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Economic Analysis of the Losses of Oil Palm (*Elaeis guineensis* Jacq.) Loose Fruits on Flat Terrain at Agritasari Prima Ltd.

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Abstract

Aims and Methods: Oil palm is a strategic commodity that contributes significantly to Indonesia's economy. The losses of oil palm loose fruits during the harvesting and transportation processes of fresh fruit bunches (FFB) pose a serious challenge for oil palm plantation industry, with potential losses reaching 3–7% of total production. This study aims to analyze the distribution pattern of the losses of loose fruits at three observation points (weed circle, carrying market, and harvest collection point (HCP)) at Agritasari Prima Ltd., calculate the economic loss due to these losses, and identify the causative factors. This study employs a qualitative descriptive survey method with sampling at three plantation divisions on flat terrain, covering 1,260 weed circles, 21 carrying markets, and 144 HCPs.
Results: The highest loss distribution occurred at carrying market (47.66 fruits/carrying market), followed with weed circle (10.15 fruits/circle) and HCP (8.14 fruits/site). The total economic loss reached IDR 463,143.83, with the largest contribution coming from the losses at weed circle of 85.44% (IDR 395,808), followed by HCP of 7.86% (IDR 36,307), and carrying market of 6.70% (IDR 31,028.83). The annual economic loss due to the losses of loose fruits on flat terrain at Agritasari Prima Ltd. is estimated at IDR 2,178,282,597.31 (around IDR 2.18 billion per year). Major causative factors comprise poorly maintained weed circles, overloaded wheelbarrows, poor route infrastructure at carrying markets, and suboptimal handling at HCPs.
Conclusion: Implementation of regular maintenance programs, standardization of vehicles' capacity, infrastructure improvements, and digital monitoring systems are recommended to reduce the level of losses of loose fruits and improve oil palm plantation operational efficiency.

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1. Introduction

Oil palm (*Elaeis guineensis* Jacq.) is a strategic commodity that contributes significantly to Indonesia's economy as the largest foreign exchange earner from the plantation sector. Indonesia is the largest oil palm producer globally and its crude palm oil (CPO) production reached 51.3 million tons in 2023, with an export value reaching US$ 22.5 billion (Fadhilah & Safitri, 2024). Agro-ecologically, oil palm grows optimally in tropical areas with the range of annual rainfall of 2,000–2,500 mm, an average temperature of 24–28°C, and high light intensity throughout the year. These characteristics make Indonesia, especially Sumatra, Kalimantan, and Papua regions, an ideal location for oil palm cultivation (Rahman *et al.,* 2020). Oil palm productivity is greatly influenced by various factors, such as agronomic aspects, selection of superior varieties, pest and disease management, and environmental management. Optimizing oil palm production is a key for maintaining competitiveness within global market, one measure of which is by minimizing the losses of oil palm fruits during the harvesting and transportation processes.

Agritasari Prima Ltd., one of Indonesia's oil palm plantation companies, is located in Pelalawan Regency, Riau Province, with a total plantation area of 8,750 ha. Approximately 65% of the company's total area is flat terrain with a slope of 0–8%, while the remaining 35% is undulating to hilly terrain with a slope of 8–25%. The topographic condition dominated by flat terrain should be a comparative advantage in minimizing harvest losses, especially oil palm loose fruits (*brondolan*), because this type of terrain can facilitate better accessibility and more efficient transportation process compared to those of undulating or hilly terrain. At Agritasari Prima Ltd., the loss of oil palm loose fruits is a serious concern considering the potential economic loss incurred, especially in areas with flat terrain, which are normally expected to experience minimal losses.

Loss in this context refers to the loss of loose fruits from fresh fruit bunches (FFB) of oil palm, since they are not thoroughly reaped or are wasted during the harvesting, transportation, or processing. Critical problems in oil palm harvest management could occur at various places, starting from the weed circle (*piringan*) around the oil palm tree during harvesting, the carrying market (*pasar pikul*) during the harvest transportation process, to the harvest collection point (HCP) when the fresh fruit bunches (FFB) are loaded onto the transport vehicles. Loose fruit is an oil palm fruit that is separated from the bunch during the harvesting and transportation process, which has a palm oil content of up to 35–40% (Hafiz *et al.,* 2023). Every kilogram of loose fruit that is lost not only reduces production volume, but also has a significant impact on the yields of oil and palm kernel obtained, thus having a direct effect on oil palm company's profits. A study by Hafiz *et al.* (2023) showed that implementing a proper harvest management system can reduce losses by up to 40%. A study by Citra & Nugroho (2023) at oil palm plantations in Central Kalimantan showed that the largest losses of loose fruits occur at weed circle (45%), followed by HCP (35%), and carrying market (20%). However, these distribution patterns could vary depending on topographic conditions, infrastructure, and the harvest management system applied.

