Exploring mechanization degree and capacity in Malaysia's oil palm plantations

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Abstract: Development of mechanization is a crucial element in oil palm plantations in Malaysia since its significant role in reducing highly dependence on manual workers. Nonetheless, the recent mechanization degree and capacity in oil palm plantations in this country is rarely studied. This study aims to determine the mechanization degree and capacity in Malaysia's oil palm plantations. Determining mechanization degree and capacity were computed based on the available secondary data from a recent survey on 4,541 oil palm estates in Malaysia. The findings showed that average mechanization degree and capacity of infield operations in Malaysia's oil palm plantations were 10.88% and 11.04%, respectively. These percentages reflected oil palm plantations mechanization was at a lower advancement as compared to the several others crops either in Malaysia itself or other countries. Conclusively, there is an urgent need to intensively promote mechanization to enhance its degree and capacity in oil palm plantations.

Keywords: mechanization degree, machine capacity, oil palm, machinery management

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1 Introduction

By its nature, the Malaysia palm oil industry is labor-intensive industry. As reported by Simeh et al. (2010), total labor in Malaysian oil palm plantations was 477,803, and they were classified into field workers and executives. Proportion of field workers were 93.25% of total labor or amounted to 445,533 (Table 1), which comprised of harvesters, fruit collectors, general workers, other general workers and supervisors. However, the shortage of labor is one of the continuing problems and more noticeably in Malaysian oil palm plantations due to local workers were less interested working in the plantations. This is also in line with a shift in demand for local labor from agricultural to other sectors such as manufacturing and service. In fact, over the years, oil palm plantations in the country have been increasingly relying on foreign labor to perform daily operation. The number of foreign workers in Malaysian oil palm plantations were 362,362 or 75.84% of total labor in the plantations (Simeh, 2010). Foreign workers are working in various critical infield jobs such as harvesting and collecting fruits, weeding and other general works. Nonetheless, it is believed that the country's reliance on foreign workers in oil palm plantation industry will not last for long-term due to social and economy factors.

Therefore, implementation of mechanization has been a crucial element in facilitating various operations in Malaysia's oil palm plantations since its early introduction on 1980's. Through its benefits, mechanization has proved its ability to remove some strenuous works processes in Malaysian oil palm

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plantations, and also reduce the country's dependence on foreign workers in the plantation sector. Although application of mechanization in oil palm cultivation is more challenging than other crops because terrain characteristics of oil palm planted areas having lots of topographic challenges that can inhibit maneuverability of farm machinery, however, Fry (2009) stated that several studies showed introduction of mechanization has offered effective use of inputs to increase the productivity of land and labor. Khalid et al. (2013) added that the introduction of mechanization in the oil palm industry has reduced labor requirement as the land labor ratio increases from 10:1 to 15:1. They expected that the current ratio still can be improved further to the ratio of 20:1 if more appropriate mechanization technologies could be introduced and adopted by the oil palm industry. Khalid et al. (2013) also emphasized that mechanization is capable of enhancing workers' productivity and efficiency.

Table 1 Distribution of job and labor in Malaysian oil palm plantations

Job Category	Peninsular Malaysia	Sabah	Sarawak	Malaysia
Harvesting supervisors	4,516	5,355	898	10,768
General supervisors	4,463	5,663	1,567	11,694
Harvesters and fruit collectors	85,391	100,263	20,916	206,570
Field workers	51,881	57,892	12,213	121,985
Other general workers	35,292	47,118	12,106	94,516
Sub Total Field Workers	181,543	216,291	47,699	445,533
Executives	13,732	6,324	256	20,312
Staff	4,321	5,772	1,865	11,958
Sub Total Executives	18,053	12,096	2,121	32,270
Total	199,596	228,386	49,821	477,803

Note: Source: Simeh et al. (2010).

