Enhancing Oil Palm FFB Yields by Water Management: Sumber Tani Agung Resources' Experiences

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Abstract.

Oil palms *(Elaeis guineensis)* are generally able to grow economically on various soil types, especially across the regions of Malaysia and Indonesia. However, in flood-prone areas, oil palms were producing lesser Fresh Fruit Bunches (FFB). Due to frequent flooding incidences palm growth were generally stunted, and in extreme cases there were huge losses of palms. In this paper, commercial FFB yield of Seret Ayon Estate and Lembah Bawang Estate, near Sambas in West Kalimantan, Indonesia is collected and compared to those from before and after the implementation of efficient water management by embankment. Annual rainfall of this region would fall within 3500 mm - 4000 mm. Out of this, almost 30-40% of the total annual rainfall is recorded in the period of October-December. Furthermore, during the same period, high rainwater from nearby Forest Reserve of Bengkayang had resulted high water volume in the streams/rivers running across both estates. As such, overflow of water from both banks usually became a stagnant in the nearby fields. A yield improvement programme was embarked to arise the existing height of riverbanks, literally speaking a 'embankment or bund management' on both banks of the river. Outlet drains were desilted and thus, improved the water-flow for smooth removal of excess water during the high pour and flooding seasons. Vetiver grasses were established on riverbanks. FFB yields were satisfactorily increased from 11-14 mt/ha/yr during 2017-2018 to 25-33 mt/ha/yr in 2021. Besides improving FFB yields, palm growth also satisfactorily improved in frequently flooding areas, especially after three years of water management by embankment.

Keywords: embankment, bund management, fresh fruit bunches, riverbanks, vetiver grass

1 Introduction

Oil palms *(Elaeis guineensis)* are generally able to grow economically on various soil types, especially across the regions of Malaysia and Indonesia. Water availability and its management are one of the key factors that influence the productivity of Fresh Fruit Bunches (FFB) in oil palms. The water footprint (WFp) as an efficiency indicator for water consumption in oil palm also revealed that WFp values for FFB production is in the range of 700 to 1,700 $m^3 ton^{-1}$ with an average of 1,034 m^3 ton^{-1}[1]. This WFp value is basically equivalent to 1,034 liters per kg of FFB [1] and this value is relatively low compared to other vegetable oil crops, about 50% of corn, soybean, peanut, coconut, olive rapeseed and sunflower [1]. Therefore, oil palm is more efficient in consuming water in a more environmentally friendly manner.

Sources and availability of water besides good water control system is very important for the development of oil palm growth. One of the factors for successful cultivation of plantations on plantations lies in the compatibility of water management between the natural resources and network of drainage systems. A good water management system maintains the level of effectiveness. water 50-70 cm (below soil surface) [2]. However, in flood-prone areas, oil palms were producing lesser FFB. Due to frequent flooding incidences palm growth were generally stunted, and in extreme cases there were huge losses of palms.

Flooding condition/environment for a long time (>3 weeks) can produce a strong anaerobic condition due to accumulation of considerable organic matter from decaying root systems and continuous waterlogging. Under such conditions, oil palm performance affected adversely. These flood-prone areas resulting from overflow of river water as accumulation of running river water from various locations, inclusive of Lembah Bawang Rain Forest Reserve.

1.1 Flooding Incidences: Causes

In Sumber Tani Agung Resources Tbk (STAR), there were palms exposed to the problems frequent flooding incidences. mainly two estates in Sambas region in West Kalimantan are facing problems of frequent floodings, namely Seret Ayon Estate and Lembah Bawang Estate (**Figure 1**).