Analysis of the losses of loose fruits is necessary for several fundamental reasons. Firstly, loose fruit has a higher palm oil content compared to that of still attached to the bunch so that the loss of loose fruit has a significant impact on the palm oil yield that could be obtained. Secondly, understanding the distribution patterns of losses at each observation point allows the development of more targeted and effective mitigation strategies. Thirdly, quantifying the economic value of the losses provides an empirical basis for management in allocating resources to handle this problem. Based on recent studies, the losses of loose fruits can reach 3–7% of total FFB production, implying significant economic loss for oil palm plantation companies (Fadhilah & Safitri, 2024). With an assumption of a CPO price of IDR 11,500/kg and a loose oil yield of 35%, each ton of the loss of loose fruit results in a potential economic loss of IDR 4,025,000. Economic evaluation of the losses of loose fruits is crucial considering the fluctuating CPO prices within global market. Thus, a comprehensive analysis of the economic loss could provide a concrete picture of the urgency of handling this problem and could be the basis for developing more effective loss control policies (Pramana & Hamzah, 2021). By understanding the patterns and magnitude of losses at each observation point, management could develop more targeted and efficient mitigation strategies. Best practices include regular weed circle maintenance, proper use of transport sacks, training of harvest workers, and strict supervision at every loss potential point. In addition, optimizing the roles of labors and supporting infrastructures also play an important role in minimizing the losses of loose fruits (Tarmadja & Vernando, 2022).

Based on the above background, the research questions in this study are formulated as follows: (1) how is the distribution pattern of the losses of oil palm loose fruits at three observation points (weed circle, carrying market, and HCP) on flat terrain at Agritasari Prima Ltd.; (2) how much is the economic loss caused by the losses of loose fruits at each observation point; and (3) what are the contributing factors of the losses of loose fruits at each observation point. Based on these questions, this study thereby aims to analyze the losses of oil palm loose fruits at three observation points on flat terrain at Agritasari Prima Ltd., then calculate and evaluate the economic loss due to the losses of loose fruits at each observation point, and identify the contributing factors of the losses of loose fruits for the development of effective mitigation strategies. Theoretically, this study's findings would contribute to the development of science in the field of oil palm plantation management, especially related to harvest optimization and loss control. This study's findings could also be a reference for further studies in developing a more efficient oil palm harvest management system (Harefa *et al.,* 2024). Practically, this study provides benefits for stakeholders in developing more effective strategies to control the losses of loose fruits based on empirical data, as well as becomes a reference for oil palm smallholders in reducing the losses.

2. Materials and Methods

This study was conducted at the oil palm plantation at Agritasari Prima Ltd., Segati Village, Langgam Subdistrict, Pelalawan Regency, Riau Province from July 30 to September 9, 2024. The objects examined in this study were productive oil palm trees and scattered loose fruit bunches. The method used was a survey with a quantitative descriptive approach, with the initial stage using a qualitative descriptive approach to identify plantation conditions, followed by quantitative data analysis to calculate the economic loss. The focused observation areas were the ones comprising flat terrain (slope 0–8%), plants aged 8–12 years, and a planting distance of 9 × 9 meters in an equilateral triangle pattern. Stratified random sampling was carried out at three selected divisions representing oil palm tree population on flat terrain.

From an average of 240 HCP per block, a sample of 48 HCP/block (20% of the total HCP) was taken, which was able to represent the variation of HCP conditions. Overall, the total samples observed were 1,260 weed circles (420 × 3 blocks), 21 carrying markets (7 × 3 blocks), and 144 HCP (48 × 3 blocks). The data collection was carried out by manually reaping each loose fruit left behind at the weed circle, carrying market, and HCP. The reaped loose fruits were then counted and weighed to obtain their weight data in kilograms. In addition, weighing calibration was carried out to obtain a conversion of the number of loose fruit per kilogram. This data were then used to calculate the economic loss due to the losses of loose fruits using the prevailing price of loose fruit (IDR/kg) at Agritasari Prima Ltd., which was IDR 1,500/kg at the time of this study's implementation. Data analysis was carried out quantitatively to calculate the losses of loose fruits and the economic loss. This quantitative approach is important to provide an accurate picture of the economic impact of the losses of loose fruits at each observation point. Data obtained from the field were then analyzed using the following formulas (Nuryadi, 2017):