Several past research literatures also indicated the benefits of agricultural mechanization in general, such as Chen et al. (2008), who stated that utilization of mechanization has increased productivity growth in China's agriculture in years 1990-2003. Clarke (2000) mentioned that mechanization is one of the management tools that available for the farmers to maximize production and profit. Besides that, mechanization also gave advantages in reducing the drudgery of daily farm operation (Singh, 2006).

From the above-mentioned statements, it was summarized that mechanization is an important agricultural input. With enormous assistances of mechanization, the oil palm industry in Malaysia has been progressively emerging since past decades. Being a labor-saving technology, mechanization has contributed in overcoming the labor shortage and improving better working conditions in oil palm plantation. Having such benefits, mechanization has a great potential to attract young local people to work in oil palm plantations in the country.

Although mechanization is one of crucial inputs in agricultural production, nevertheless, the recent mechanization degree and capacity in oil palm plantations in Malaysia is rarely studied. According to Almasi et al. (2000), mechanization degree is one of the quantity indicators for assessing the progress of implementation of mechanization in farmland. In other words, Sharabiani (2008) mentioned that the mechanization degree is used for determining to which extent of various field operations that can be carried out by farm machinery. Meanwhile, according to Siemens et al. (2008), machine capacity can be defined as the quantity of the crop (area, weight or volume) that can be handled in a given time period (season). Apart from the previous of machine capacity methods, Paman et al. (2012) adopted a new approach is called mechanization capacity. This method refers to a concept that considers the potential of all farm machine availabilities to work per year, which is ignored in previous works. The method also permits the assessment of mechanization capacity for all types of agricultural operations.

Hence, this study aims to determine the mechanization degree and capacity in oil palm plantation in Malaysia. By knowing mechanization degree and capacity, it permits to assess the level of its adoption among the plantations. Furthermore, this study would be useful for evaluating the advancement of mechanization in Malaysia's oil plantations and seeking improvement for lifting-up plantations' productivity and efficiency in the future. This study may also assist the government to establish any relevant policy to encourage mechanization adoption among the oil palm plantations in Malaysia. Last but not least, the findings could contribute in enriching the database in the literatures concerning on the implementation of mechanization on various crops production system.

2 Material and methods

The analysis of mechanization degree and mechanization capacity were made from the available secondary data. The data were originated from a recently survey on 4,541 estates in Malaysia that was conducted by the Malaysian Oil Palm Board (MPOB) in year 2013. The survey covered all oil palm estates in Sabah, Sarawak and Peninsular Malaysia. The operation, machine types, numbers of estates, numbers of machines, overage areas mechanized and total oil palm plantations areas were recorded as parameters for the computation of mechanization degree and capacity (Table 2 and Table 3). The topography features of the surveyed estates were flat, undulating and hilly terrains. The mechanization degree is defined as the ratio of the oil palm plantation areas mechanized to the total oil palm plantations areas. It was adopted from the methods of previous studies (Karimi et al., 2008; Sharabiani and Ranjbar, 2008; Ghadiryanfar et al., 2009). The total oil palm plantations areas (TP) areas amounting to 5,076,929 hectares were used in this calculation. The formula of mechanization degree is shown in Equation 1 and expressed in percent (%). Mechanization degree was also discussed in regards to type of machine and operations as well.

$$MD = \frac{MO}{TP} x\ 100\% \quad (1)$$

where:

MD = Mechanization degree, (%)

MO= Oil palm plantations areas mechanized (ha)

TP = Total oil palm plantations areas (ha)

Table 2 The operation, type of machine, numbers of estates, numbers of machines, and areas mechanized

Operation	Type of macnine	Numbers of estates (dimensionless)	Numbers of machines (unit)	Areas mechanized (ha)
Weeding	Motorized Sprayer	443	2,159	646,556
Pest & Disease (P&D)	Trunk Injector	70	155	159,484
	Motorized Sprayer	67	197	99,030
Fertilizing	Fertilizer spreader	160	335	345,370
	Sub-surface application	16	54	22,002
Harvesting	Motorized cutter	82	616	119,738
Infield Collection	Motorcycle trailer	33	87	27,169
	Tractor - trailer	824	3,616	993,937
	Tractor - trailer with grabber	127	637	272,440
	Three wheels cart	97	997	208,713
	Vacuum- loose fruits collector	3	22	3,434
	Others	85	603	166,112

