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Performance Comparison of Different Harvesting Methods in Oil Palm Plantation

Ahmad Syazwan Ramli*, Mohd Azwan Mohd Bakri, Mohd Rizal Ahmad, Nabilah Kamaliah Mustaffa, Mohd Ramdhan Mohd Khalid, Ikmal Hafizi Azaman

Malaysian Palm Oil Board, Persiaran Institusi, Bandar Baru Bangi, 43000 Kajang, Selangor.

*Corresponding author: Ahmad Syazwan Ramli; ahmad.syazwan@mpob.gov.my

Abstract: Mechanisation in the oil palm industry has long been promoted to increase efficiency and productivity; however, its adoption is low. One of the reasons is the sceptical view of the high cost of mechanisation adoption and the lack of productivity data to compare the performance of manual versus several mechanised operations. This paper analysed the performance of different harvesting methods available in the oil palm industry and assessed the efficiency of each method. This study compared the fresh fruit bunch (FFB) harvesting performance of a manual, mechanised cutter (i.e., CANTAS) and an excavator-based harvesting machine. The price and productivity data of each method were taken from the literature. The capital expenditure (CAPEX) and operational expenditure (OPEX) in terms of cost per tonne were calculated. Each method's performance was then projected as labour to land ratio to determine the efficiency. The CAPEX of the excavator-based harvesting machine is the highest (RM 280,155.55), followed by CANTAS (RM 3,806.33) and manual harvesting (RM 601.00). This is reflected in the slightly higher OPEX for the excavator-based harvesting machine (RM 46.45/tonne) as compared to CANTAS (RM 28.72/tonne) and manual harvesting (RM 39.35/tonne). The excavator-based harvesting machine was shown to harvest more plantation areas with a labour-to-land ratio of 1:86 ha, compared to 1:35 ha for CANTAS and 1:21 ha for manual harvesting. In conclusion, mechanised harvesting machinery increased harvesting efficiency by covering more plantation areas. Although the adoption of mechanisation is unfavourable due to the high initial capital cost, the difference in OPEX between manual and harvesting machines was shown to be small and even lower compared with CANTAS in the long term.

Keywords: harvesting; mechanisation; productivity; capital expenditure; operational expenditure

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1. Introduction

Oil palm harvesting is a critical step in producing palm oil, used in many products, including food, cosmetics, and biofuels. However, traditional manual harvesting methods can be labour-intensive and time-consuming, leading to the development of new technologies to improve efficiency and reduce costs.

Over the past 30 years, local and international manufacturers have made many efforts to develop fresh fruit bunches (FFB) harvesting technologies. However, there was little success due to several reasons, i.e., low efficiency, high capital expenditure (CAPEX), and high operational expenditure (OPEX) (Ismail, 2014). Those are the main reasons why developing a low-cost harvester is crucial. Another issue is that a cost-effective harvester is currently not available in the market for tall palms with heights between 8 to 15 meters. In addition, the price of the existing mechanical harvester is high, ranging from d to RM 300,000.00, with very high cost-effectiveness (i.e., RM 21/bunch) (Ramli, 2022).

The FFB harvesting task in oil palm plantations involves cutting the fronds that support the FFB and the FFB stalk once it is identified to have achieved the ripeness standard. This activity is commonly done twice a month for certain hectares of the plantation (Baskett *et al.*, 2007). This harvesting cycle between visits, around 10 to 15 days, is also known as harvesting interval. However, due to the critical labour shortage issue, this cycle has been extended up to as long as once every three months, reducing the productivity of FFB yield in the oil palm industry. This was due to the severe labour shortage issue during the COVID-19 pandemic that further trampled the industry (Ma'Soad & Khairuddin, 2022). Any FFB or loose fruit that goes uncollected within 24 hours will cause an increase in free fatty acids (FFA) and a reduction in oil content.

Mechanisation is a pertinent approach to improving productivity and reducing worker requirements. Malaysian Palm Oil Board (MPOB) has made significant breakthroughs in developing technologies some of which have successfully been commercialized such as Aluminium harvesting pole (Zirafah and Hi-Reach), Motorised Cutter (Ckat and CANTAS), Mechanical loader (Grabber), FFB infield transporters (Beluga and Rhyno), and Loose Fruit Picker for loose fruits collection (Jelani & HItam, 2002).

