area of 205.72 ha; (4) slope 15 – 25% covering 40.07 ha; (5) slope 15 – 40% covering an area of 0.86 ha; and (6) slope > 40% is 1.66 ha.

The food estate development in Phase 1 is planned on an area of 2057 ha (from the planned food estate area of 33,700 ha) and begins at the end of 2020. The area with an area of 2057 ha covers most of the area in Gunung Mas Regency. Topographic factors, land use by local communities, limited water resources, and environmental sustainability are some of the limiting constraints and must be considered in the design of gardens in this area. Furthermore, Table 3 contains a plan for the main types of designation (in an area of 2057 ha), which consists of: (1) plantation block, (2) Buffer Zone, (3) livestock zone, (4) settlements, (5) factory zone, WTP (waste treatment plan) and WWTP (wastewater treatment plan), (6) ware house area, and (7) dam plan.

Table 3. Area per type of land use in the site plan

No	Utilization type	Area (ha)	Area (%)
1	Mill, WTP and WWTP areas	63.68	3.1
2	Dam	37.88	1.8
3	Warehouse	6.00	0.3
4	Buffer zone	605.24	29.4
5	Livestock (cattle)	5.63	0.3
6	Plantation (cassava)	1325.12	64.4
7	Office and housing	14.04	0.7
	Total	2057.58	100

Figure 2 shows the layout of the site plan on an area of ± 2057.58 ha. Taking into account several constraining factors (ie factors: topography, land slope, areas that have been used by the community), not all land in the 2057.58 ha area is used as plantation blocks. The plantation block is planned for an area of 1325 ha. However, from a total of 1325 ha designated for plantation blocks, 170,35 ha is land that has the potential for conflict if it is released because it has been used by the community as a sorghum plantation area, village forest, community gardens, vacant land/ex-mining and oil palm plantations. Therefore, the total land area suitable for cassava plantation is 1227.57 ha which is then divided into blocks with details of the area presented in Table 4.

3.2. Land Preparation Process

3.2.1. Primary Soil Tillage

The first soil tillage (primary) for the cultivation of cassava plants at the food estate Gunung Mas, Central Kalimantan using a disc plow as an implement. This plow was chosen because it was considered the most suitable for the soil conditions in the field. Some of the advantages of using a disc plow are due to its ability to work on hard, dry, sticky, rocky, rooted soils and on soils that require deep work. Tillage on peat lands should be treated in dry conditions to reduce tractor wheel slip.

Table 4. Plantation block areas at the site-plan

Block number	Area (ha)	Block number	Area (ha)
L1	41,93	L13	59,71
L2	37,13	L14	37,01
L3	61,38	L15	51,58
L4	46,71	L16	53,77
L5	54,51	L17	32,27
L6	51,66	R1	63,33
L7	58,64	R2	57,59
L8	61,59	R3	52,68
L9	56,51	R4	60,11
L10	58,00	R5	53,97
L11	54,32	R6	36,00
L12	58,23	R7	28,94