The mechanization capacity is the ratio of multiplying the available machines by potential working capacity per year to the total operation expressed as a percentage. Mechanization capacity was also analyzed and calculated from secondary data in Table 2. However, pest and disease control was excluded from the calculation of mechanization capacity since the operation was executed occasionally and in the case if it is

necessary. Similarly, land preparation and planting operations were also excluded from the determination of mechanization capacity. The exclusion is because such operations were carried out once every 30-years of cycles of productive palm trees. In oil palm plantation practice, the palm trees aging 30 years and above should be felled since the total costs for crop-upkeep is more than the return obtained. Therefore, both operations were only undertaken when performing either replanting on the present areas or planting on newly opened areas. The mechanization capacity was calculated and expressed in percent. Formula for computing mechanization capacity was derived from a previous study by Paman et al. (2012) as shown in Equation 2. However, an average yearly frequency of operation in respect of the machines that commonly found in the oil palm plantations were added as an additional parameter in the calculation to indicate the average yearly frequency of operation. The reason behind adding this parameter is just because such as operations have yearly frequency of operation in accordance with the standards of agronomic practices for crop production in oil palm plantations.

$$\mathrm{Mc} = \frac{\mathrm{Nm\ X\ Wc\ x\ Fo}}{\mathrm{Ao}}\ x\ 100\% \qquad (2)$$

where:

Mc = Mechanization capacity (%)

Nm= Total number of available machines (unit year^{-1})

Wc= Average yearly working capacity for each machine (ha unit^{-1} or ton unit^{-1})

Fo = Average yearly frequency of operation by machine (dimensionless)

A_o = Total annual outcome obtained by operation, (ha year^{-1} or ton year^{-1})

Table 3 Productivity of each operation in Malaysian oil palm plantations

Operation	Total numbers of available machines per year (unit year^{-1})	Average yearly working capacity of each machine (ha unit^{-1} or ton unit^{-1})	Average yearly frequency of operation (dimensionless)	Total annual outcome by operation (ha year^{-1} or ton year^{-1})
Weeding*	2,159	4.25	4	646,556
Fertilizing*	389	22.5	3	367,372
Harvesting**	616	4	36	478,952
Fresh fruit bunch (FFB) infield collection**	5,359	24.2	36	36,437,770.6

Note: *ha unit^{-1} and ha year^{-1}; **ton unit^{-1} and ton year^{-1}

3 Results and discussion

3.1 Mechanization degree

The study has successfully determined mechanization degree in Malaysia's oil palm plantation on the basis of types of machine and operation. The term of mechanization degree here refers to percentage of hectarage covered by an operation using a machine in oil palm plantation. The operations that have been mechanized in the surveyed estates, namely weeding, pest and disease (P&D) control, fertilizing, harvesting, fresh fruit bunch (FFB) infield collection and others.

Various machines have been utilized in five major operations (i.e. weeding, pest and disease (P&D) control, fertilizing, harvesting and infield collection) in Malaysian oil palm plantations. The machines consisted of motorized sprayers for weeding, motorized sprayer and trunk injector for pest and disease (P&D) control, and fertilizer spreader and sub-surface fertilizer applicator for fertilizing. Motorized cutter was used for harvesting operation. Motorcycle trailer, tractor- trailer, tractor- trailer with grabber and three-wheels cart were operated for fresh fruit bunch (FFB) infield collection. Vacuum loose fruits collector was employed for loose fruits infield collection. While, the others were defined as the machines functioning beyond of the said five major operations.

Based on type of machine, the tractor-trailer for fresh fruit bunch (FFB) infield collection had the highest mechanization degree at value of 19.58% level of adoption as shown in Figure 1, followed by motorized sprayer (12.74%) for weeding operation. The lowest degree at 0.07% was recorded by the vacuum loose fruit collector for loose fruits infield collection operation.