1. Average loss of loose fruits per weed circle = Total loose fruits left behind at each sample weed circle/Number of sample weed circles
2. Average loss of loose fruits per carrying market = Total loose fruits left behind at each sample carrying markets/ Number of sample carrying markets
3. Average loss of loose fruits per HCP = Total loose fruits left behind at each sample HCP/Number of sample HCP
4. Total average loss of loose fruits per sample block = Average loss at weed circle per block + Average loss at carrying market per block + Average loss at HCP per block
5. Economic loss due to the losses of loose fruits per weed circle (IDR) = Average loss per weed circle (kg) × Price per kg of loose fruit (IDR/kg)
6. Economic loss due to the losses of loose fruits per carrying market (IDR) = Average loss per carrying market (kg) × Price per kg of loose fruit (IDR/kg)
7. Economic loss due to the losses of loose fruits per HCP (IDR) = Average loss per HCP (kg) × Price per kg of loose fruit (IDR/kg)
8. Total economic loss due to the losses of loose fruits per block (IDR) = Total loss at weed circle + Total loss at carrying market + Total loss at HCP
9. Estimated economic loss per year for the entire plantation area (IDR) = Total loss per block (IDR) × Number of blocks × Harvest frequency per year

All calculations were performed for each sample block, then the average values of the three sample blocks were used to represent the condition of the losses of loose fruits at the plantation area as a whole. The results of this quantitative analysis were used to identify critical points with the highest level of losses of loose fruits as well as to calculate the economic loss due to the losses of loose fruits, thereby serving as a basis for developing the more effective loss control strategies.

3. Results

This study determined the amount of losses of loose fruits using using three divisions, where one block was used as a sample in each division. The parameters observed were the losses of loose fruits at weed circle, the losses of loose fruits at carrying market, the losses of loose fruits at HCP, the average losses of loose fruits at weed circle, carrying market, and HCP, as well as the labor costs for reaping loose fruits at weed circle, carrying market, and HCP. The analysis and calculation results from 420 weed circles/block, 7 carrying markets/block, and 48 HCPs/block are as displayed as follows:

3.1 Losses of loose fruits at weed circle

Table 1. Losses of loose fruits at weed circle.

No.	Division	Block	Area (ha)	1st Replication	2nd Replication	Average/weed circle
1.	Division I	E12	29.17	3,917	879	11.4
2.	Division II	C34	27.82	4,482	985	13.01
3.	Division III	A48	12.14	1,592	943	6.04
			Total average			***10.15***

Source: Primary data (2024)

It is shown in Table 1 that the largest number of losses of loose fruits at weed circle occurred in the first replication of Block C34, Division II and Block E12, Division I. The main factor causing difficulties in reaping loose fruits was the condition of the weed circles, which were filled with bushes. This hindered workers in performing their duties. Moreover, workers were also in a hurry to reap the loose fruits for meeting their work-base target, which made them less thorough in reaping and collecting the fruits. Several workers even showed tendency to ignore loose fruits scattered around the weed circles.

3.2 Losses of loose fruits at carrying market

Table 2. Losses of loose fruits at carrying market.

No.	Division	Block	Area (ha)	1st Replication	2nd Replication	Average/carrying market
1.	Division I	E12	29.17	453	11	66.28
2.	Division II	C34	27.82	224	21	35
3.	Division III	A48	12.14	243	49	41.71
			Total average			***47.66***

Source: Primary data (2024)

It is shown in Table 2 that the largest number of losses of loose fruits at carrying market occurred in the first replication of Block E12, Division I, and Block A48, Division III. One of the main factors causing high losses of loose fruits was the FFC transportation method to HCP. During the transportation, the wheelbarrows used were loaded up to its maximum capacity, resulting in spilled or scattered loose fruits throughout the carrying market. This condition shows that the excessive loading on wheelbarrow is the main cause of the increased number of the losses of loose palm fruits during the transportation process.

