The analysis of labor efficiency on sugarcane cultivation through mechanization application

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Abstract. One of the problems that often arise in people's sugarcane cultivation is the scarcity of labor and high wages. The application of mechanization is an alternative solution to this problem, especially in people's sugarcane fields on the island of Java. Land ownership of sugarcane farmers on the island of Java is relatively narrow, with an average land area of less than 0.25 ha. This requires the application of mechanization by the area of the land. This study examines the prospects for the application of tools and machines in sugarcane cultivation by farmers, planters, and companies. Mechanization in sugarcane cultivation can be carried out starting from soil processing, seeding, planting, weed control, and root cutting (pedot oyot) for sugar cane treated with ratoon. The use of mechanization in sugarcane cultivation can increase efficiency by 45.91% and save labor as much as 22 people. The use of mechanization in sugarcane cultivation in Indonesia needs to be encouraged, especially in planting and maintenance activities, to increase farmers' income and support the country's sugarcane plantation sustainable development.

Keywords: sugarcane cultivation, labor efficiency, mechanization approach, income improvement

1. Introduction
Mechanization in sugarcane cultivation is needed to improve the performance of sugarcane production in Indonesia. The advantages of implementing agricultural mechanization are time, energy, and cost efficiency [1]. According to [2], mechanization is very substantial because it can increase the productivity of agricultural land. But on the other hand, the conversion of land for housing and infrastructure development causes decreasing in agricultural land. The land area in Java based on land ownership on average is less than 0.25 ha [3]. Application of mechanization has been carried out so far only on the pre-harvest process using a simple tractor. Mechanization is a must to overcome the problem of labor scarcity and achieve sugarcane planting targets. The labor scarcity in the agricultural sector makes it difficult to obtain timely labor [4]. According to [1, 5], mechanization is also substantial because it will simplify the processing process and higher efficiency. The Indonesian sugarcane areas, especially out of Java, are stagnant event decreased due to labor scarcity. Through mechanization in the plantation, the farm competitiveness and the sugarcane areas development will increase.

1.1 Sugarcane cultivation at farmer level
Increasing the competitiveness of the national sugar industry faces problems, especially those stemming from low productivity and efficiency. The application of agricultural mechanization on sugarcane faces
obstacles, mainly because of very narrow land ownership. This causes the scale of farming to be below the optimal value, causing relatively high cultivation costs. The other cause is the land area is not matched by adequate labor. Agricultural mechanization will be optimal if using mechanization tools and machines with large capacity.

Sugarcane is generally cultivated by farmers in small areas, with the total area of sugarcane plantations in Indonesia reaching 458.4 ha [6]. Agricultural tools and machines (hand tractors) used by sugarcane farmers in narrow areas are for land processing, planting plots, and weeding, as shown in Figure 1.

Harvesting sugar cane in one hectare of land requires approximately 11-14 workers for five days. At the same time sugarcane harvesting, the need for labor also increases, resulting in a shortage of labor. On the other hand, many workers in agriculture have switched professions to other sectors. According to [4], many agricultural workers have changed to another sector profession. The presence of labor for the maintenance and harvesting of sugarcane is also decreasing, causing labor costs to be more expensive. This case also happens in other countries such as Sri Lanka, and the workforce is decreasing so that the mechanization of agriculture in sugar cane becomes substantial [7]. Therefore, small-scale agricultural mechanization is needed that can replace the increasingly scarce sugarcane workforce. Illustrations of weed control and manual harvesting carried out by sugarcane farmers can be seen in Figure 2.

1.2 Cultivation of sugar cane in plantations

The innovation of mechanization of sugarcane cultivation was required for both narrow and large fields. Machinery in private sugarcane companies such as PT GMP (Gunung Madu Plantation) and PTPN (PT Perkebunan Nusantara) requires a large capacity, namely four-wheel tractors. Meanwhile, mechanization in a narrow area uses a hand tractor (Figure 3).
The application of mechanization is expected to increase efficiency and productivity in sugarcane cultivation. Through agricultural mechanization, timeliness in agriculture activities can be more improved. Therefore, it is increasingly substantial in sugarcane cultivation [8]. Agriculture is an activity that depends on the seasons. During the growing and harvesting seasons, it requires a large amount of labor. However, at other times it requires less labor, resulting in unemployment.

Agricultural mechanization can have an impact on better crop yields and can reduce farmers’ boredom at work. Labor can be reallocated to other agriculture or activities in other sustainable sectors [1]. According to [9], sugarcane equipment and machinery costs in South Africa account for 30-40% of the total production cost. Of all these costs, loading is 38%, transportation is 42%, and the rest is for production activities, especially land preparation and planting 7%, plant maintenance 9%, and other costs 4%. Based on cost analysis of the cutting and transportation at PT Gula Putih Mataram, the use of rental trucks for transportation is cheaper than using a self-driving tractor or contractor services [10].