Figure 2 shows mechanization degree of oil palm

plantation by operation. The fresh fruit bunch (FFB) infield collection indicated the highest mechanization degree with value at 29.66% of adoption level. This percentage revealed this activity was the most mechanized operation in Malaysian oil palm plantations. Weeding recorded 12.74% of adoption level was the second highest mechanization degree. While, harvesting noted 2.36% of adoption level was the lowest mechanization degree. On average, the mechanization degree in oil palm plantations in Malaysia by operation was 10.88% % of adoption level.

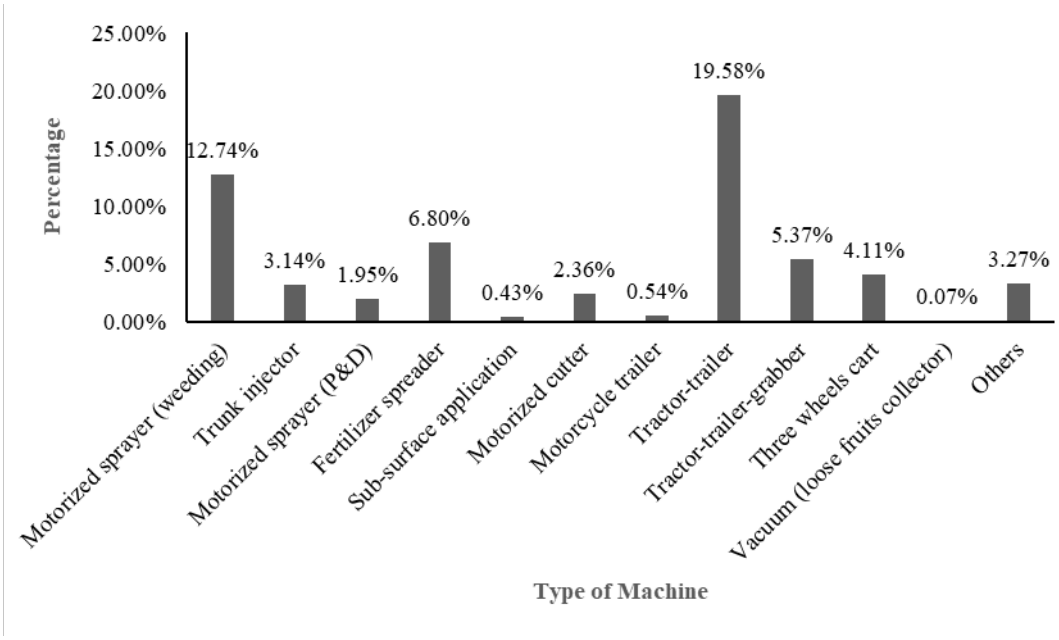

Figure 1 Mechanization degree by type of machine

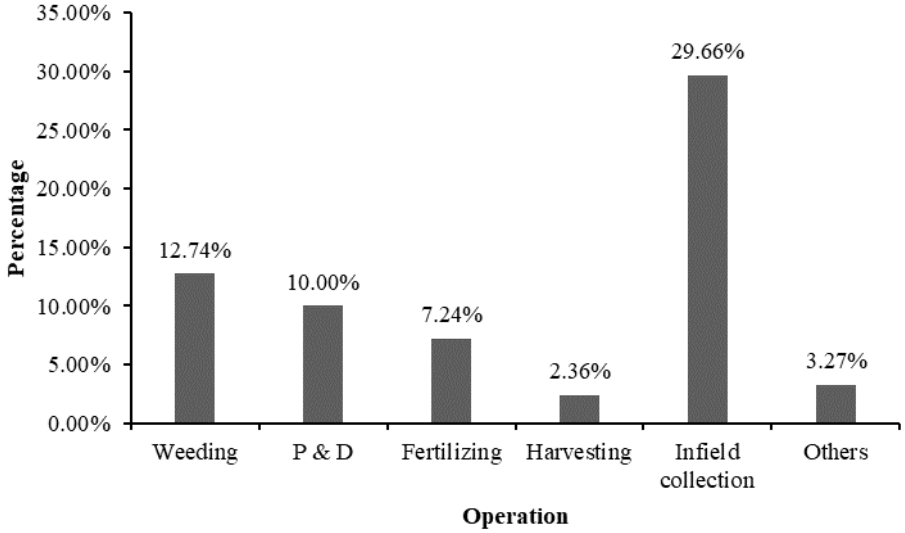

Figure 2 Mechanization degree by operation

Under such mechanization degrees, generally, the infield operations in Malaysia's oil palm plantations did not yet fully utilize mechanization system. Some manual practices using hand-tools such as chisel and sickle for harvesting fresh fruit bunch (FFB), cleaver for weeds slashing, and wheelbarrow for fresh fruit bunch (FFB) infield collection were still applied by the plantations.

The fresh fruit bunch (FFB) infield collection operation was the highest mechanization degree which reached 29.66% of adoption level. The majority of plantations have employed mechanization systems for collecting and transporting fresh fruit bunch (FFB) by using motorcycle trailer, tractor-trailer, tractor-trailer with grabber and three-wheels cart. The use of mini tractor- trailer, mini tractor trailer with mechanical loader and mini tractor-trailer with grabber with a high-lift

trailer have proved their effectiveness for infield collection operation (Simeh et al., 2010). Quick and efficient methods are really needed for this operation because the fresh fruit bunch (FFB) have to be delivered to the mill within 24 hours after harvesting in order to the fruits remain in good quality. Performing this operation in oil palm plantations with high efficiency can help the mills to obtain higher average oil extraction (OER) from the fruits. Hence, higher OER means higher profit margin to the plantations. This is the main reason for the plantations always insist the implementation of mechanization on the fresh fruit bunch (FFB) infield collection. This situation has become a push factor that made the operation achieves the highest mechanization degree. On contrary, the shortfalls of such machine for this operation may affect the efficiency of milling operation as well as the whole industry eventually.

