Application of Oil Palm Dissection Method to Predict Bunch Production in Commercial-Scale Oil Palm Plantation

Sukarman [1,*] Akhmad Rizalli Saidy [1] Gusti Rusmayadi [1] Dewi Erika Adriani [1]
Septa Primananda [2] Suwardi [2] Herry Wirianata [3]
Andri Prima Nugroho [4] Lilik Sutiarso [4]

[1] *Agricultural Science, Universitas Lambung Mangkurat (ULM), Jl. Brigjen H. Hasan Basri, Banjarmasin, Indonesia, Kotak Pos 219*
[2] *Wilmar International Plantation, Region Kalimantan Tengah, Indonesia*
[3] *Institute of Agriculture (INSTIPER), Yogyakarta, Indonesia*
[4] *Department of Agricultural and Biosystem Engineering, Universitas Gadjah Mada, Yogyakarta, Indonesia*
[*] *Corresponding author. Email: sukarman.emu@gmail.com*

ABSTRACT

Prediction of the annual oil palm yield is an important decision-making tool in harvesting operational management, management of Palm Oil Mill (POM), trading of Crude Palm Oil (CPO) and its derivative products along with management of POM waste. The palm census method has a better accuracy rate than using previous year's production data. Calculation the bunch number on the tree is used as an annual prediction by using the Oil Palm Dissection (OPD) method. OPD is carried out to calculate the number of inflorescence and bunches as a basis for predicting bunches for the next 18 months. The purpose of this study is to analyze the application of the commercial scale OPD in bunch prediction activities in oil palm plantations. This research was conducted on oil palm aged 13 – 15 years (plateau yield phase). The research stages include sample selection, tree dissection, inflorescence and bunch modeling, as well as testing the accuracy of the OPD compare to actual production. Prediction-accuracy test uses Mean Absolute Percentage Error (MAPE). The accuracy of OPD in predicting the bunch number is 70% (feasible criteria) and the prediction of oil palm yields production is 81% (good criteria) in oil palm plantations on a commercial scale. Prediction of OPD needs to consider some correction factors such as climate, environment, Average Bunch Weight (ABW), palm age, and soil type, to improve the validation result and accuracy of predictions. The percentage of error in the bunch number between 10 - 32% of the OPD prediction can be combined with other factors to determine the value of the correction factor for bunch loss and oil palm yield production.

Keywords: oil palm dissection, prediction, bunch, oil palm, commercial

I. INTRODUCTION

The annual prediction of palm oil yields is an important decision-making tool to support plantation operational management, Palm Oil Mill (POM) management, and the Trading Department. Palm fruit bunches (PFB) annual production data is used by plantation operational management for labor management (harvesting, fertilization, weed control, and other operations), transportation unit management (Fresh Fruit Bunch (FFB) and POM waste, POM waste application management (empty fruit bunch, solid decanter, and land application) likewise other operational activities during the coming year [24]. POM management requires FFB prediction data to arrange monthly processing capacity plans, FFB purchase ratios (main plantations, plasma and smallholders) as well as major breakdown schedule. This is different from the Department of Trading, which requires FFB prediction data to develop a trading strategy for CPO, Palm Kernel Oil (PKO) and other derivative products.

Besides annual predictions, generally oil palm plantations also apply daily prediction and monthly prediction method [20]. The Black Bunch Census or BBC and the trossen telling method as shown in Figure 1 can predict FFB production for the next 4 and 6 months [15,32]. The method of bunche cencus on palm (BBC and trossen telling method) has better accuracy because it is based on result of the census on bunch number on trees, but cannot predict on an annual basis. So far, the annual prediction method uses data sources from the previous year's FFB production, so the level of accuracy varies, such as; Tsukamoto method 47 – 57% [28], Exponential smoothing 87 – 91% [39], Regression 97.5% [2]. The variation in accuracy is influenced by internal and external factors.