To overcome this problem, the ideal loading capacity of wheelbarrow is maximum 75% of its total capacity or around 250–300 kg per wheelbarrow. This loading limitation would prevent the spillage of loads (loose fruits) during the transportation process and ensure sufficient distance between the pile of loads and the top of wheelbarrow. Implementation of the proper loading standard of wheelbarrow would significantly reduce the losses of loose fruits and increase harvest efficiency. In addition, the installation of higher dividing walls or safety nets around the wheelbarrows could also greatly reduce the likelihood of the losses.

3.3 Losses of loose fruits at harvest collection points (HCP)

Table 3. Losses of loose fruits at harvest collection points (HCP).

No.	Division	Block	Area (ha)	1st Replication	2nd Replication	Average/HCP
1.	Division I	E12	29.17	245	150	8.22
2.	Division II	C34	27.82	219	142	7.52
3.	Division III	A48	12.14	156	262	8.70
			Total average			***8.14***

Source: Primary data (2024)

It is shown in Table 3 that the largest number of losses of loose fruits at HCP occurred in the second replication of Block A48, Division III, and the first replication of Block E12, Division I. The main factors causing the high losses of loose fruits at HCP were the fruit handling method when placed at this area and the incomplete transportation by fruit loaders. This careless movement process caused several loose fruits to fall and scatter around the HCP area, which means they were not thoroughly collected by the loaders to be loaded onto the transport vehicles, leaving behind a lot of loose fruits at the HCP area.

3.4 Average loss of loose fruits per sample block

Table 4. Average loss of loose fruit per sample block.

No.	Division	Block	Area (ha)	Weed circle	Carrying market	HCP	Total
1.	Division I	E12	29.17	2,398	232	197.5	2,828
2.	Division II	C34	27.82	2,733.5	122.5	180.5	3,036.5
3.	Division III	A48	12.14	1,267.5	371	209	1,847.5
	Total			***6,399***	***725.5***	***587***	***7,712***

Source: Primary data (2024)

The largest average loss of loose fruits at weed circle occurred at Block C34, Division II, namely 2,733.5 fruits. The largest average loss of loose fruits at carrying market occurred at Block A48, Division III, namely 371 fruits. The largest average loss of loose fruits at HCP occurred at Block A48, Division III, namely 209 fruits. Based on the number of losses at weed circle, carrying market, and HCP, the largest loss of loose fruits occurred at Block C34, Division II, namely 3,036.5 fruits. Based on the calibration carried out through field examination, it was found that there were 100 fruits in 1 kg of loose fruits so that the total loss of loose fruits from all sample blocks was 77.32 kg.

3.5 Economic loss due to the losses of loose fruits at weed circle

Table 5. Economic loss due to the losses of loose fruits at weed circle.

No	Division	Block	Average/weed circle (kg)	Amount of loss (IDR)
1.	Division I	E12	0.114	353.4
2.	Division II	C34	0.130	403
3.	Division III	A48	0.060	186
		Total average		***942.4***
		Total amount of loss		***395,808***

Source: Primary data (2024)

The economic loss was calculated as follows: the average loss of loose fruits per weed circle was multiplied by the price per kg of loose fruit, which was IDR 3,100 in September 2024. The largest economic loss per weed circle occurred at Block C34, Division II, namely IDR 403 per weed circle. If multiplied by the number of samples used, the total loss at Block C34 is IDR 169,260. This is mainly attributed to the difficulty in reaping loose fruits due to the condition of the weed circles that were filled with bushes.

3.6 Economic loss due to the losses of loose fruits at carrying market

Table 6. Economic loss due to the losses of loose fruits at carrying market.

No.	Division	Block	Average/carrying market (kg)	Amount of loss (IDR)
1.	Division I	E12	0.662	2,054 .68
2.	Division II	C34	0.35	1,085
3.	Division III	A48	0.417	1,293.01
		Total average		***4,432 .69***
		Total amount of loss		***31,028.83***

Source: Primary data (2024)

The economic loss was calculated as follows: the average loss of loose fruits per carrying market was multiplied by the price per kg of loose fruit, which was IDR 3,100 in September 2024. The largest loss per carrying market occurred at Block E12, Division I, namely IDR 2,054 per carrying market. This is because it rained at Division I, causing difficulty for workers to conveniently transport the fruits due to the poor route condition of carrying market, leading to a lot of losses of loose fruits at the area.

3.7 Economic loss due to the losses of loose fruits at HCP

Table 7. Economic loss due to the losses of loose fruits at HCP.