Harvesting indicated 2.36% of adoption level was the lowest mechanization degree in Malaysia's oil palm plantations. Till to date, harvesting is considered as the most challenging operation to be mechanized in oil palm plantations. Manual method of cutting fresh fruits bunches using chisel and sickle with pole are still widely applied for daily harvesting in most oil palm plantations. Therefore, the use of motorized cutter that has been introduced by the MPOB must be extensively encouraged in the plantations in order to increase mechanization degree of harvesting operation and make this operation much easier and efficient as well.

Overall, the field operations of oil palm plantations in Malaysia were lagging behind the field operations of rice cultivation in the country's paddy fields on mechanization degree. Based on a survey reported by the DOA (2015) and Ismail and Pebrian (2018), the average mechanization degree of rice cultivation operations in Malaysian paddy fields was 74.22%. This percentage was very much higher than the average of 10.88% achieved by the operations of oil palm plantations in the country. Breakdown of mechanization degree of rice cultivation operations comprised of harvesting (100%), land preparation (100%), transplanting (2.1%), direct seeding (80.7%), fertilizer application (76.9%), and crop spraying (85.6%). The differences between characteristics of the planted areas for paddy and oil palm cultivations have affected the advancement of mechanization on both crops. Various types of plantations terrains have been planted with oil palm trees such as flat, undulating and hilly. The terrains characteristics of undulating and hilly areas have inhibited the advancement mechanization for this crop production (Simeh et al., 2010). On contrary in rice cultivation, paddy was planted on rice granaries areas, which are perfectly flat land. Thus, mechanizing operations on such area did not find any significant constraint. In addition, rice granaries areas were also very accessible with farm machinery. These situations have made mechanization in rice cultivation running smoother than that of the oil palm. Not only that, mechanization in rice cultivation was also more progressive as compared to the oil palm cultivation.