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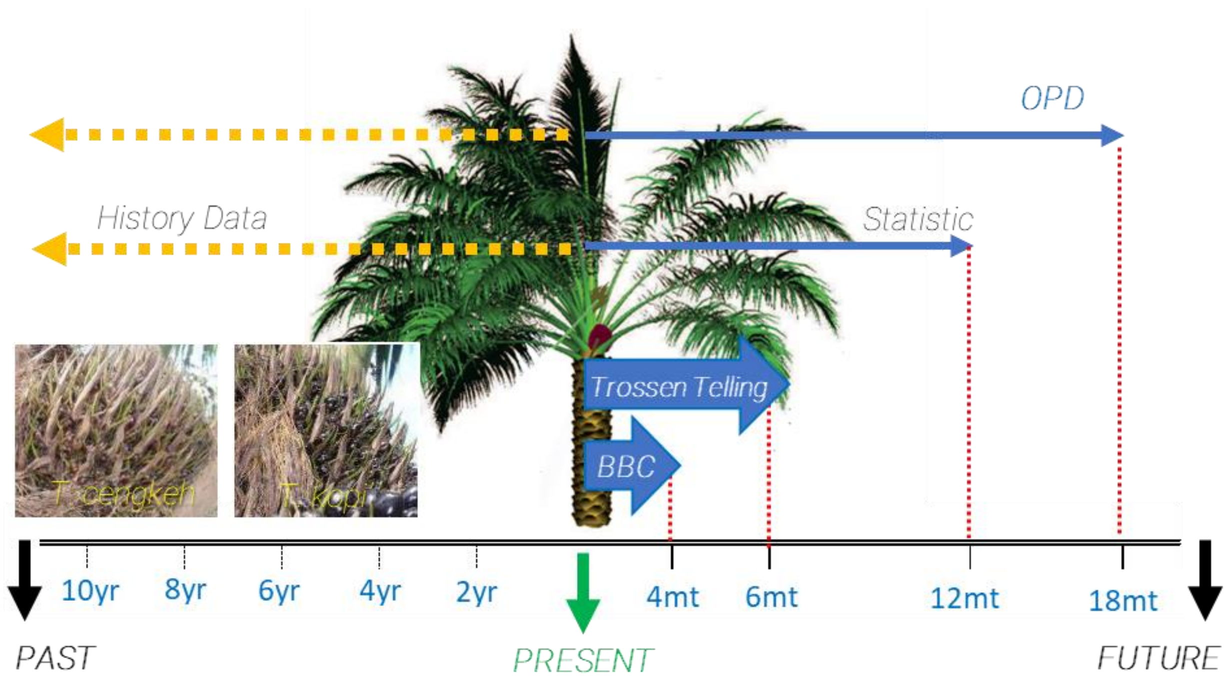

Figure 1 FFB prediction method in oil palm plantation (Modified: Perez, 2017)

Sukarman [43] reported that OPD method can be used to calculate the sex ratio and bunch number for the next 18 months so that it can be developed for an annual prediction method. Observation of inflorescence development cycle up to bunches can be used as a reference for oil palm harvesting time and strategy [8,48]. The use of OPD was previously reported to analyze inflorescence development, number and weight components of oil palm bunches [6]. Lamade et al. [22] used OPD to analyze the distribution of nutrients N, P, K, Mg, Ca, and Cl in young to old palm leaves.

OPD can be developed into a new method for predicting accurate annual FFB production because it is based on the bunch number in the palm. However, the guidelines for the method of selecting tree sample and how to determine the distribution of bunches per month are not known yet, so this method needs to be studied further. OPD that used to study inflorescence to fruit development is important to be developed into a new method for predicting annual in oil palm plantations (commercial scale). The purpose of this study is to analyze the application of the commercial scale OPD in bunch prediction activities in oil palm plantations.

II. METHOD

The research was conducted in 2016 – 2021 in oil palm plantations in Central Kalimantan. The oil palm trees used in the experiment were in the age range of 13 – 15 years or in PYP (the most productive phase during the oil palm life cycle) with an area 5,264 Ha. The research stages include sample selection, tree dissection, inflorescence and bunch modeling, and comparison of production predictions between OPD and BBC methods with actual.

Sources of data consist of primary data (number of infloresence and bunches) and secondary data (FFB production and area statement). Prediction of harvest month was determined based on the average growth of frond per month at the study site. It was because there were differences in production of oil palm fronds and inflorescence each month which were influenced by variations in climate, environment and genetic factors. Tools and materials needed were palm cutter, machete or knife, chainsaw, nylon rope, trinocular microscope, paint, brush, and OPD form.