The existing motorised cutter (CANTAS) (Figure 1) has proven effective. However, unfortunately, it can only reach a maximum harvesting height of 7 meters, which covers about 50% of the plantation area in Malaysia (Shaik Husin & Sukawa, 2015). There is indeed still a big gap to be filled, such as finding ways to increase its harvesting reach, reducing strong vibration from the machine, and reducing the weight of the harvesting tool (Salleh *et al.*, 2013). These arising matters needed to be addressed accordingly so harvesting could be done more efficiently. Harvesting activity, the most crucial task in an oil palm plantation, is still preferably conducted manually. This hinders any possibility of improving or increasing the productivity of harvesting FFB. Several harvesting machines have been invented to overcome this issue, such as an excavator-based oil palm harvesting machine by MPOB (Figure 2). However, they are not adopted in the industry due to their high initial CAPEX and OPEX and low efficiency and productivity (Mohd Ramdhan & Abd Rahim, 2014). Labour shortages are also critical issues, especially in harvesting operations. It was reported that about 94% (i.e., 164,938 out of a total of 174,472) of harvesters and collectors are foreign workers (Ismail, 2014). Therefore, there is a dire need to develop a cost-effective oil palm harvester to address the productivity issue and the labour shortage problem.

Figure 1. An oil palm motorised cutter (CANTAS)

Figure 2. An excavator-based oil palm harvesting machine developed by MPOB

This study aims to analyse and assess the performance of different harvesting methods available in the oil palm industry. It provides a comprehensive comparison to determine the efficiency of each method. It provided a comprehensive comparison of the fresh fruit bunch (FFB) harvesting performance of a manual, mechanised cutter (i.e., CANTAS) and an excavator-based harvesting machine; hence, the advantages and disadvantages of each harvesting method can be better assessed.

2. Methods

In this study, the performance and technical specification data for the excavator-based harvesting machine were taken from research by Mohd Ramdhan and Abd Rahim (2014). In contrast, the performance of CANTAS and manual harvesting was based on a study by Azman (2014) and Jelani *et al.* (2018).

The primary consideration for the industry before adopting any technology is by considering the CAPEX and OPEX of the technology (Stanners & George, 1992; Setiawan *et al.*, 2022). The lower the CAPEX and OPEX values, the more likely the industry will adopt the technology. Therefore, the OPEX and CAPEX were calculated to analyse and assess the performance of each harvesting method by the following formulae:

$$CAPEX = C_{machine} + \delta \tag{1}$$

$$\delta = \frac{C_{machine}}{\Delta D} \tag{2}$$

$$OPEX = \frac{\lambda_{labour} + \lambda_{fuel} + \lambda_{R\&M} + \delta}{\sigma_{productivity}} \tag{3}$$

$\boldsymbol{C_{machine}}$ is the machine's total cost, δ is the depreciation value, and ΔD is the total number of working days. In the formula for OPEX, $\boldsymbol{\lambda_{labour}}$ is the labour cost, $\boldsymbol{\lambda_{fuel}}$ is the fuel cost, $\boldsymbol{\lambda_{R\&M}}$ is maintenance and repair costs, and $\boldsymbol{\sigma_{productivity}}$ is the tonnage of productivity. Then, the total coverage area for each harvesting method is compared according to the literature data to assess those selected harvesting methods.

3. Results

The results of OPEX and CAPEX calculations and land-to-labor ratio performance for each harvesting method are summarized in Table 1. The price for the selected harvesting method showed that the harvesting machine has the highest price (i.e., RM 280,000.00), which is 46 times higher than CANTAS and 466 times higher than the manual harvesting pole. However, it showed a higher economic life of 6 years compared to 2 years for CANTAS and manual harvesting poles. The labour cost was standardized for each method at RM 60/person-day. The depreciation value for the harvesting machine was the highest, which is RM 155.55, due to its high machine price, compared to only RM 6.33 for CANTAS and RM 1.00 for the manual harvesting pole. The values for fuel consumption and cost, as well as repair and maintenance cost, were based on the initial study in the literature (Mohd Ramdhan & Abd Rahim, 2014).

Table 1. Economic analysis of excavator-based harvesting machine, CANTAS, and manual harvesting.

Items	Excavator-based harvesting machine	CANTAS	Manual
Machine price (RM)	280,000.00	3,800.00	600.00
Economic life (Years)	6	2	2
Productivity (tonne/ man-day)	6	2.47	1.55
Labour cost (RM/day)	60	60	60
Depreciation (RM/day)	155.55	6.33	1.00
Fuel consumption (L/day)	18	1.5	-
Fuel cost (RM/day)	38.70	3.03	-
Repair & maintenance cost (RM)	100	1.57	-
Total Cost	364.70	70.93	61.00
CAPEX (RM)	**280,155.55**	**3,806.33**	**601.00**
Cost per tonne / OPEX (RM/tonne)	**46.45**	**28.72**	**39.35**
Labour-to-land ratio	**1:86**	**1:35**	**1:21**

