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ANALYSIS ON OPTIMAL SUGAR CANE HARVESTING SYSTEM IN JATITUJUH SCP, MAJALENGKA

Setyo Pertiwi and Vidy Haryanti
Bogor Agricultural University
Bogor-Indonesia

ABSTRACT

Sugar cane harvesting always draws attention on sugar cane plantation management since it is considered as one of the factors affecting sugar cane production as well as its profitability. This paper discusses about analysis of optimal sugar cane harvesting system for Jatitujuh Sugar Cane Plantation (SCP). It covers analysis on three harvesting system that are implemented in the plantation, i.e. manual harvesting system, semi-mechanical harvesting system and mechanical harvesting system, each related with several parameters, i.e. harvesting cost, loss caused by uncollected sugar cane from the field and trash taken to the factory, and the impact of harvesting operation and sugar cane transportation on physical soil properties. Final decision analysis to determine the optimal sugar cane harvesting system was made by employing Analytical Hierarchy Process which involves four actors as the decision makers, i.e. Chief of Harvesting and Transportation Section, Chief of Mechanization Section, Chief of Manufacturing Section, and Chief of Research and Development Section. From the analysis it was found that manual harvesting system was considered as the priority system, followed by semi-mechanical harvesting system and mechanical harvesting system with assigned weight of 0.581, 0.283 and 0.137, respectively. From this result it can be concluded that manual harvesting system is the optimal harvesting system for Jatitujuh SCP.

***Keywords**: harvesting system, sugar cane, analytic hierarchy process*

INTRODUCTION

Sugar as one of the basic needs of Indonesian people has a strategic position in food security issues. The increase of population as well as the increase of food and beverage industries has caused the increase in sugar demand and consumption. Unfortunately, this increase is not balanced with the increase in domestic sugar production. Even, domestic sugar cane (*Saccharum officinarum* L.) production as the main source of sugar in the country shows a decrease, from 31,139.969 tons in 2005 to 30,244.051 tons in 2006 (Hadi, 2007). Therefore, efforts have been made to increase the production level. Besides improvement of sugar cane cultivation, improvement of sugar cane harvesting system always draws attention on sugar cane plantation management since it is considered as one of the factors affecting sugar cane production as well as its profitability.

Sugar cane harvesting is defined as the whole activities of taking the potential sugar product from the field to be processed further to become sugar crystal in the factory (GPM Group, 1995). Nowadays, there are three harvesting system practiced by Jatitujuh Sugar Cane Plantation (SCP), i.e. manual harvesting system, semi-mechanical harvesting system and mechanical harvesting system.

On manual harvesting system, all activities related with harvesting are carried out manually by harvesting laborers. In this operation, cane is cut at about ground level, the top green leaves are cropped off, the stalk is bundled, and then it is loaded to the truck/trailer. Similar ways are done on semi-mechanical harvesting system except on loading the cane to truck/trailer which is done by using grab loader. On mechanical harvesting system all activities are carried out mechanically by using cane (chopper) harvester. Cut cane is chopped into short lengths and mechanically loaded in to the truck/trailer.

The objective of this research is to analyze the optimal harvesting system for Jatitujuh SCP based on cost analysis, analysis on the loss caused by uncollected sugar cane from the field and trash taken to the factory, and analysis on the impact of harvesting operation and sugar cane transportation on physical soil properties of the three sugar cane harvesting systems.

MATERIALS AND METHOD

The research was carried out on May – July 2008, comprises field investigations, laboratory works, interviews, secondary data collecting, and data analysis.

Field investigations and laboratory works were carried out mainly for collecting data on technical performances of sugar cane harvesting systems, i.e. field capacity, efficiency, loss caused by uncollected sugar cane from the field and trash taken to the factory, and impact of harvesting operation and sugar cane transportation on physical soil properties. However, during field investigation mechanical harvesting system was not practiced. Therefore, all of data related with mechanical harvesting system was secondary data from Jatitujuh SCP. Interviews and secondary data collecting were carried out mainly for collecting data and information regarding harvesting cost and decision makers' perception on sugar cane harvesting system.