2.1 Palm Sampling

Exactness in the selection of tree criteria and the number of samples have a large effect on the accuracy of FFB predictions. Several factors need to be considered in determining the block and number of OPD samples are land area (ha), soil type, palm age, contour or slope conditions of the area, and company considerations if any, according to Figure

The sampling method used two stages cluster sampling. The sample tree was taken by purposive random sampling. The criteria for the sample tree must be healthy and visually represent the condition of the tree in the sample block. During 2016 – 2020, 45 oil palm trees were sampled.

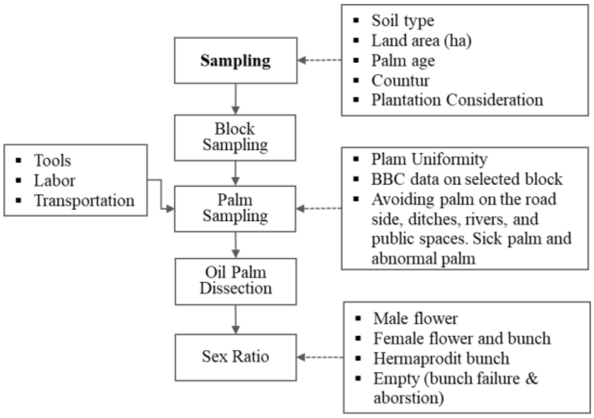

Figure 2 Flow diagram of palm sampling on OPD

2.2 Palm Dissection

The selected sample trees were cut using chainsaw. Each frond was numbered by using paint for easy identification of inflorescence and bunches sequences. Inflorescence and bunches were harvested using palm cutter and then recorded on the observation form according to number of the frond. Observation parameters consisted of the bunch number, female flowers, male flowers, hermaphrodite flowers, empty fronds (no inflorescence or bunches were found), inflorescence abortion, and bunch failure. Not all inflorescence sex observations could be observed in the field. Generally, inflorescence on +8 to -12 fronds were difficult to observe with naked eye, so observations were made in the laboratory using a trinocular microscope with a magnification of 100 - 400×.

2.3 Bunch Distribution Modelling

Data of inflorescences and bunches were inputted into the form using code F (female), M (male), H (hermaphrodite), and 0 (empty or no inflorescence found). Prediction the bunch number per month was calculated based on the conversion of F and H codes with a value of 1 bunch, while M and 0 codes with a value of 0 bunches. The prediction formula for the OPD is bunch number multiplied by average bunch weight in oil palm plantation.

2.4 Feasibility Test of Prediction Method

The feasibility test of OPD is based on result of the Mean Absolute Percentage Error (MAPE) with the criteria of the MAPE range < 10% = very good, 10 – 20% = good, 20 – 50% = feasible, and > 50% = poor (Halimi et al., 2013; Dalam et al., 2020; Septiyana and Bahtiar, 2020).

$$MAPE = \left(\frac{100}{n}\right)\sum\left|A_t - \frac{F_t}{A_t}\right| \quad (1)$$

Description:
At = Actual FFB production in period-t
Ft = Prediction of FFB production in period-t
N = Number of prediction periods involved

III. RESULT AND DISCUSSION

3.1 Bunch Number Prediction

Bunch number prediction and monthly distribution were generated by modeling bunches according to the order of prediction of harvest months. Prediction of harvest month was determined based on the average growth of fronds per month at the study site. Prediction the bunch number by BBC method showed a very good result (8%) and by OPD method showed a feasible criterion (30%) based on the result of MAPE analysis (Table 1).