L = left side of main road, and R = right side of main road

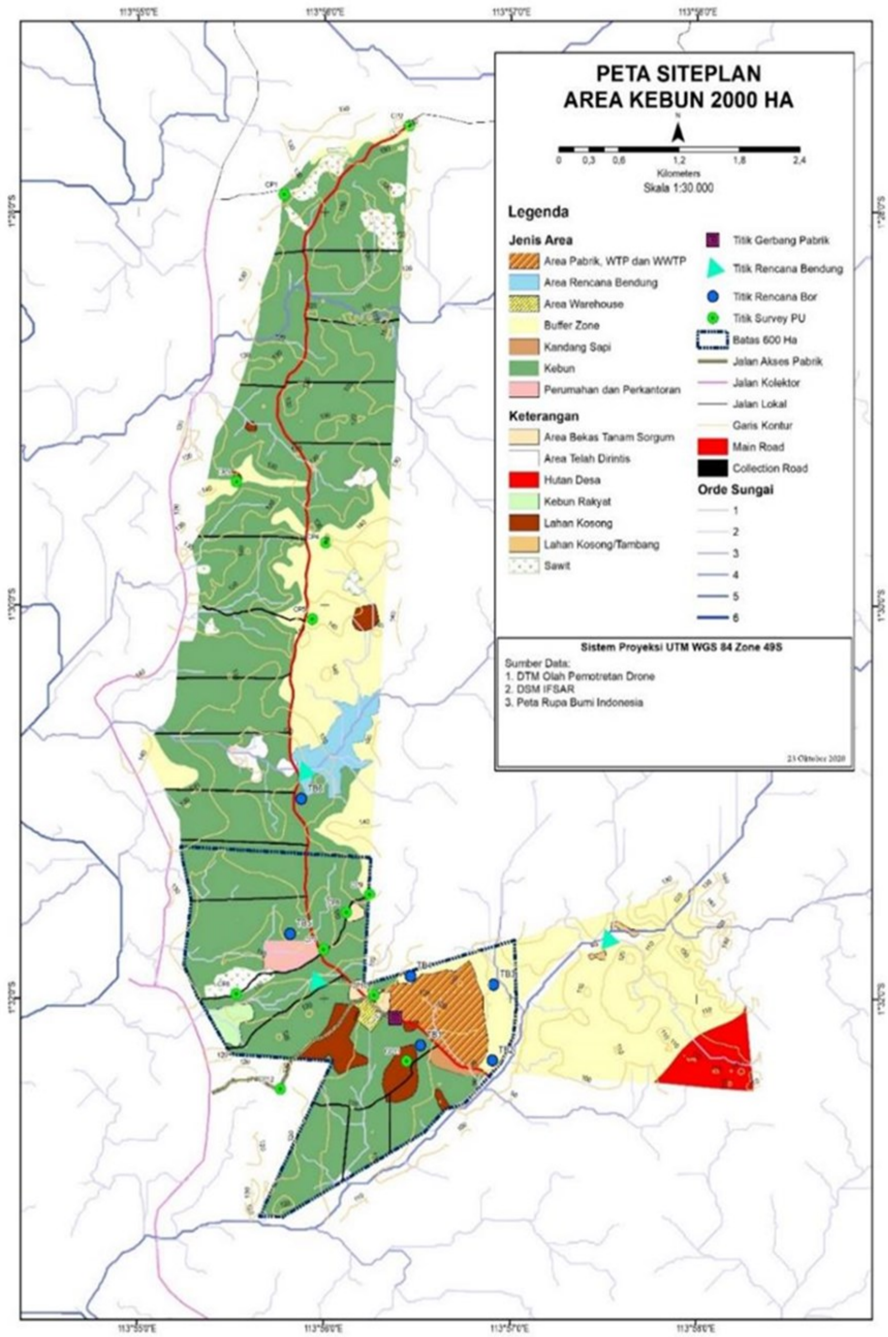

Figure 2. Layout of site-plan food estate Gunung Mas, Central Kalimantan

The recommended tractor for plowing is a four-wheel double axle medium tractor. This type of tractor has performance requirements with the implementation of a single -blade plow, including an effective field capacity of 0.165 ha/hour, a minimum field efficiency of 60% on dry land, an optimal working speed of 4 - 6 km/hour, a tillage depth of 130 - 170. mm, wheel slip 25% on dry land, fuel use 6.5-16 liters/hour, and a minimum tractor pulling force of 7 kN (BSN, 2013).

Analysis of tractor need in this study is based on the calculation of field capacity in land preparation for cassava cultivation. The calculation is determined by the variation of the number of disc plows, namely disc plow of 3, 4, and 5 blades with a working width presented in Table 2. The results of the calculation of theoretical field capacity (C_T) and effective field capacity are presented (C_E) in Table 3, which only includes plowing activities. While the total time of work (plowing) in the land area of all blocks is presented in Figure 3.

Table 5. Calculation of theoretical and effective field capacity for primary tillage

Parameter	Unit	Number of disc plow		
		3	4	5
C_T*	ha/h	0.450	0.600	0.750
Field efficiency	%	60	60	60
C_E**	ha/h	0.270	0.360	0.450