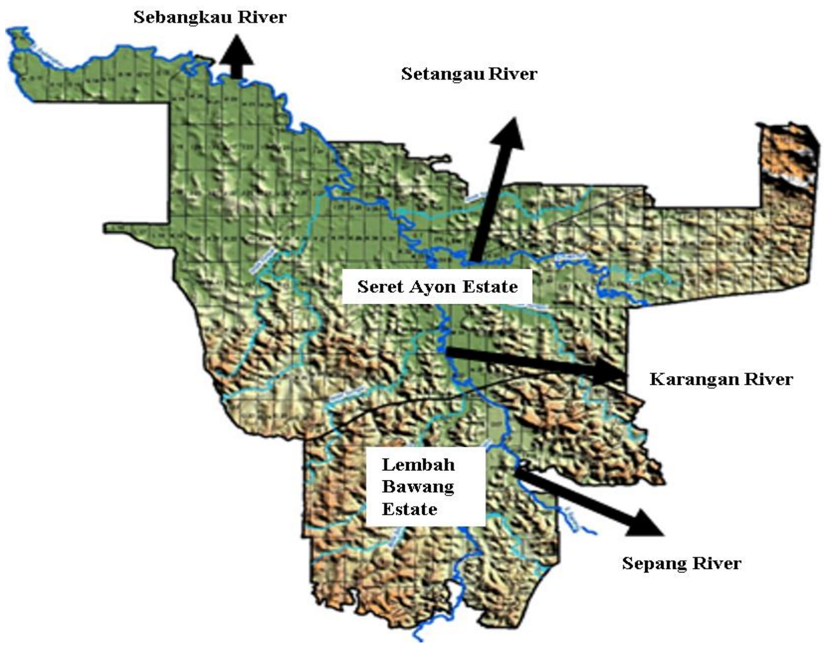

Figure 1: Location of study areas with four main rivers and directions of waterflow in respective river

According to Central Bureau of Statistics [3], annual rainfall in Sambas Region normally ranged from 2,737 to 3,050 mm/year or an annual average of 2,893 mm/year with a monthly average of 241 mm/month. [4] highlighted that if this rainfall falls on the Sambas Groundwater Basin (GWB) area with an area of around 3,229 km^2 or 3,229 million m^2, a rainfall discharge of around 778,189 million m^3/year will be obtained. Furthermore, the amount of rain intensity (rainfall divided by rainy days) in the Sambas area ranges from 8.2 to 24.6 mm/day or an average of around 15.9 mm/day. The monthly air temperature in Sambas region generally ranges from 26.12^0 to 27.20^0 C [3].

The irrigation project for oil palm was initiated when rainfall below 200 mm/month was recorded in the northern region of Columbia [5]. However, distribution of rainfall above 200 mm per month is generally considered as wet months for oil palms in South-East Asia region. As such, a monthly average of 241 mm/month rainfall in Sambas region reflects that both estates generally have a relatively wet climate[3]. Apart from rainfall, a large amount of water is also from the Lembah Bawang/Bengkayang National Reserve Forest which is a type of limestone and granite-limestone mixture. Presence of such limestone mixture could allow a considerable amount of rainwater passing through the hilly areas of Lembah Bawang/Bengkayang National Reserve Forest, reaching the foothills of the study area, even after a couple of days.

There are some important factors that cause flooding incidences as as (i) intensity of raining even at the surrounding areas, (ii) lack of watershed retention /water catchment areas, (iii) faster silt-up in the river channels, and (iv) poor planning in making drainage channels / ditches. Proper maintenance of field drains in the estates also plays an important role as these drains meant to remove the excess water from the fields. Although a network of drainage system exists with proper drain depth and sizable dimensions, palms still exposed to problems of frequent flooding, high water-tables and flash-flooding as well as wet-foot. Any planters on the ground must be able to identify the status of flooding conditions that are potential threat to the normal growth of oil palms.

1.2 Impact of Flooding Incidences

Oil palm is generally tolerant of relatively high watertables [6] and is thus most suited to water management techniques such as maintain water levels in the drains. For an example with proper water management by maintaining water level at 45-60 cm on acid sulfate soils oil palm yields are greatly improved. [7] [8] also stated that FFB yield exceeding 35 ton per ha per year are achievable on acid sulfate areas with controlled drainage by maintaining the water table at 45 to 60 cm as long as possible and not exceeded 75 cm depth. Otherwise, there is a risk of accelerated oxidation of the pyrite layer during dry weather conditions [9].

However, oil palm is intolerant to floodings especially for flooding cases of more than > 3 weeks. Palm growth on flooding areas is stunted as nutrient uptake is affected adversely. Besides poor growth of oil palm, normal / routine operations of plantations also hindered such as;

(i) Uncollected bunches after the harvesting of oil palms at each harvesting intervals. In a condition of high water table and poor drainage where crop losses of 3-20% were recorded [10].