Comparisons with same crops from other oil palm producing countries were not possible because unrevealing similar studies in the past research literatures. However, when compared to other crops from other countries, the mechanization degree in Malaysian oil palm plantations was also lower than palm date (69%), citrus (69%), progmegrate (91%), banana (108%), mango (79%), pistachio (130%), apricot (81%) and grape (93%) in Beluchestan province, Iran as reported by Shahraki (2012). Nonetheless, the opportunities of increasing mechanization degree in oil palm plantations are still there for the following reasons. Firstly, mechanization is the only way to combat the current labor shortage problem in Malaysian oil palm plantations. When workers are not sufficient or not interested to works in plantations anymore, hence, farm machinery will surely play major role to replace human labor in oil palm plantations operations in Malaysia. Secondly, high usage of human energy was still persistence problem in most of infield operations in oil palm plantations as mentioned by Pebrian et al. (2014). This is shown by 71.42% of total infield operations were categorized into heavy and very heavy operations on the basis of human energy expenditure. Therefore, the only option available to lighten such operation is by massive use of farm machinery. In due course, the whole oil palm plantations

will ultimately use mechanization in their daily infield operations. Off course, these situations will automatically increase the mechanization degree in Malaysia's oil palm plantations.

2.2 Mechanization capacity

The mechanization capacity of operation was measured with the respective of the yearly capacity of weeding, fertilizing, harvesting and fresh fruit bunch (FFB) infield collection operations. Figure 3 shows that the highest mechanization capacity was recorded by harvesting with value of 18.52%, followed by fresh fruit bunch (FFB) infield collection (12.81%), fertilizing (7.15%) and weeding (5.68%). Although in mechanization degree, harvesting achieved the lowest percentage of adoption level, however, this operation showed the highest mechanization capacity among the operations. This is due to the MPOB has tremendously introduced a motorized cutter known as CANTAS in 2006 for harvesting intermediate palm height (less than 5 m height). This machine was capable of giving two or three increments of harvesting capacity when compared with the conventional sickle and pole as stated by Jelani et al. (2008). An operator can harvest 560 to 750 fresh fruit bunch (FFB) per day using CANTAS. Khalid et al. (2013) added that, the presence of this machine is well-accepted by the oil palm industry since it offers high efficiency, ergonomics design, comfortable and safety in handling and operation, and doubling income to the operator as well. The CANTAS is widely used for harvesting and pruning. This equipment employs a specially patented C-sickle to perform fruits cutting operation by a vibrating mechanism. Fresh fruit bunch (FFB) infield collection with mechanizations capacity of 12.81% was the second highest capacity. Actually, yearly frequency of operations of both harvesting and fresh fruit bunch (FFB) infield collection in Table 2 are the same because they were run sequentially as the harvesting at first, and followed by the infield collection. However, harvesting capacity is higher than that of the fresh fruit bunch (FFB) infield collection as the ratio of total numbers of available machines and average yearly working capacity of each machine in harvesting operation is also higher. Meanwhile, weeding at capacity of 5.68% was the lowest mechanization capacity is just because the frequency of operation per year was not that many as compared the harvesting and fresh fruit bunch (FFB) infield collection, although the numbers of available machines that being used for weeding was the second largest. As shown in Table 2, overall, the average of mechanization capacity in oil palm plantation in Malaysia is 11.04% for four operations i.e. weeding, harvesting, infield collection and fertilizing.

Anyway, comparisons were made between mechanization capacity of Malaysia's oil palm plantations and mechanization capacity in rice cultivations in Indonesia and Philippines, even though there were differences in type of crops and crops production systems. It was found that the average mechanization capacity of 11.04% in Malaysia's oil palm plantations was lower than that of the rice cultivations in Indonesia (30%) and Philippines (21.7%) based on the reports by Handaka (2005) and Elepaño et al. (2009), respectively.