No.	Division	Block	Average/HCP (kg)	Amount of loss (IDR)
1.	Division I	E12	0.082	254.2
2.	Division II	C34	0.075	232.5
3.	Division III	A48	0.087	269.7

Total average	***756.4***
Total amount of loss	***36,307***

Source: Primary data (2024)

It is shown in Table 7 that the average economic loss per HCP at Block A48, Division III is the largest compared to those of other divisions. The economic loss was calculated as follows: the average loss of loose fruits per HCP was multiplied by the price per kg of loose fruit, which was IDR 3,100 in September 2024. The large loss at HCP was due to the condition of HCP at Block A48 and other HCP, which were dirty and filled with bushes, causing the loose fruits to be almost practically invisible to loose fruit reapers and fruit loaders.

4. Discussion

4.1 Distribution of the losses of loose fruits at three observation points

This study's findings show a varied distribution pattern of the losses of loose fruits at three observation points at Agritasari Prima Ltd. The highest distribution of losses occurred at carrying market with an average of 47.66 fruits/carrying market, followed by weed circle with an average of 10.15 fruits/weed circle, and HCP with an average of 8.14 fruits/HCP. These findings are in line with a study by Widjaja *et al.* (2024), which identified that yield losses on transportation routes reached 40–60% of total loss at oil palm plantations. Firstly, analysis results of the distribution of losses at weed circle show significant variation across divisions, with the highest distribution of losses occurring at Block C34, Division II (13.01 fruits/weed circle) and the lowest at Block A48, Division III (6.04 fruits/weed circle). This pattern indicates the influence of block management on the reaping effectiveness, as stated by Riski *et al.* (2023) in their study on oil palm harvest optimization.

Following, analysis results of the distribution of losses at carrying market show an uneven pattern with high variation across blocks. Block E12, Division I recorded the highest losses (66.28 fruits/carrying market), while Block C34 Division II recorded the lowest losses (35 fruits/carrying market). This pattern correlates with the infrastructure condition and transportation methods applied, in line with the findings by Herviandinata *et al.* (2025) on the efficiency of FFB transportation. Finally, analysis results reveal that the distribution of losses at HCP was relatively more even compared to those of weed circle and carrying market, with an average loss ranging from 7.52 to 8.70 fruits/HCP. According to a study by Imaroh & Efendi (2020), the stability of losses at HCP is often related to the standardization of harvest handling procedures at the area.

4.2 Factors causing the losses of loose fruits at weed circle

The condition of weed circle is the dominant factor that influences the level of losses. This study's findings reveal that weed circles filled with bushes significantly hampered the effectiveness of reaping process. This is supported by a study by de Vos *et al.* (2023), which found a positive correlation between the level of cleanliness of weed circle and the efficiency of loose fruit reaping, where a well-maintained weed circles can reduce losses by up to 40%. High work-base target was also revealed to affect the quality of loose fruit reaping. Workers who are in a hurry to meet their work-base target tend to ignore scattered loose fruits, especially in hard-to-reach areas. This phenomenon is in line with the findings by Khalid *et al.* (2021), which identified that excessive work pressure can increase the losses potential by up to 25%. Evaluation results of the reaping method show that workers often adopt suboptimal measures, such as ignoring the periphery of weed circles and focusing instead on areas that are considered easy to reach. This method contributes to increased losses, as validated by a study by Yusoff *et al.* (2020), which emphasized the importance of reaping method standardization.

Weed circle was the observation point that contributed the most to the economic loss, namely 85.44% of the total loss. Therefore, it is necessary to conduct an in-depth analysis of factors causing the losses at this area. Identification of the causative factors was conducted based on the observation at three sample divisions, namely Division I (E12), Division II (C34), and Division III (A48).

Table 8. Factors causing the losses of loose fruits at weed circle.

Causative factor	Division I (E12)	Division II (C34)	Division III (A48)
Weed circle condition	Lots of weeds and bushes	Lots of wild bushes	Relatively clean
Work-base pressure	High	Very high	Moderate
Reaping method	Not careful	In a hurry, just reap carelessly	Relatively good
Hard-to-reach area	Ignored	Untouched	Partially reached

Average loss (fruits)	11.4	13.01	6.04

Source: Primary data and author's analysis (2024)

It is shown in Table 8 that Division II (C34) exhibited the worst weed circle condition, highest working pressure, and least effective reaping method, resulting in the highest average loss. In contrast, Division III (A48) showed relatively better reaping performance. This emphasizes the importance of weed circle maintenance, workload management, and technical training in reaping loose fruits as an effort to reduce the losses of loose fruits at weed circles.