(ii) Extended harvesting intervals as the harvesters are unable to work during floodings/rainy days.

(iii) Harvester movement and activity are limited as fields are subjected to wet foot condition or wet areas as water subsiding from aftermaths of heavy rain. As such, there is more hardship of harvesters as well as bunch collectors in the frequent flooding areas.

(iv) Missing of bunches at the harvested palms and (possible)theft of harvested bunches are equally contributing to lower oil palm production in these flooding affected areas.

(v) Additional expenditure occurs as the estate need to plan to remove the excess water from the fields/drains as soon as possible. Generally, in frequently flooding areas, flood pumps were employed to pump out excess water. In one such estate, 8 flood pumps with capacity ranging from 50,000 to 80,000 litres/minute were used to remove flood water. In addition, construction of a continuous peripheral bund (1-2 m high) is vital to minimize the influx of water from the outside into the estate [10].

As such constructing a bund or *embankment* would be a panacea for controlling influx of water especially during wet seasons [6] [10] [11]. STAR had embarked on a programme of improving fields suffering from frequent flooding. Approximately 600 ha was identified areas under frequent- flooding problem. However by end 2022, the problems of frequent floodings were minimised with the implementation of embankment project as well maintenance of drainage system in the affected areas in for Seret Ayon and Lembah Bawang Estates, Sambas, West Kalimantan. In this paper, commercial FFB yield of Seret Ayon Estate and Lembah Bawang Estate, near Sambas in West Kalimantan, Indonesia is collected and compared to those from *before* and *after* the implementation of efficient water management by embankment.

2 Materials and Methods

2.1 Study Area

In STAR, mainly two estates in Sambas region in West Kalimantan are facing problems of frequent floodings, namely Seret Ayon Estate (4289 ha) and Lembah Bawang Estate (2511 ha) (**Figure 1**). The study area is in a region where heavy pour is normally more than 200 mm per month. An average of 332 mm/month of rainfall was registered in both estates throughout the period of 2020-2022 (**Tabel 1**). Total rainfall in this region is about 3500 mm to 4000 mm per year.

There are four main rivers within these two estates, namely Sebangkau, Setankau, Karangan and Sepang rivers. Commercial FFB yield of these two estates is collected and compared to those from *before* and *after* the implementation of efficient water management by embankment.

2.2 Details on Rainfall

Generally, the amount of rain in 2020-2022 (at an average of > 3985 mm/year) is very high (**Table 1**) for both estates. At the end of the year usually quite high rainfall occurs. For example in Seret Ayon Estate, the total rainfall in 2022 for the months of October, November and December are 1.124 mm or 28% of the total rainfall in 2022. For the Lembah Bawang Estate, about 32% (1,446 mm) rainfall occurs in the last 3 months of 2022. As a result, there is a major barrier to harvest, fertilizer and weed spray programs due to heavy rainfall during these last 3 months. Access to the main and minor roads is also poor due to heavy rainfall and this results in difficulty in FFB evacuation and thus, transportation of FFB to mills [10].

Table 1: Annual rainfall in Seret Ayon and Lembah Bawang Estates in Sambas Region , Indonesia (2020-2022)

	Seret Ayon Estate						Lembah Bawang Estate					
Month	**2020**		**2021**		**2022**		**2020**		**2021**		**2022**	
	Rain Days	**Mm**	**Rain Days**	**mm**	**Rain Days**	**mm**	**Rain Days**	**Mm**	**Rain Days**	**mm**	**Rain Days**	**mm**
Jan	18	241	16	351	9	329	22	227	15	327	12	449
Feb	14	244	6	244	14	403	13	180	6	202	18	486
Mar	12	286	15	338	12	276	12	175	15	322	12	204
Apr	17	413	10	148	15	255	18	311	14	202	16	224
May	13	473	12	303	11	251	18	311	15	494	15	127
Jun	15	540	16	191	21	394	15	399	14	201	25	418
Jul	17	698	7	174	10	259	16	691	7	179	10	213
Aug	11	263	14	473	18	411	13	257	14	400	20	721
Sep	18	389	15	347	15	309	19	398	18	301	16	298
Oct	11	249	10	232	21	302	15	289	13	203	19	299
Nov	23	436	17	300	18	391	25	558	19	362	20	593
Dec	14	208	13	274	17	431	15	319	19	207	17	554
Total	**183**	**4,440**	**152**	**3,376**	**181**	**4,011**	**201**	**4,115**	**169**	**3,399**	**200**	**4,586**
Average	**15**	**370**	**13**	**281**	**15**	**334**	**17**	**343**	**14**	**283**	**17**	**382**