Table 1. Result of MAPE prediction bunch number on BBC, OPD, and actual

Bunch Number	Bunch Number per Palm					Average
	2017	2018	2019	2020	2021	
Actual	8.3	11.7	11.6	11.5	9.7	10.6
BBC Prediction	8.6	10.2	9.6	11.1	10.2	9.9
OPD Prediction	9.3	14.5	16.6	14.6	14.3	13.9
MAPE BBC (%)	3.0	12.0	17.0	4.0	4.0	8.0
MAPE OPD (%)	12.0	24.0	43.0	27.0	47.0	30.0

The result of BBC was more accurate in predicting the bunch number, but could not be used to predict the bunch number for a year as in the OPD. The concept of OPD is the same as BBC, that is counting the number of inflorescence and bunches on palm trees, but the calculation of OPD starts from the sex differentiation stage until the ripe bunches are ready to be harvested by dissection therefore it can be used to predict FFB annually. Although the accuracy of OPD had only reached 70% (100% minus 30% of MAPE), it still had a potential to increase to > 90% (very good criterion) with improvements to the formula and modeling of bunches. This potential is indicated by similarities of the distribution pattern in comparison figure of the production prediction the number of OPD per month with the actual (Figure 3). This pattern also shows that OPD has a better similarity pattern with the actual than BBC. Figure of BBC distribution pattern shows a lower dominant position than the actual, while figure of OPD distribution pattern consistently shows a higher pattern position.

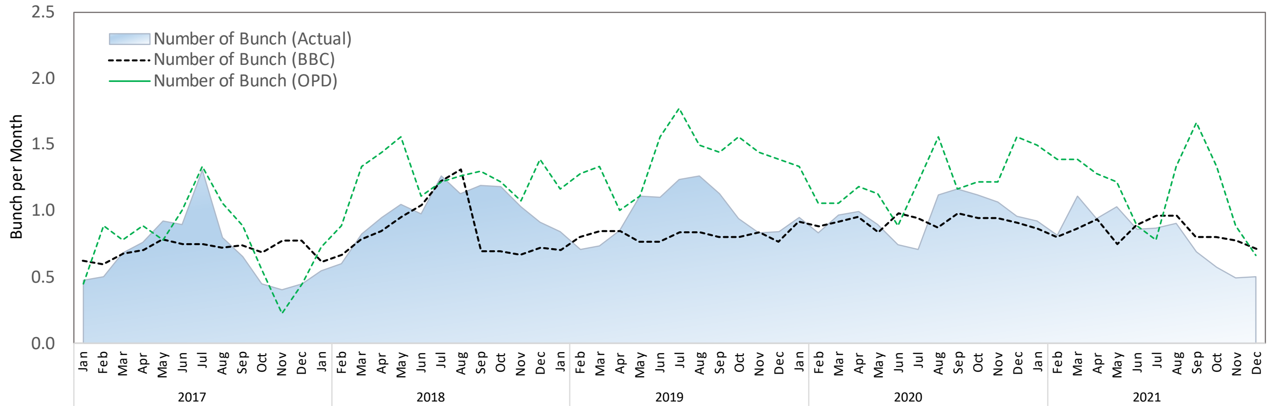

Figure 3 Comparison production of bunch number based on OPD and BBC prediction with actual

The error rate of 30% for OPD is due to loss the bunch number 0.28 bunches per month (3.3 bunches or 31% bunches year^{-1}) either a decrease in sex ratio by 14%. This value is still in the range of decreasing sex ratio. It was reported by Woittiez et al. (2017) that there can be decrease in sex ratio about 10 – 20% due to effect of a severe water deficit. Based on OPD, the predicted average sex ratio for 5 years in PYP is 58% (39 – 67%), but due to a loss of 14%, the actual sex ratio will be 44% (35 – 49%). Both actual and predicted, the sex ratio is still relatively low because according to Henson and Dolmat [19] sex ratio in PYP is 60 – 90%, and continues to decline according to palm age [12].

The number OPD bunches is higher than the actual because it is calculated based on total potential bunches that can be harvested over the next 18 months without any reduction over failure of inflorescence development. Whereas potential availability of number of ripe bunches that can be harvested after the sex determination phase can be reduced because of abortion of female flowers and bunch failure [11,47,50]. Based on actual bunch number, percentage error of OPD prediction between 10 – 32% can be combined with other factors to determine value of correction factor for bunch loss. Based on this, it is preferably in use of OPD to consider loss factor as a correction to improve prediction accuracy to very good criteria (error rate < 10%).