4.3 Factors causing the losses of loose fruits at carrying market

Evaluation results of the transportation method using wheelbarrows reveal fundamental problems in the transportation procedure. The use of overloaded wheelbarrows is the main cause of high losses at carrying market. A study by Shuib *et al.* (2020) confirmed that optimizing the capacity of transport vehicles can reduce losses by up to 30% on the transportation route. Uncontrolled loading capacity causes loose fruits to spill throughout the transportation route. The finding shows that the highest losses occurred at Block E12 with 66.28 fruits/carrying market, where wheelbarrows were often loaded beyond their maximum capacity. A study by Jumintono *et al.* (2022) showed that standardization of vehicles' capacity is a critical factor in FFB transportation management. Damaged route condition, especially when it rains, contributes significantly to increased losses at carrying market. This is evident at Division I, where poor route condition caused losses of up to IDR 2,054.68 per carrying market. This finding is consistent with a study by Lim *et al.* (2021), which identified a strong correlation between infrastructure quality and the level of losses during FFB transportation process. Losses at carrying market are mainly caused by technical factors, such as transport vehicles and route infrastructure condition. Observation was conducted in three divisions and the results show that Division I (E12) was the area with the highest number of losses.

Table 9. Factors causing the losses of loose fruits at carrying market.

Causative factor	Division I (E12)	Division II (C34)	Division III (A48)
Harvest loading on wheelbarrow	Overload	Within capacity limit	Almost exceeding the capacity limit
Route condition	Damaged and muddy	Good enough	Slippery when it rains
Condition during transportation	The loads are unstable	The loads are relatively stable	The loads spill on downhill route
Transportation supervision	Not enough	Moderate	Little
Average loss (fruits)	***66.28***	***35***	***41.71***

Source: Primary data and author's analysis (2024)

Table 9 shows that harvest loading on wheelbarrow exceeding the capacity limit and severely damaged route condition at Division I were the main causes of the increased number of scattered loose fruits on the route, directly contributing to the losses. For this reason, standardization of transport vehicles' capacity and route improvements are the main recommended solutions to reduce the losses of loose fruits at carrying markets.

4.4 Factors causing the losses of loose fruits at HCP

Analysis results of the fruit handling methods at HCP reveal several critical factors contributing to the losses of loose fruits. The average loss at HCP reached 8.14 fruits/HCP, ranging from 7.52 to 8.70 fruits/HCP across all divisions. According to Roundtable on Sustainable Palm Oil (2020), the handling effectiveness at HCP is greatly influenced by the standardization of operational procedures and infrastructure condition.

Table 10. Factors causing the losses of loose fruits at HCP.

Causative factor	Division I (E12)	Division II (C34)	Division III (A48)
HCP condition	Dirty, bushy	Relatively clean	Dirty, bushy
Transfer method	Not careful	Standard	Not careful
Reaping of loose fruits	Not thorough	Good enough	Not thorough
Average loss (fruits)	***8.22***	***7.52***	***8.70***

Source: Primary data and author's analysis (2024)

Evaluation results of the fruit transfer and loading process identify that carelessness during the transfer process was the main cause of losses, especially at Block A48, Division III, which showed the highest losses (8.70 fruits/HCP). A study by Rizkha (2023) confirmed that standardization of the transfer process can reduce losses by up to 35% at HCP. The dirty and bushy conditions of HCP at several blocks, especially Blocks A48 and E12, significantly hampered the reaping effectiveness of loose fruits. This is in line with the findings by Samian & Rizal (2024), which showed that good HCP maintenance can increase the recovery rate of loose fruits by up to 40%.

4.5 Analysis of economic loss per observation point

Analysis results of the economic loss show significant variation across all observation points. The economic loss due to the losses at weed circle reached IDR 395,808, making it the observation point with the highest economic loss. This finding aligns with a study by Prihatiningtyas *et al.* (2024), which confirmed that the losses at weed circle generally contribute at 60–70% of the total economic loss at oil palm plantations.

Table 11. Total economic loss due to the losses of loose fruits.