It was observed that the progress of mechanization degree and capacity in Malaysian oil palm plantations were also affected by the topographical terrains features in the plantations. Generally, the terrains characteristics in Malaysian oil palm plantations were grouped into three types i.e. flat, undulating and hilly terrains. According to Simeh et al. (2010), undulating terrain was the largest areas, which covered 39.21% of total oil palm plantations in the country, followed by hilly (36.64%), and flat (24.25%) terrains. Simeh et al. (2010) also added that flat and undulating terrains were favorable for plantation mechanization. Common machinery such as mechanical buffalo and mini tractor-trailer with grabber for infield collection, tractor mounted spreader for fertilizing, tractor mounted sprayer for weeding and pest and disease control, and control droplet applicator (CDA) for weeding were convenient to be operated on such terrains. On other hand, hilly terrain required extra costs for implementing mechanization. Yet the productivity on hilly terrain was less due to the terrain conditions restrict the machines movements. Thus, without other options, the operations on hilly terrains extremely depend on manual labor. Moreover, until to date, the suitable prime

mover that meets the requirements of the local hilly terrains is still unavailable. However, there is still a way to increase mechanization capacity in oil palm plantations through improving field efficiency of each operation. Siemens et al. (2008) mentioned that field efficiency of farm operation can be improved by minimizing some lost-time factors that are built into the operation such as loading and unloading procedures, filling procedure, turning time at headland and field conditions.

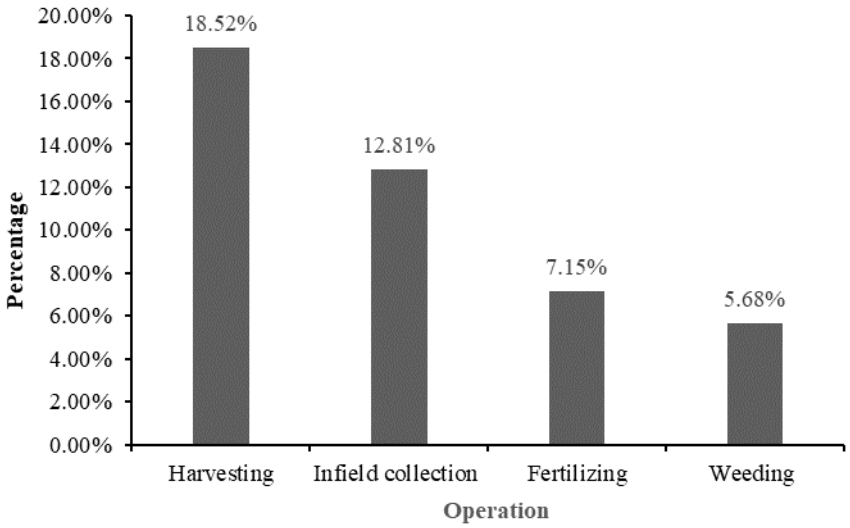

Figure 3 Mechanization capacity by operation

4 Conclusion

The existence of mechanization in Malaysian oil palm industry has been around for a very long and almost four decades since it was firstly introduced on 1980's. This study has successfully explored the progress of the mechanization implementation in the country's oil palm plantations through investigating its degree and capacity. Overall, average mechanization degree of field operations in Malaysia's oil palm plantations were 10.88% and considered a slow pace when compared to 74.22% of mechanization degree in Malaysia's rice cultivation. While, the average of mechanization capacity in oil palm plantations in Malaysia was 11.04% based on the capacity of weeding, harvesting, infield collection and fertilizing operations. Such as percentages reflected low mechanization capacity. Hence, intensive promotion of mechanization in oil palm plantations is an urgent need to enhance mechanization degree and capacity, and later on it permanently solves labor shortage problem and creates an attractive job in the oil palm plantations. Implementation of mechanization in oil palm plantations is in line with the Malaysia's government policy to reduce the country's dependence on foreign workers. The effort requires a strong collaboration between relevant agencies such as research/academic institutions, farm machinery manufacturers, dealers and related government agencies to create mechanization technologies that comprehensively considered the oil palm plantations conditions from technical, economical, geographical, topographical and agronomic aspects.

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