According to [11, 12], agricultural mechanization includes tools, machines for land development, crop production, harvesting, storage preparation, storage, and processing. Machine operations management manages machine operations activities include the amount and type of tillage, the type and size of machines, and field operation methods that support increased field efficiency and time efficiency. Mechanization of large-scale sugarcane farming can be seen in Figure 4.

**Figure 3.** Hand tractor for cultivating soil (left) and sugarcane harvesting machine (right).

![Hand tractor and sugarcane harvesting machine](image1)

Source: Wiratama  
Source: Balitbangtan

**Figure 4.** Soil processing machine (A), weeding machine (B), fertilizing machine (C) and sugarcane harvesting machine (D).

![Soil processing, weeding, fertilizing, and harvesting machines](image2)

Source: Gunung Madu Plantation
Agricultural mechanization can improve time and cost efficiency, the effectiveness of work, and reduce farmer fatigue. So that can increase yield quality and reduce yield losses during agricultural activities [14]. The use of agricultural machinery in Indonesia is based on the agroecological and socio-economic conditions of each region. According to [13], agricultural machinery that is suitable with the agroecological and socio-economic characteristics in each region can increase productivity, farm efficiency, increase added value, and empower farmers.

The economic management will calculate and analyze the total operating costs of machine tools, determine the economic time of the machine, the selling value, the time of replacing, and the time of renting the machine. Suggestions from the manager of large-scale agricultural mechanization on sugar cane include:

1. (1) Create the necessary main lines during field operations,
2. Use a higher gear and lower gas if the load is light, and
3. Using the appropriate wheel size, recommended wheel pressure, and appropriate weight, so that the wheel slip is still within the allowable limits.

2. Soil cultivation
Tillage is a process in which the soil is physically changed so that the properties of the soil are changed and it can be used for plant growth. According to [14], tillage is loosening the soil using a plow or harrow, which is pulled by a tractor. Meanwhile, according to [15], tillage is divided into primary and secondary tillage. Primary tillage can absorb 50% of the power for cultivation and harvest operations. Tools for cultivating the soil can be in the form of chisels, *singkals*, plates, and rotary plows. Soil processing is carried out with the aim that the land is ready to be planted with sugar cane. Before planting sugar cane, stumps, weeds and plant debris must be removed. According to [17], tillage is intended to increase productivity and consider the long-term adverse effects through compaction or increased erosion. Minimal tillage can be done with a strip tillage system or a plow with limited rotational speed, such as a plate or chisel plow. This is done to save costs when operating earthmoving machines (saving fuel consumption by reducing the number of passes) [18]. However, this does not result in poor tillage quality. Soil with a good and light soil structure is sufficient with minimal tillage or no tillage. Soil tillage and plotting and fertilization using large-scale tractors can be seen in Figure 5.

Optimal tillage will result in the growth of the first PC plant (Plant Cane) and good ratoon growth. According to [19], soil structure will develop along with root development during the PC period and help support sugarcane growth. If the soil structure has been formed, then the soil will be suitable for cultivation for at least one day. A good and stable soil structure requires a good organic matter content. The making of planting grooves and fertilization is done after the tillage process is complete. The tractor was equipped with a tool for making soil grooves and fertilization that is placed on the back.

3. Seed selection and care
Seed production and planting of milled sugarcane generally use mule sugar cane seeds. According to the origin, the source of sugarcane seeds can come from conventional plants and tissue culture. Further seed propagation can be carried out using mule seeds, bud sets (one eye), or bud chips. Making mules or
bud set seedlings is relatively easy, so it is generally done manually. Making bud chip seedlings is more complex and must be done with tools or machines. ISFCRI and other institutions have developed tools for making bud chip seeds (Figure 6). Budchip seedlings are planted by transplanting, while mule seedlings are generally planted directly in the field.

Mechanical sugarcane cultivation is not yet widespread in Indonesia. The testing of the PG Ngadirejo planter machine in Kandat District, Kediri, for planting and fertilizing was reported to be very efficient. Manual planting and fertilizing activities on two hectares area require a workforce of twelve people in a week or 84 workers per day (WPD). However, it can be completed in a day using five people (5 WPD) using a cultivator. With mechanization, fertilization is more evenly equally so can increase sugarcane yield [20]. Mechanical planting can be done using mules or elongated seeds or transplanting [21, 22]. Different planting methods have different characteristics [23]. Transplantation has advantages in terms of efficient use of irrigation water, seed requirements, the intensity of tillage, and planting time in the field. The method of planting using long seeds using double plates or singkal + wide nets produces higher growth rates than mule seeds with singkal + wide wedges [24].

Sugarcane maintenance aims to prepare soil conditions to allow good root development and support plant growth. The first sugarcane maintenance period is carried out before the plants are 3-4 months old. The first maintenance carried out was fertilization on sugarcane (PC) plants at 2.5 months. Fertilization is carried out using a four-wheel tractor equipped with a fertilizer storage device located at the back of the tractor, spreading fertilizer in a predetermined amount [25]. For fertilization and planting of sugarcane plants using a four-wheel tractor with fertilization tools and planting, tools can be seen in Figure 7.