2.3 Initiation of Embankment Project

There is a huge tendency for areas in both estates exposed to the problems of flooding incidences as (i) Annual rainfall of this region would fall within 3500 mm-4000 mm, (ii) Out of this, almost 30-40% of the total annual rainfall is recorded in the period of October-December (iii) Furthermore, during the same period, high rainwater from nearby Forest Reserve of Bengkayang had resulted high water volume in the streams/rivers running across both estates. Factors from (i) to (iii) generally would cause overflow of water from both banks which usually became a stagnant in the nearby fields (**Figure 2**).

A yield improvement programme was embarked in 2017 and 2019 for Seret Ayon Estate and Lembah Bawang Estates respectively to arise the existing height of riverbanks, literally speaking a ‘bund management’ on both banks of the river. Basically, embankment programme is related to efforts taken to control over-flow of water from any side of riverbanks.

Figure 2: Conditions of rivers as well as surroundings of fields during heavy rainfall season within study area

2.4 Pre-preparations for Embankment

The steps that need to be taken to identify flooding problems or inundated areas/blocks are as follows:

1. A survey should be conducted first to demarcate areas that prone for flooding incidences. The survey will also reveal the severity of impact of floodings on oil palm growth as poor palm growth is evident. Survey results should be analyzed further for any improvement actions required. To analyze this problem, we need to check the water channels in the surrounding area.
2. Based on the survey results, areas that need a mere improvement such as desilting of drains should be identified and eliminated from embankment programme. Water flow in such areas could be improved if desilting of drains is programmed and carried out periodically.
3. Decisions for further actions such as construction of flap-gates, building of embankments, construction of drainage/reservoirs can be made after analyzing the main problem. An action plan should be prepared to rectify the main problem.
4. Budgets should be prepared based on action plans. Appropriate maps, time frame and and cash flow should be calculated before implementation of embankment programme.
5. Once the budget is approved, the estate management should be able to find the suitable supplier to provide the required item on time , such as machinery items involved in this embankment project.

2.5 Basic Designs for Drains in Embankment Areas

The function of outlet drain is to hold water from all existing drains as well as overflow from plantation areas, then drains it into rivers or other water disposal sites. Outlet drain is made with a size of 5 x 2 with a depth of 1.75 m. This size is generally depends on the existing field conditions.

Main drain would collect water from secondary drains, foothills and smaller drains then channels it to outlets or canal ditches and/or to a larger river. Dimension of main drain is 3 m x 2 m with a depth of 1.75 m meanwhile collection drain is made with a size of 2 x 1.5 m and a depth of 1.75 m (**Figure 3**). The function of collection drain is to directly collect water from the surface of the field, especially the lower parts, then drains it into the primary/main drain. The sizes of main and collection drains are very dependent on the amount of water that needs to be accommodated. Field drain or so called subsidiary drain is a drain that collects water from the area or from lowland and channels it directly to the collection drains. Field drain is made with a size of 1 x 0.45 m and a depth of 0.8 - 1 m. Field drain is built parallel to the row of plants to drain water into the collection drain (**Figure 3**).