Related with above mentioned activities, the materials involved in the research were mainly sugar cane fields, collected and uncollected sugar cane stalks (stems), trash taken to the factory, and soil samples. Tools being used mainly were stopwatch, cone penetrometer, sample ring, balance, desiccators and oven.

Field capacity of each harvesting system (ton/day) was investigated by measuring harvested area, amount of harvested sugar cane and actual working time. Actual working time was compared with standard working time for the harvested area to find field efficiency (%). Loss caused by uncollected sugarcane is observed from plant stump and cane pieces left in the field (kg/Ha). Trash taken from field to factory is measured as the percentage of trash taken from sample sugar cane.

The impact of harvesting operation and sugar cane transportation is analyzed in terms of soil compaction, reflected by soil penetration resistance (kg/cm^2), bulk density (g/cm^3), and soil porosity (%) (Williford, 1980). Observation was carried out on samples taken from 0-10, 10-20, 20-30, 30-40, and 50-60 cm soil depth by using soil sample ring. Soil penetration resistance was measures by using cone penetrometer, while bulk density and soil porosity was analyzed by using gravimetric method. Since there was no mechanical harvesting system operated during the field investigation, the values for this harvesting system were taken from the available documentation and testimony.

Harvesting cost is the cost incurred for harvesting, loading, and transporting sugar cane from field to factory. In the manual harvesting system, it covers cost for harvesting as well as loading labors, cost for transportation and other cost related with provision of labors. Jatitujuh SCP hires local harvesting labors as well as labors from other regions, herein named as "imported" labors. Imported labors cause additional cost for their housing. In the semi-mechanical harvesting system it covers cost for harvesting labors, cost for loading with grab loader and cost for transportation, while in the mechanical harvesting system it covers the cost of machinery used in the harvesting as well as transportation, i.e. cane harvester, truck, tractor and trailer.

Based on the above mentioned parameters, the optimal sugar cane harvesting system for Jatitujuh SCP was determined by employing Analytical Hierarchy Process (AHP) that involves four actors as the decision makers, i.e. Chief of Harvesting and Transportation Section, Chief of Mechanization Section, Chief of Manufacturing Section, and Chief of Research and Development Section. The AHP is a theory of measurement through pair-wise comparisons and relies on the judgments of experts to derive priority scales. It is these scales that measure intangibles in relative terms. The comparisons are made by using a scale of absolute judgment that represents, how much more, one element dominates another with respect to a given attribute (Saaty, 2008). The AHP decision model was as presented in Figure 1. Then, the pair-wise comparison matrices constructed by the four decision makers involved were analyzed by commercially available software.

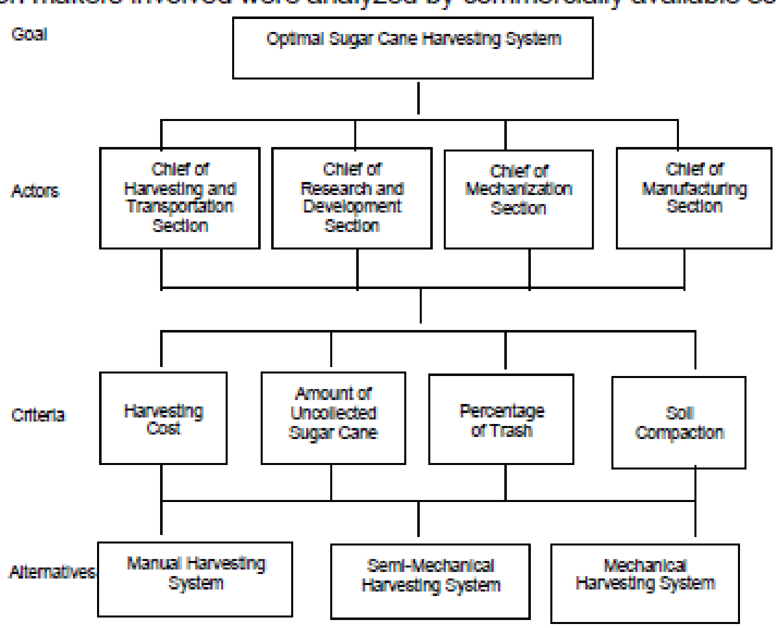

Figure 1. The AHP decision model for determining optimal sugar cane harvesting system