Observation point	Total loss (kg)	Price/kg (IDR)	Total loss (IDR)	Percentage (%)
Weed circle	127.68	3.1	395,808	85.44
Carrying market	10.01	3.1	31,028.83	6.70
HCP	11.71	3.1	36,307	7.86
Total	***149.40***	**-**	***463,143.83***	***100***

Source: Primary data (2024)

Following, the economic loss due to the losses at carrying market reached IDR 31,028.83, suggesting the importance of improving the transportation system and route infrastructure. Finally, the economic loss due to the losses at HCP reached IDR 36,307, highlighting the importance of optimizing fruit handling. Overall, the total economic loss reached IDR 463,143.83, with the largest contribution coming from the losses at weed circle (85.44 %).

4.6 Estimated economic loss per year for the entire plantation area

It is revealed that the loss data per block (on average) reached IDR 463,143.83. The total plantation land area is 8,750 with a flat area of 65% = 5,687.5 ha, where the average block area is 29 ha. Thus, the estimated total number of blocks are 5,687.5 ha/29 ha/block = 196 blocks, with the assumption that the harvest frequency per year reaches 24 times (once every two weeks). Thus, the estimated economic loss per year was calculated as follows: IDR 463,143.83 x 196 x 24 = IDR 2,178,282,597.31. It is then concluded that the annual economic loss due to the losses of loose fruits on flat terrain at Agritasari Prima Ltd. is estimated at IDR 2,178,282,597.31 (around IDR 2.18 billion per year).

4.7 System improvement recommendations to minimize the losses of oil palm loose fruits

Based on the above comprehensive analysis, several system improvements are recommended to minimize the losses of oil palm loose fruits. Regarding the reaping system at weed circles, periodic maintenance of weed circle and adjustment of more realistic work-base target are the priorities. According to Cahyadi *et al.* (2021), proper work-base management can increase the reaping effectiveness by up to 45%. The transportation methods at carrying market could be optimized through the standardization of wheelbarrows' loading capacity and improvement of route infrastructure. The use of transport vehicles with better loading capacity and improvement of route condition can reduce the losses of loose fruits by up to 30% (Shuib *et al.*, 2020).

To increase the harvest handling effectiveness at HCP, the main recommendations comprise routine maintenance of HCP area, standardization of fruit transfer procedures, and implementation of a stricter monitoring system. This is in line with the findings by Riski *et al.* (2023), which showed that a systematic approach to HCP management can reduce the losses by up to 40%. Overall, continuous monitoring and evaluation strategies are recommended, particularly via the implementation of digital monitoring system and periodic evaluation of the performance of each observation point. The system includes daily digital recording of losses, weekly evaluation of workers' performance, and monthly audits to ensure the effectiveness of the improvements implemented.

5. Conclusion

Based on this study's results and the above discussion, it is concluded that the level of losses of oil palm loose fruits at Agritasari Prima Ltd. varied at three main observation points with different distribution patterns. The highest losses occurred at carrying market with an average of 47.66 fruits/carrying market, followed by weed circle with an average of 10.15 fruits/weed circle, and HCP with an average of 8.14 fruits/HCP. The condition of weed circles filled with bushes and high work-base target pressure were the main factors causing the high losses at these areas, especially at Block C34, Division II, where the loss reached 13.01 fruits/weed circle. At carrying market, the use of wheelbarrows with excessive loading capacity and damaged route condition, especially when it rains, contributed significantly to increased losses, with the highest loss reaching IDR 2,054.68 per carrying market at Block E12. Meanwhile, at HCP, carelessness during the FFB transportation process and the dirty and bushes-filled conditions of the area caused the losses to reach 8.70 fruits/HCP at Block A48, Division III. The total economic loss reached IDR 463,143.83, with the largest loss resulted by weed circle, namely 85.44% (IDR 395,808), followed by HCP of 7.86% (IDR 36,307), and carrying market of 6.70% (IDR 31,028.83). The annual economic loss due to the losses of loose fruits on flat terrain at Agritasari Prima Ltd. is estimated at IDR 2,178,282,597.31 (around IDR 2.18 billion per year).

The analysis results show that the periodic maintenance of weed circle, standardization of wheelbarrows' loading capacity, improvement of route infrastructure, and handling optimization at HCP could significantly reduce the level of losses. Continuous monitoring and evaluation system through digital monitoring and periodic audits are also necessary to ensure the effectiveness of the improvements implemented. Overall, these findings emphasize the importance of a systematic and integrated approach in managing the losses of oil palm loose fruits to improve operational efficiency and reduce economic loss at oil palm plantations.

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