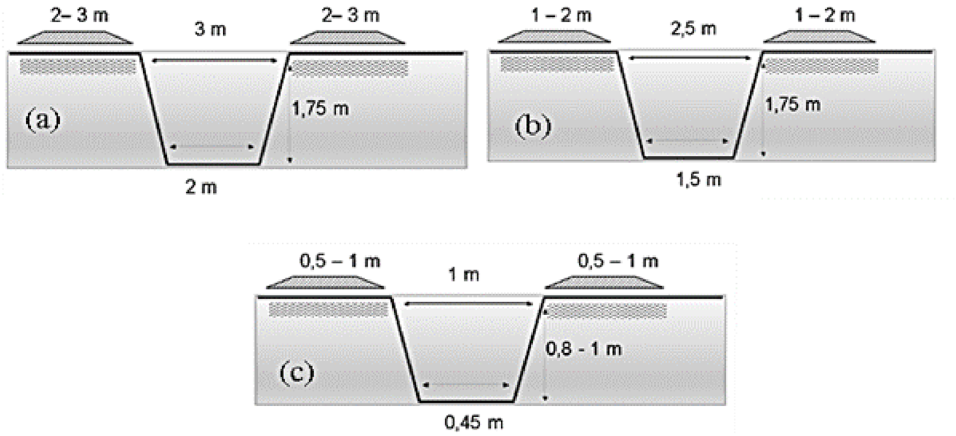

Figure 3: Dimension of drains in the surroundings of embankment areas (a) main drains, (b) collection drains and (c) field drains (in-field drains)

A typical illustration for embankment or heightening of both banks of the river is given in **Figure 4.** The width of 3 meters is maintained throughout the areas designed for embankment. Soils to top up the bank were also taken from riverside, approximately 3 meters away from the base of banks. This 3-meter distance from base of riverbank is necessary to ensure the stability of the bank. On the other side (i.e. field side), a bund drain is constructed so that this drain able to channel out any excess water from river due to leaking through bund or rain water.

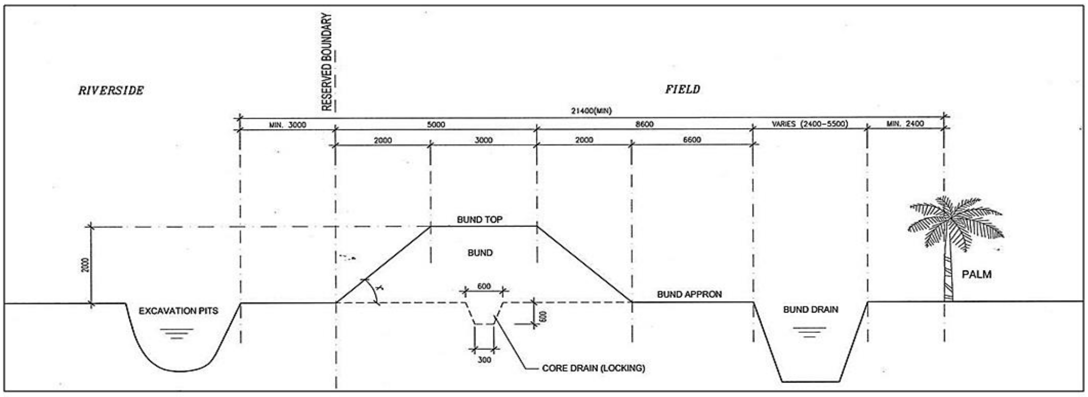

Figure 4: Illustration on embankment areas along the proposed riverbanks

When making a drain, lay out the drain that has been determined in the drawing on the work map and marked with stakes or peg or rope in the field. Drain work starts from the large ditch, then followed by the smaller one and drain digging starts from the outlet (downstream) to adjust the depth of the drain.

2.6 Monitoring Progress of Embankment Project

Embankment project was carried out phase by phase in both Seret Ayon and Lembah Bawang estates since 2017 and 2019 respectively. A total of 38.39 km along the rivers of Sebangkau, Setangau and Sepang in Seret Ayon Estate while for Lembah Bawang Estate, a total of 8.9 km along the Sepang and Karangan rivers (**Figure 5**).

(a) (b) (c)

Figure 5: Heightening of banks along the rivers (a) works by excavators, (b) embankment in progress and (c) completed embankment with 3 meter width on the top surface

Efforts should be taken to ensure the stability of riverbanks together with embankment. After a heavy pour, a patrol should carry out monitoring and checking of any weakness in embankment area such as sudden collapse of riverbank (due to more sandy type of soil texture) and /or overflow of river after for an extended period of rainfall. Estate personnel must continue monitoring the riverbanks throughout the year, be wet or dry seasons.