RESULTS AND DISCUSSION

1. Field capacity and efficiency

After field investigation it was found that working capacity of local harvesting labors was about 1.09 ton/man/day for man and about 0.88 ton/man/day for women while working capacity for non local (imported) harvesting labors was about 1.2 ton/man/day. Field efficiency was about 84% for local man, 89% for local women, and 92% for non local labors. Non local harvesting labors tend to have higher working capacity and field efficiency since they are more concentrated on the job compared to those local labors. Field efficiency can be improved by improving field supervision to the labors.

Field capacity of grab loader was about 0.163 ton/minutes. This was far below field capacity observed in other plantation due to the difference of working system implemented. In Jatitujuh SCP, the truck was waiting for loading in a certain point outside the field and grab loader was moving from the cutting points to the truck, while in other plantation truck is moving together beside grab loader. It seems that in Jatitujuh SCP the truck could not move into the field due to field condition that was not well prepared for it. Preparing the suitable field condition, implementing suitable working system and improving operator skill will increase the quantity and quality of sugar cane transported to the cane yard.

Field capacity of mechanical harvesting by using cane (chopper) harvester in Jatutujuh SCP was recorded as 20 ton/hour.

2. Field loss and trash taken to the factory

Field loss on sugar cane harvesting is related with parts of stalk that remain un-cut in the stand (stump) and uncollected sugar cane stems from the field. Cane stump is part of sugar cane plant that has the highest sugar content. On the other hand, trash is related with sugar cane leaves and extraneous matter that are taken to the factory together with sugar cane stems. Trash taken to the milling factory will reduce the sugar yield. Table 1 presents the field loss and percentage of trash observed from the three harvesting system. As a note, the allowable value of uncollected stems is about 0.6 ton/ha while that of un-cut stump is about 0.9 ton/ha. Percentage of allowable trash is of 5%.

Table 1. Percentage of trash, un-collected stems and un-cut stump

Harvesting system	Average		
	Trash (%)	Uncollected stems (ton/ha)	Un-cut stumps (ton/ha)
Manual	1.79	0.01	1.24
Semi mechanical	3.11	0.02	0.35
Mechanical (testimony)	>>	<<	<<

As shown in Table 1, the quality of manual harvesting system was better than semi-mechanical harvesting system in terms of the percentage of trash taken to the factory and the amount of uncollected stems. However, manual harvesting system resulted to higher value of un-cut stump, even it was higher that the allowable value, because manually it is difficult to cut sugar cane plant just at about ground level.

From interview with field officers it was learned that in the mechanical harvesting system the amount of un-collected stems and un-cut stumps were less than those of manual and semi-mechanical harvesting system. However, trash taken to the factory tends to be higher.

3. Physical soil properties

Figure 2, Figure 3 and Figure 4 show the observation results on the impact of harvesting operation and cane transportation on physical soil properties, especially on second ratoon cane.

As can be seen from the figures, a lower soil porosity (%), higher soil penetration resistance (kg/cm²) and higher bulk density (gr/cm³) have been observed after harvesting operation, both in manual as well as semi-mechanical harvesting system. The average porosity value was 0.62-0.63% on manual harvesting system and 0.50-0.65% on semi-mechanical harvesting system. On the other hand, the average soil penetration resistance on manual harvesting system and semi-mechanical harvesting system was 2.38-3.17 kg/cm² and 3.39-4.32 kg/cm², respectively, and the average bulk density was 0.98-1.01 gr/cm³ for manual harvesting system and 0.94-1.32 gr/cm³ for semi-mechanical harvesting system.