3.2 Prediction of Palm Oil Production

Prediction of OPD uses principle of crop modeling to get a prediction bunch number. Crop modeling is needed to help explaining process understanding in oil palm yield prediction. The result of prediction bunch number according to results in Table 2, BBC is very good (5%) and OPD is good (19%). The 19% error rate for OPD was caused by correction factor had not been considered as a research variable in prediction bunch number. Referring to OPD, prediction of 5-year average production at PYP is 32.0 tons ha^{-1} year^{-1} (24.5 – 36.8 tons ha^{-1} year^{-1}), but by virtue of a 19% loss factor, the actual production will be 26.9 tons ha^{-1} year^{-1} (23.5 – 29.9 tons ha^{-1} year^{-1}).

Table 2. Result of MAPE prediction yield productivity of oil palm (BBC, OPD, and actual)

Bunch Number	Productivity (Ton/ha/year)					Average
	2017	2018	2019	2020	2021	
Actual Yield	23.5	29.9	27.0	28.4	25.5	26.9
BBC Yield	23.6	31.2	25.7	25.4	26.2	26.4
OPD Yield	24.5	36.8	33.9	31.5	33.2	32.0
MAPE BBC (%)	0	4.0	5.0	11.0	3.0	5.0
MAPE OPD (%)	4.0	23.0	26.0	11.0	30.0	19.0

Prediction results of BBC are better at predicting FFB production, but cannot be used to predict FFB production for a year. Prediction of OPD is generated from bunch number multiplied by ABW, because components of FFB production consist of weight of bunches (ABW) and bunch number [30]. Both have the same role in determining prediction accuracy or production model used. Accuracy of prediction methods in oil palm plantations varies both between plantations and between seasons [44]. Furthermore, Annisa (2013) explained that most of current estimates are based on plantation sampling and their accuracy ranges from 70 – 80% with actual. The estimate is considered correct if maximum deviation between estimate and actual production is 5 – 10% [5].

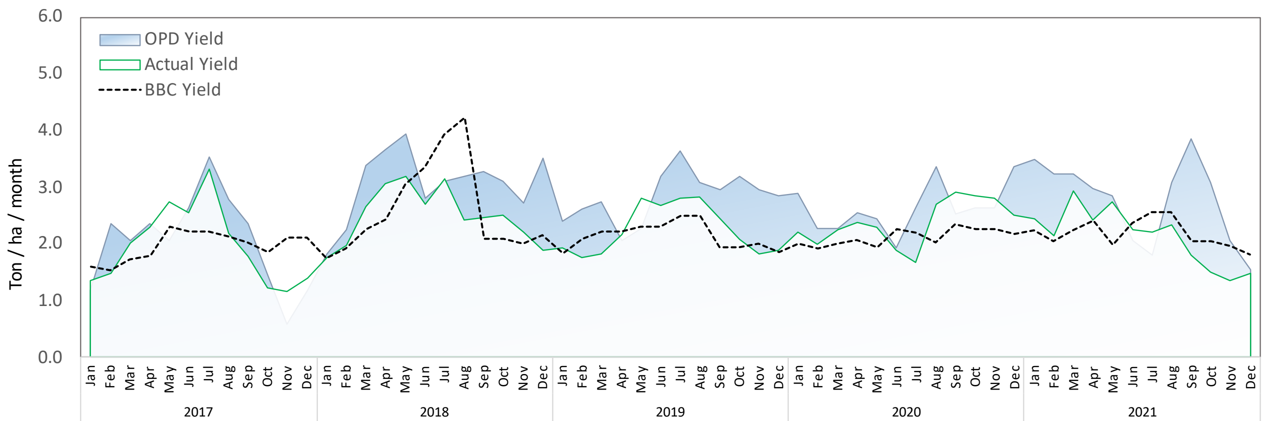

Figure 4 Comparison of productivity (ton/ha/month) based on OPD and BBC prediction with actual

The monthly production distribution pattern in Figure 4 shows same patterns as previous figure of distribution bunch number, that is the pattern number of OPD bunches is consistently higher than the actual, while BBC is lower.