Figure 6: Monitoring fields during the embankment project

2.7 Basic Maintenance Works

In all situations, for an embankment system to be effective, constant supervision and good maintenance of the water-control structures such as monitoring watergates, flap-gates, weeds in the drains and smooth removal of excess water after raining should be carried out (**Figure 6**).

Outlet drains are desilted and thus, improved the water-flow for smooth removal of excess water during the high pour and flooding seasons. It is necessary to pay attention to the maintenance/desilting/washing of the drains. Normally the drains are desilted at least once every two years and this desilting programme is depending on the condition of the drains. Desilting of drain can be done mechanically by deepening the drains that are heavily silted up over the period. While the manual method can be done to small drains by cleaning/removing mud, wood and other rubbish.

(a) (b) (c)

Figure 7: Maintenance and repairing works (a) fixing culvert, (b) flap-gate maintenance and (c) planting of Vetiver grass on recently embankment area, so not easily eroded if the water rises.

Maintenance/desilting of drains are very important because it will greatly affect the volume and smoothness of the outgoing water to main outlets. Repairing of main drains, collection drains, field drains or outlet drains, must be attended immediately to prevent any breakdown of embanked riverbanks. Immediate attention should be given to any water gates or flap-gates requires repairs or fixings (**Figure 7 (a & b)**). Vetiver grasses were also established on riverbanks (**Figure 7 (c)**). Planting of such Vetiver grass would help to reduce soil erosion and thus it is envisaged that lifespan of embankment be extended.

3.0 Results and Discussion

3.1 Yield improvement after Embankment Project

As a result of embankment project, total areas improved by 2022 are 413.48 ha and 152.97 ha in Seret Ayon and Lembah Bawang estates respectively. In Seret Ayon Estate, with the construction and elevation of the embankment, FFB yield production has increased from 10.48 tons/ha in 2019 to 33.05 tons/ha in 2022 (**Figure 8**). This representing an increment of 22.57 tons/ha or 315%. If converted to the current price of palm oil in the West Kalimantan region of IDR 2,370/Kg, the profit due to embankment project is IDR 53,490,900/Ha (22,570 Kg/Ha x IDR 2,370/Kg). As approximately 413.48 ha of land was improved from the adverse impacts of frequent floodings, a total of IDR 22,117,417,332 was realized in 2022 (IDR 53,490,900/Ha x 413.48 Ha).

Similarly, there was an increment in FFB production in Lembah Bawang Estate from 11.66 tons/ha in 2017 to 25.94 tons/ha in 2022, representing an increase of 14.28 Tons/ha or 223%. With the palm oil price of IDR 2,370/Kg in the West Kalimantan region, the profit from the increased FFB production is IDR 33,843,600/Ha (14,280 Kg/Ha x IDR 2,370/Kg). As such, for an improved area from frequent flooding incidences of 152.97 ha in Lembah Bawang Estate, IDR 5,177,055,492 worth of FFB production is realised in 2022 (IDR 33,843,600/Ha x 152.97 Ha). Assuming the conversion rate of 1 USD = IDR 15,000, an additional income due to embankment project for Seret Ayon and Lembah Bawang estate is equivalent to USD 1,474,494 and USD 345,137 respectively.