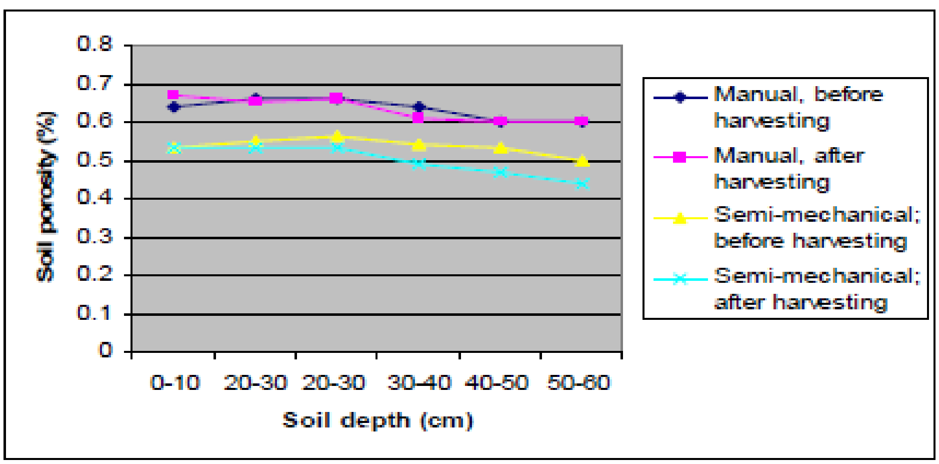

Figure 2. Average of soil porosity on various soil depths before and after harvesting operation

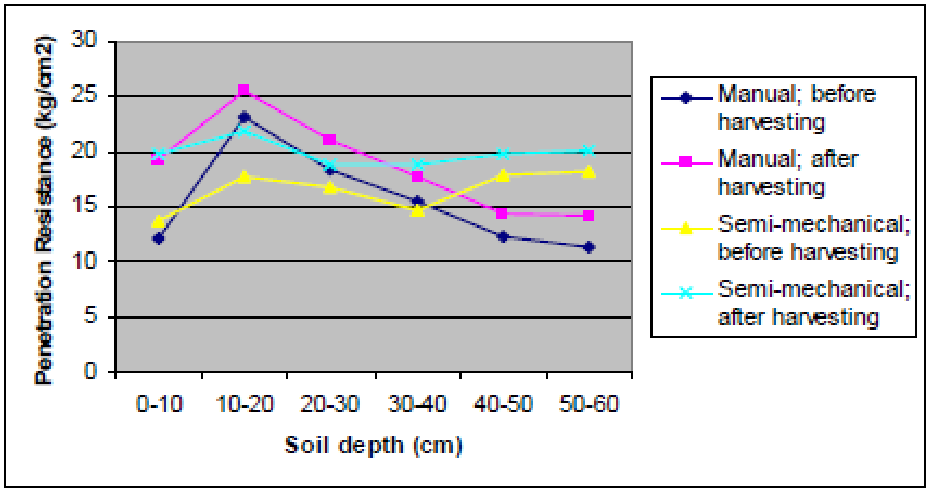

Figure 3. Average of soil penetration resistance on various soil depths beforeand after harvesting operation

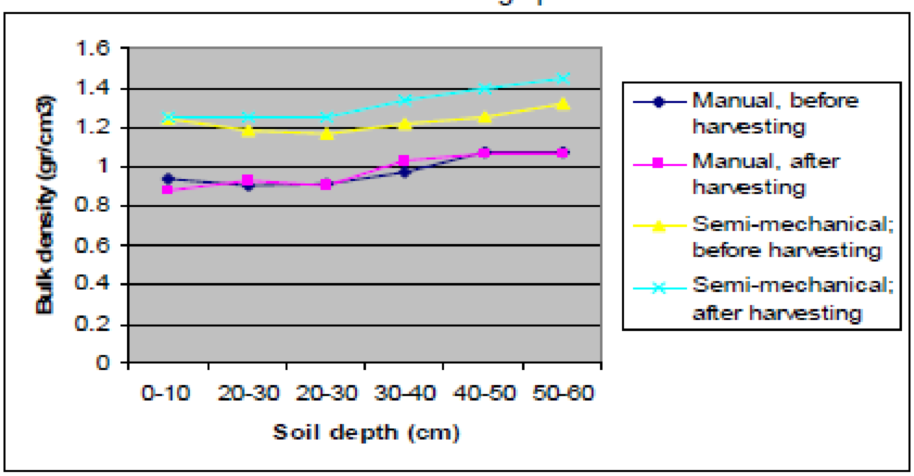

Figure 4. Average of bulk density on various soil depths before and after harvesting operation

The above mentioned values indicate that harvesting operation and cane transportation have impacts on physical soil properties. However, manual harvesting system gave better impacts to the soil, indicated by higher soil porosity, lower penetration resistance and lower bulk density. Based on those results naturally it can be understood that mechanical harvesting system will have greater impacts on physical soil properties, i.e. cause soil compaction, due to its heavier load given to the soil. To overcome soil compaction problem, Jatitujuh SCP irregularly carry out rippering operation, especially to break hard pan on 40-60 cm soil depth.