* CT = Theoretical field capacity, **CE = Effective field capacity

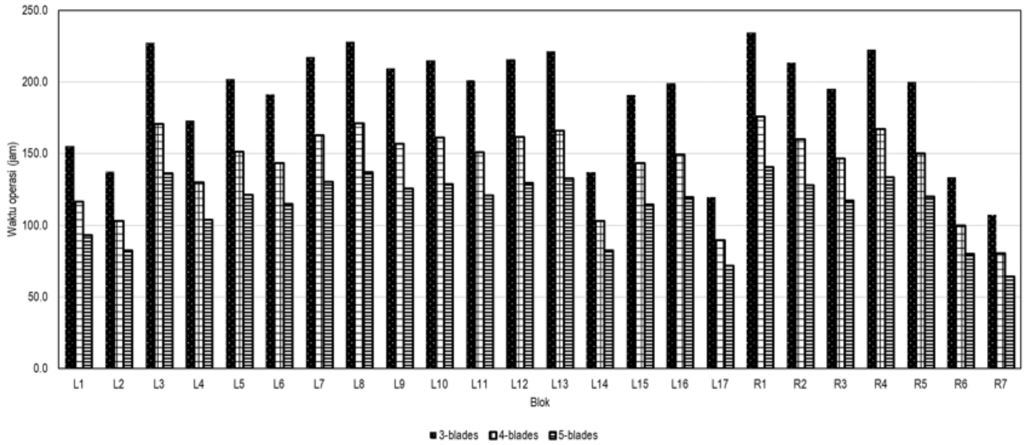

Figure 3. The relationship between the number of plates and the length of time for plowing the land per block

Based on the results of the studies that have been carried out, at a medium tractor working speed of 5 km/h (BSN, 2013) and the working width of the implements presented in Table 1, the theoretical field capacity (TLC) produced is 0.450, 0.600, and 0.700, respectively. ha/hour. With 60% field efficiency (BSN, 2013), the resulting effective field capacity (C_E) is 0.270, 0.360, and 0.450 ha/hour, respectively. For the known area of the cassava plantation, the working time (soil tillage) for the three types of disc plows was 4546,6, 3409.9, and 2727.9 hours, respectively.

3.2.2. Secondary Soil Tillage

Soil loosening (harrowing) was carried out with a coupled roto-cultivator and a blade rotation source from a small four-axle four-axle small tractor PTO. In this operation, the tractor used has a rotary implement at an effective field capacity of 0.375 ha/hour, a minimum field efficiency of 60% on dry land, an optimal working speed of 3 - 4 km/ hour, a tillage depth of 130 - 170 mm, wheel slip 25% on dry land, fuel use 6.5 liters/ hour, and a minimum tractor pulling force of 5 kN (BSN, 2013). Calculations determined by the variation of three types of roto-cultivators with working widths are presented in Table 2. With a working speed of 3.5 km/hour, the calculation results of theoretical field capacity (TLC) and effective field capacity (C_E) are presented in Table 6, which includes harrowing activities (loosening) and piling with a roto-cultivator. While the total time of loosening of the soil in the area of land in all blocks is presented in Figure 4.

Table 6. Calculation of theoretical and effective for secondary soil tillage

Parameter	Unit	Width of roto-cultivator		
		100 cm	120 cm	150 cm
C_T*	ha/h	0,350	0,420	0,525
Field efficiency	%	60	60	60
C_E**	ha/h	0,21	0,252	0,315

* C_T = Theoretical field capacity, **C_E = Effective field capacity

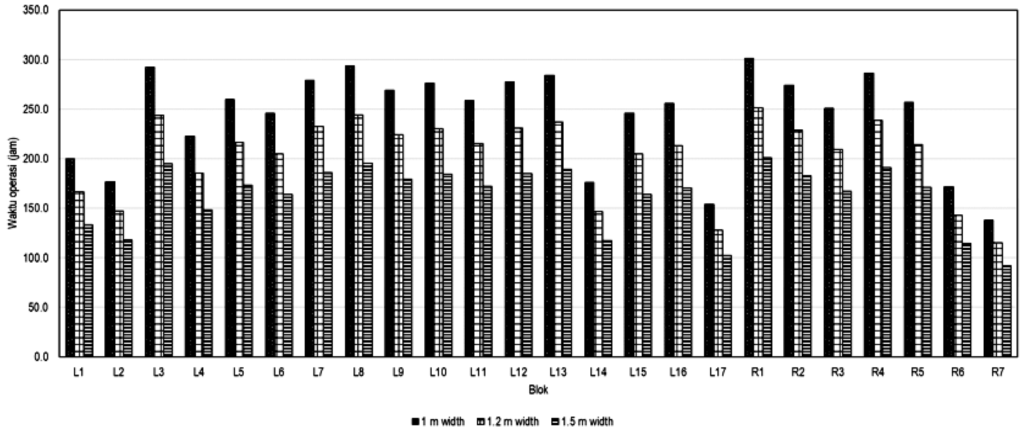

Figure 4. The relationship between the working width of the roto-cultivator and the time of loosening of the soil per block