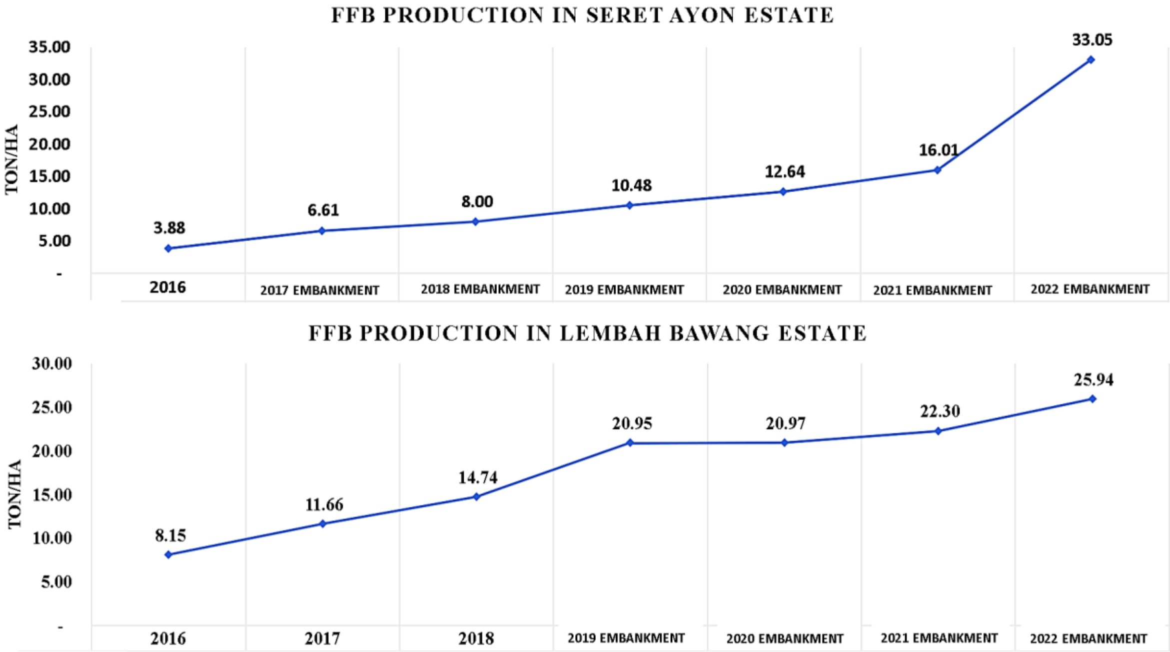

Figure 8: FFB yield improvement after embankment project in Seret Ayon and Lembah Bawang estates

Basically, the improvement in field conditions, drains and roads had resulted in the betterment of FFB evacuation and transportation of FFB to mills. As a result, there is a major FFB yield improvement realised in 2022 in both estates. As shown in **Figure 8**, throughout the years of 2016-2021, yields in Lembah Bawang Estate was higher than those from Seret Ayon Estate for the same period. However, in 2022, there was a significantly higher FFB yield production in Seret Ayon Estate (33.05 tons/ha/yr) as compared to those from Lembah Bawang Estate (25.94 tons/ha/year). This might had attributed due to earlier embankment project in 2017 for Seret Ayon Estate as compared to Lembah Bawang Estate, where an embankment project was initiated only in 2019. Furthermore, total areas improved due to embankment project in Seret Ayon Estate was approximately 413.48 ha as compared to the 152.97 ha of improvement areas in Lembah Bawang Estate. As such, the FFB yield increment in Seret Ayon Estate was better than Lembah Bawang Estate. **Figure 9** shows the improvement on the ground *before* and *after* the embarkment of embankment project in Seret Ayon and Lembah Bawang estates in STAR.

Figure 9: Field condition and appearance of palm health *before* and *after* embankment project in the same areas in Seret Ayon and Lembah Bawang estates, near Sambas, Indonesia

4. Conclusions

FFB yields were satisfactorily increased from a mere production of 6.61 ton/ha/yr in 2017 to 33.05 ton/ha/yr in 2022 in Seret Ayon Estate. Meanwhile, for the same period in Lembah Bawang Estate, FFB yield was increased from11.66 ton/ha/yr to 25.94 ton/ha/yr. This FFB yield increment was attributed mainly to the implementation of embankment of riverbanks within the project areas. FFB yield production of more than 35 ton/ha/yr is highly possible, even in areas with annual rainfall reaching above 4000 mm per year. There were also other agronomic practices implemented throughout the same period to ensure maximum FFB production in this frequently-flooding areas, such as continuous application of fertiliser at the optimal rates and field maintenance. Although other agronomic practices played equally significant roles, the embarkment of embankment project is remained a single major factor for ensuring maximum FFB yields in the flooding areas.

Besides improving FFB yields, palm growth was also satisfactorily improved in frequently flooding areas, especially after three years of water management by embankment. Maintenance and cleaning works on embankment areas also should be carried out to ensure that embankments are not damaged, for example monitoring vetiver grass planted on the edges of the embankments and monitoring riverbanks before heavy rainy days. As such, decision to carry out embankment project especially on heavy rainfall areas really could bring fruitful returns, at four to six years of embankment project.

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