4. Harvesting cost

Harvesting cost for each sugar cane harvesting system was calculated under assumption that harvesting operation is totally carried out by each of those systems and all prices and wages are those applicable in the research period. Related with machinery operation that incurs fixed (ownership) cost for depreciation, maintenance and garage, the harvesting cost will be affected by the harvesting area or the amount of sugar cane harvested within a year. For example, the total sugar cane harvested in year 2007 was 498.727 tons.

From all calculations, it was found that the harvesting cost with manual system was less than those of semi-mechanical system as well as mechanical system. They were Rp. 53,290/ton, Rp. 63,160/ton, and Rp. 55,680/ton, respectively. However, the low working capacity and the limited supply of the harvesting labors may cause un-fulfillment of milling capacity in the factory (milling unit).

5. Decision analysis by using AHP

As shown in Figure 1, there are four actors involved in decision analysis, four criteria for determining optimal sugar cane harvesting system and 3 alternatives to be considered. The four actors have equal importance and contribution to the analysis indicated by equal weight assigned to each of the actor with respect to decision, i.e. 0.25. The four actors constructed pair wise comparison matrices that reflect their perception on the relative importance of the criteria and their relative preference of alternative sugar cane harvesting system with respect to each criterion. From the matrices then local weight of each criteria as well as alternatives can be determined as shown in Table 2.

Table 2. Local weight/priority of criteria and alternatives

Actor	criteria	Weight of criteria	Weight of alternative with respect to each criterion		
			Manual	Semi-Mechanical	Mechanical
Chief of Harvesting &Transportation Section	Cost	0.412	0.661	0.208	0.131
	Loss	0.282	0.582	0.309	0.109
	Trash	0.231	0.250	0.500	0.250
	Soil compaction	0.075	0.659	0.185	0.156
Chief of Mechanization Section	Cost	0.356	0.705	0.211	0.084
	Loss	0.406	0.701	0.193	0.106
	Trash	0.170	0.733	0.199	0.068
	Soil compaction	0.068	0.740	0.167	0.094
Chief of R&D Section	Cost	0.303	0.761	0.166	0.073
	Loss	0.389	0.643	0.255	0.101
	Trash	0.130	0.413	0.260	0.327
	Soil compaction	0.178	0.571	0.286	0.143
Chief of Manufacturing Section	Cost	0.243	0.671	0.256	0.073
	Loss	0.230	0.493	0.311	0.196
	Trash	0.474	0.429	0.429	0.143
	Soil compaction	0.053	0.678	0.179	0.142

As indicated in the table, the relative importance of criteria and relative preference of alternatives with respect to each criterion from each actor varies. They are influenced by each actor's interest related with their task and responsibility. For example, Chief of Manufacturing Section assigned the highest weight on trash related criterion since it has the greatest impact on the operation in the milling unit. On the other hand Chief of Harvesting and Transportation Section concern a lot on harvesting cost. From those local weights than the composite weight of each alternative with respect to the goal, i.e. optimal sugar cane harvesting system was calculated and the result was 0.581, 0.283 and 0.137 for manual harvesting system, semi-mechanical harvesting system and mechanical harvesting system, respectively.

CONCLUSIONS

From the Analytic Hierarchy Process it can be concluded that manual harvesting system is the optimal harvesting system for Jatitujuh SCP, and therefore considered as the priority system, followed by semi-mechanical harvesting system and mechanical harvesting system. From this result, the harvesting operation is carried out mainly by manual harvesting system. When supply of labors does not meet the required number, part of the operation is better to be carried out by semi-mechanical harvesting system.

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