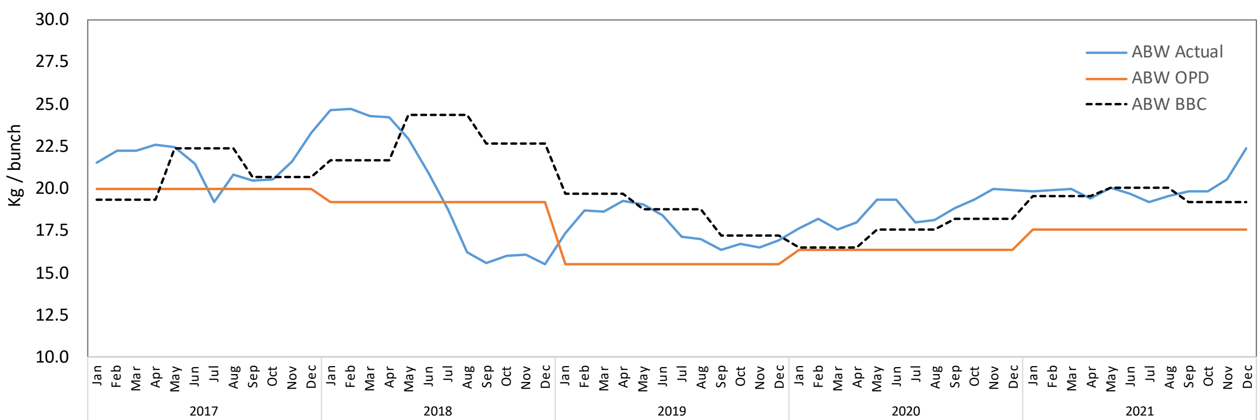

Figure 5 Comparison of ABW based on OPD and BBC prediction with actual

The MAPE value predicted production is better than predicted number of MAPE bunches, the reason is in production prediction there is a ABW prediction component that can affect MAPE value. Pattern of actual ABW increase in Figure 5 seems to fluctuate every month. This is different from pattern of increasing ABW BBC which is the same every 4 months and ABW OPD which is the same every year. The difference is because the method used has a different target prediction period. BBC is used to predict for the next 4 months therefore generally ABW value used for 4 months prediction is the same, while OPD is used to predict yearly so that ABW value used for 1 year prediction is also the same. However, it is possible to develop a method for predicting an increase in ABW every month based on factors that influence development of ABW. The main components determine ABW are number of spikelets, number of flowers per spikelet, and number of fruits (Murugesan et al., 2021). ABW generally increases with palm age [14,19]. Appropriate cultivation techniques and balanced fertilization techniques affect ABW, the fulfillment of potassium elements increase fruit formation in oil palm. ABW responded positively to the increasing availability of assimilate [29]. Gawankar et al., (2003) stated a decrease in ABW as a result of water stress reached 40.9%. Effect of water stress on oil palm production was reported to be 20 – 30% [34], even reached 70% [29].

3.3 Analysis of Factors Causing Loss of Bunches

Rainfall is a limitation factor that affects oil palm yield production, but has a negative correlation with water deficit, meaning that low rainfall causes high water deficit in oil palm. Result of regression analysis data in Figure 6 shows a water deficit of 404 mm (in 2015), 169 mm (in 2018), 324 mm (in 2019) had an effect on decreasing sex ratio by 24%, 27%, 47% in 26 months before harvest (MBH). Although 2017 did not occur a water deficit, in 2019 there was also a decline in production. It was predicted because of cluster abortions (11 – 13 MBH) due to water deficit in 2018 and bunch failure (2 – 4 MBH) over water deficit in 2019.