Based on the calculation results, at a working speed of 3.5 km/h, the theoretical field capacity (C_T) produced is 0.35, 0.42, and 0.525 ha/hour, respectively. With 60% field efficiency, the resulting effective field capacity (C_E) is 0.21, 0.252, and 0.315 ha/h, respectively. For a known area of land per block, the resulting working time (soil loosening) is 5845.6 , 4845.6 , and 3897.0 hours, respectively for the working width of the roto-cultivator 100, 120, and 150 cm.

3.2.3. Bed Forming

The formation of beds is carried out using a bed former implement or a ridge pulled by a small tractor. The beds are used to plant grafted cassava seeds before planting in cassava plantations. This activity is carried out on a 2 ha land. By forming a bed, it will make it easier to dispose of rainwater, absorb water, and facilitate road access for planting cassava seeds, grafting, watering, and maintaining plants. The small tractor operated has a theoretical field capacity (C_T) of 0.375 ha/hour (BSN, 2013). With an efficiency of 60%, it has an effective field capacity (C_E) of 0.420 ha/hour. The time required to complete this work is 5 hours.

3.3. Number of Tractor Analysis

In this study, the number of tractors needed is determined from the work of tillage, both plowing, harrowing and bed forming for the preparation of grafting cassava seeds.

Preparation of grafted cassava seeds was carried out on a 2 hectare land with a planned total of 122,800 ready-to-plant seeds. The time needed for the preparation of grafted cassava seeds is 3-4 weeks before planting in the plantation field. Soil preparation activities at the seedling stage include plowing, harrowing, and bed forming.

The first and second tillage activities in cassava plantations covering an area of 1227.57 ha were carried out for one full month (240 hours with 8 hours of work per day) at the end of the dry season - the beginning of the rainy season. The planning of tractor requirements for the first and second tillage is presented in Table 7. The amount of tractor requirements for plowing and loosening is highly dependent on the implements used. The wider the work area, the wider the field capacity, so the time used for operation is faster. In the implementation of disc plow and roto-cultivator with a width of 1.5 m, the number of needs for medium tractors for plowing is planned for 12 units and 17 units for loosening with small tractors. After tillage, grafting seeds that are ready for planting are then planted in the plantation field with a spacing of 1 m x 1 m. The period of cassava cultivation from tillage to harvest is one year depending on the variety of cassava grown.

Table 7. Number of tractors needed for tillage

Operation	Implement	Type	Total time (jam)	Number of tractor (unit)	Note.
Plowing	*Disc plow*	3-blades	4546.6	19	Medium Tractor
		4-blades	3409.9	15	
		5-blades	2727.9	12	
Harrowing	Roto-cultivator	1-m width	5845.6	25	Small Tractor
		1.2-m width	4845.6	21	
		1.5-m width	3897.0	17	
Bed forming	Ridger	2-row	23.8	1	Small

4. CONCLUSIONS AND RECOMMENDATION

Based on the results of land mapping in Gunung Mas Regency on an area of 2057 ha and taking into account the suitability of topography and land use, the suitable land area for cassava plantations is 1227.57 ha. With a mapped land area, it is divided into 24 blocks with varying land area for each block. In this study, it was also determined that the tractor used was a medium type tractor with a power of 45.6 – 95.1 HP and a small type of 18 - 46 HP. Variations of soil plowing implements are 3-4-5 blade disc plows and for loosening use a roto-cultivator with variations in implementation width of 100-120-150 cm. Meanwhile, the fertilization of the beds for the preparation of grafting cassava seeds uses a 2-row bed former pulled by a small tractor. Variations in the width of the implements determine the difference in the value of C_T and C_E. The wider the work area of the implementer, the faster the time used for operations (soil tillage). In the implementation of disc plow and roto-cultivator width of 1.5 m, the number of needs for medium tractors for plowing is planned for 12 units and for small tractors for loosening as many as 17. Suggestions for further research are to evaluate technically and economically the need for tractors in tillage for cassava cultivation as a whole from cultivation to harvest.

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