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**Figure 6. Budchipper tool.**

**Figure 7. Fertilizing and hoarding using a tractor.**
Mechanical weed control can be done in two ways: cultivators and sprayers for herbicide applications. According to [10], cultivating machines began to decline and were replaced by herbicides, both pre-growing and post-growing herbicides. The knapsack sprayer is suitable for small scale because its capacity is 1 – 1.5 ha/day. The multi-row sprayer boom is suitable for large plantations as it has a capacity of up to 15 ha/day. The use of a multi-row sprayer can increase the spraying capacity up to 10 times faster.

4. Harvest, post harvest and ratoon care
Harvesting is done after the sugarcane yields reach the cuttings age (yield reaches the peak and is evenly equal from the bottom to the top of the cane). Sugarcane is suitable for cutting if it does not fall, is clean (the leaves are bent), the sugarcane is of good height (>2m), and ripe (maturity 25-30%). Delay in harvesting will result in low sugarcane yield and weight, which will harm farmers [26; 27]. Good sugarcane cutting produces sugarcane with the criteria of Sweet, Clean, and Fresh (SCF). Sweet means that the cane contains high sugar (yield). Clean means that the cane is free from leaves, garbage, shoots, or other non-sugar impurities. Fresh means that the cane is milled as soon as possible after cutting (less than 48 hours).

Manual harvesting is labor intensive and can be a severe problem when harvesting is carried out over a large area of nearly the same age and maturity, resulting in higher wages. Inaccuracy due to delay in harvesting will be detrimental because the yield is lower [31; 32]. Cutting machines for large-scale plantations are available, but small-scale farmers’ are indispensable. The use of cutting machines requires supporting conditions such as flat land, upright sugarcane that does not collapse, and uniform clump spacing [33]. Harvesting capacity can reach 20 tons/hour. The loading and unloading of sugarcane using harvesting machines and trucks are shown in Figure 8.

![Source: Dumbreck](image)

**Figure 8.** Logging and transporting sugar cane using harvesting machines and trucks.

5. Analysis of farming using agricultural tools and machinery
Sugarcane farming is an activity to utilize existing resources to increase cultivation yields so can achieve maximize profits. The farming analysis provides benefits to determine the condition of resource utilization effectively and efficiently, which can provide output that exceeds input. According to [28], paying attention to intensive cultivation in organic fertilization of 5 tons per hectare, adequate irrigation, overlapping cropping systems, and adequate klentek activities can provide an average production of 150 tons per hectare, providing a net income of Rp. 32.38 million per hectare. The use of machines is also the use of technological resources to provide benefits for sugarcane farming.

According to [29], fertilization, cultivating and making mounds using machinery in the Comal Gardens spend Rp. 535,528, - and manually spend Rp. 990,000, - so 45.91% more efficient than the manual method. The data is presented in tables. 1.
This activity also saves labor by 22 people working days. Thus, based on research, mechanization activities in sugarcane cultivation provide benefits and labor efficiency. According to [35], cropping patterns by using machinery have a positive effect on costs and labor (efficiency).

6. Conclusion
In Java, sugarcane cultivation generally uses small-scale mechanization meanwhile a big company such as PTPN uses large-scale mechanization. Mechanization activities in sugarcane cultivation include soil processing, plant caring, and harvesting. The use of mechanization in sugarcane cultivation can increase efficiency by 45.91% and save using of labor (as many as 22 people). The acceleration of mechanization in sugarcane cultivation increase competitiveness of the plantation development.

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Table 1. Comparison of machinery and manual labor costs in the Comal Garden. Area of 0.3 hectares

| Work                        | Operator Fee (Rp) | Alsintan Rent (Rp) | Solar cost amount (Rp) | Manual amount of wages (HOK) | Labor wages (Rp) | Mechanical efficiency against manual (%) |
|-----------------------------|-------------------|--------------------|------------------------|-----------------------------|------------------|------------------------------------------|
| Fertilizing I               | 74.286            | 42.857             | 15.910                 | 133.053                     | 2.5              | 112.500 (18,27)                         |
| Fertilizing II              | 74.286            | 42.857             | 11.470                 | 128.613                     | 2.5              | 112.500 (14,32)                         |
| Piling I                    | 66.129            | 48.387             | 14.060                 | 128.576                     | 5                | 225.000 (42,86)                         |
| Piling III                  |                   |                    |                        | 15.910                      | 5                | 225.000 (100,00)                        |
| Mounding/input              | 73.214            | 53.571             | 18.500                 | 145.286                     | 7                | 315.000 (53,88)                         |
| Total                       | 535.528           | 22                 |                        | 990.000                     | 22               | 45,91%                                  |

Source : Purwantoro et al., (2018).
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