The CAPEX of the excavator-based harvester is the highest, which is RM 280,155.55, compared to RM 3,806.33 for CANTAS and RM 602.00 for the manual harvesting pole. However, the harvesting machine has the highest productivity, 6 tonne/man-day, compared to 2.47 tonne/man-day for CANTAS and only 1.55 tonne/man-day for manual harvesting poles. Due to this advantage, the harvesting machine could reduce its OPEX value to RM 46.45/tonne. However, this value is slightly higher than the manual harvesting pole at RM 39.35/tonne and RM 28.72/tonne for CANTAS. Therefore, if the OPEX parameter alone is to be considered for choosing a harvesting method, CANTAS would be a better choice than the manual harvesting pole, even if the price of CANTAS is six times higher.

If a broader perspective is taken into account, the labour-to-land ratio parameter also serves as another better parameter to assess the performance of a harvesting method. Based on the comparison, the harvesting machine achieved the highest labour-to-land ratio, which is 1:86 ha, compared to 1:35 ha for CANTAS and 1:21 ha for the manual harvesting pole. This means that a single harvesting machine can have a more comprehensive coverage of the harvesting area, increasing the plantation's productivity significantly. This is because the operator only needs to sit in the driver seat of the harvesting machine to go around the plantation during the harvesting activity instead of walking around if either CANTAS or a manual pole is used. Hence, the operator can save much of his energy, reduce fatigue and prolong his harvesting endurance when using the machine. Therefore, the labour required to run the harvesting operation can be further reduced, adding extra cost savings to OPEX overall.

4. Discussion

Adopting mechanisation either by using CANTAS or harvesting machines increases productivity compared to manual harvesting. However, due to the significantly high cost of the harvesting machine, its OPEX was calculated to be 62% higher than CANTAS and 18% higher than manual harvesting. This finding was also in line with the results of studies done by Jelani *et al.* (2008) and Mohd Ramdhan and Abd Rahim (2014) when comparing them both. Although the CAPEX of CANTAS was six times higher than manual harvesting, it was found that the OPEX for CANTAS was 27% lower than manual harvesting. This is consistent with a study by Jelani that showed the same performance when comparing the cost-effectiveness of harvesting using CANTAS and manual harvesting poles and sickles (Jelani *et al.,* 2008). This advantage was contributed by the higher value of productivity that CANTAS was able to achieve. This showed the importance of the productivity parameter in assessing the efficiency and reliability of a particular harvesting method.

In addition, although the OPEX of the excavator-based harvesting machine was the highest among those three methods, it was found that it could cover more hectares of harvesting area in the oil palm plantation. This advantage was also contributed by the higher productivity value it achieved, which was also shown in a study conducted by Mohd Ramdhan and Abd Rahim (2014). By comparison, the machine could cover 59% more harvesting area compared with CANTAS, up to 75% higher than the manual method. The machine significantly reduced the burden and energy needed by the plantation operator to carry out his harvesting task. Therefore, the operator could travel a greater distance and cover more area, which reduced labour requirements for harvesting activity in oil palm operations.

However, it is worth noting that CANTAS can only harvest FFB on trees with a maximum height of 7 m, whereas the harvesting machine can harvest up to 11 m in height. Therefore, each harvesting method has advantages and disadvantages that must be determined and assessed before being implemented on the palm oil plantation.

5. Conclusions

A comprehensive comparison between the three harvesting methods available in the palm oil industry has been made to assess and analyse their advantage and disadvantages, especially in evaluating the effect of adopting mechanisation in the palm oil industry. From this study, a common misconception that mechanisation in palm oil plantations is unworthy of adoption due to its high cost can be appropriately addressed. By comparing the CAPEX and OPEX of each method, a clear comparison and assessment can be made to determine which harvesting method is suitable to implement in the designated plantation. If lower OPEX is aimed at harvesting operations, then CANTAS would be the option to be adopted since it was proven that this method has the lowest OPEX value among those three harvesting methods. As seen in the result section, adopting mechanisation such as CANTAS or harvesting machine required high CAPEX, a few times folds compared to the manual harvesting method. However, mechanisation has proven to be able to increase productivity significantly. This would lead to a lower OPEX in the long run, which would be more beneficial to the plantation industry. At the same time, more plantation areas can be covered, reflected in a higher labour-to-land ratio value when the mechanisation element is adopted. Therefore, it is concluded that the implementation of mechanisation in the oil palm industry should be encouraged due to the benefits that can be gained, and those benefits would outweigh the disadvantage of the high initial capital cost that the industry is so concerned about.

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