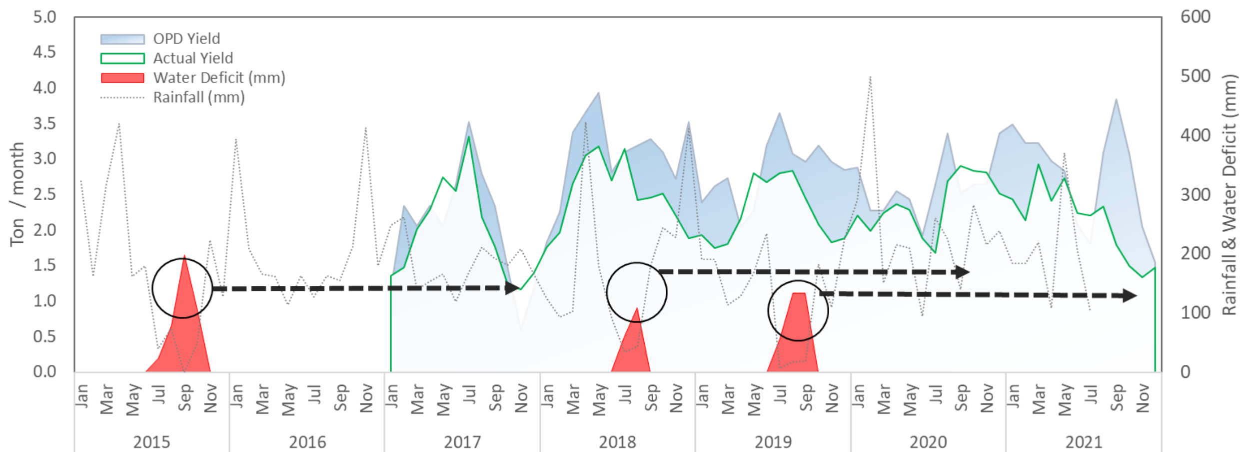

Figure 6 Relation of Water deficit and bunch production on OPD, BBC, and actual

Low rainfall followed by a high-water deficit has a negative impact in decreasing bunch number for all palm ages [16,43]. Carr [9] reported that water stress by cause of water deficit every 100 mm can reduce 10% of oil palm production. Every 100 mm increase in water deficit reduces productivity by 6% in sex determination phase and 7% in abortion phase (Surhayanti et al., 2020) and can even reach 86%. Salmiyati et al. [34] revealed an increase in water deficit of 50 mm year^{-1} and a temperature of 1°C simultaneously can reduce production by 2.15 tons ha^{-1} year^{-1}. Agustiana et al. [3] stated a 40% decreased in number of female flowers at 4 – 10 months after drought stress. Water deficit > 400 mm year^{-1} impacts in a reduction one-third of potential yield, but depending on additional factors such as temperature, wind speed, soil texture, and soil [50].

In general, the loss of oil palm bunches is affected by variations in climate, environmental conditions and also genetic factors [21,23,36]. Climatic factors, especially water stress and time thermal, contribute to differences in growth from unopened fronds to ripe bunches [45,37]. Temperature is positively correlated with activity in immature bunches, whilst rainfall and high humidity are positively correlated with production of mature bunches of oil palm [10]. However, rainfall and high humidity also cause severe damage to FFB due to attack of fungus *Marasmius palmivorus* [30,46].

Apart from climate and environmental influences as previously described, poor dataset (age, number of palm, bunch number, and production) can also increase prediction error rate [1]. Amount and location of sample points that do not represent the condition of the block as a whole can also be a deviation between predictions and actual [4,33]. The difference in predictions is also caused by level of accuracy of census labor, palm height, and harvest quality [25], not transported FFB to POM [26], and significant ABW differences [40].

Commonly, when calculating predictions, they do not pay attention to the loss factor during harvesting activities [49]. In fact, production losses due to FFB losses, loose fruit losses and harvesting unripe bunches are suspected to contribute to difference between predictions and actual yields [35], so it is essential to carry out strict monitoring and supervision from plantation managers [41]. Related to this, loss of production is something that must be avoided in order to achieve targeted quantity and quality of production [25]. Sofiana [42] explained several sources that could cause production losses in field, that is: 1) ripe bunches on three were not harvested, 2) unripe bunches were harvested, 3) loose fruit losses, 4) loose fruit were sticked to the stalks.

IV. CONCLUSION

The application of OPD method in commercial-scale oil palm plantations has an accuracy in predicting bunch number of 70% (feasible criteria) and predicting oil palm yields of 81% (good criteria). The BBC (92% and 95%) has better accuracy than OPD, but it cannot be used as an annual prediction because it can only cover the next 4 months. OPD for prediction is determined based on total potential of bunch for the next 18 months, but during its development it can be reduced due to failure at inflorescence and bunch development stage therefore it is necessary to consider climatic factors, environment, ABW, palm age, and soil type as the correction factors so that prediction accuracy increasing. The percentage of error in the bunch number between 10 – 32% of OPD prediction can be combined with other factors to determine the value of correction factor for bunch loss and oil palm yield production.

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