

Vintage Approach to Forecasting Palm Oil Production in Peninsular Malaysia

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ABSTRACT

Oil palm is an important crop to the Malaysian economy. Due to its strategic significance there is a need to have a reliable estimate of the production of the commodity to facilitate decision-making by policy-makers and industry participants. The vintage approach has been shown to be more efficient in taking into account the age of palms and their yield profile when estimating production compared with other methods. The study utilised the vintage approach adapted from Smit (2010). The findings suggest that the vintage model developed is capable of projecting as well as simulating the impact on the palm oil sector if a change or shock is injected into the system.

Keywords: vintage approach, CPO forecast, Peninsular Malaysia, agricultural policy, NKEA replanting policy.

INTRODUCTION

Capital is a fundamental component of agricultural production, and its accumulation is the key to growth and development. In the case of the palm oil industry, the palms represent the capital. The major problem when considering oil palms to be capital goods is that they are aggregated as if they performed the same function although they are drawn from different vintages with different production functions. Besides, being a perennial crop, the oil palm like other forms of physical capital decays in its productivity over time; hence, 'replanting' is

necessary to ensure continuous productivity other than clonal and farming improvements. Malaysia has instituted an accelerated replanting programme as well as incentive packages under the recent National Key Economic Areas (NKEA) initiatives for the palm oil sector (PEMANDU, 2011). However, the inability to incorporate the age distribution may impair a meaningful quantitative assessment of the effects of these incentive schemes for replanting and new planting, and hence of the trajectory of future output. Thus, there is a need for a better approach in estimating oil palm production that takes

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into account the age composition of the palms and technological improvements. Towards this end, the vintage approach used by the International Rubber Study Group was adopted to study palm oil as this approach has proved to be reliable and an efficient tool for the study.

CONCEPTUAL FRAMEWORK IN THE VINTAGE APPROACH

The study utilised the vintage approach adapted from Smit (2010). Although there have been many studies utilising this approach since the 1960s, the framework discussed here is based heavily on Smit (2010) which in turn referred to Burger and Smit (1997) and Smit (1984).

There are two major steps in the vintage model development process: estimation of the age profile and then estimation of the production. The simulations included are a base run, simulation of the NKEA's replanting policy, and simulation based on the use of a high yield variety. Due to limited data availability, the vintage model was developed for Peninsular Malaysia using data for the period 1995-2009. To operationalise the forecasting and simulation, an electronic spreadsheet-based (using Excel software) application was developed to provide a platform for policy-makers or researchers to experiment and analyse the implications of changes in policy variables and technological advances on palm oil production.

As mentioned before, the vintage approach in analysing long-term perennial crop production such as the oil palm basically consists of two parts:

- estimation of age composition of existing palm stands; and
- estimation of production by multiplying the age profile

of stands with the age-yield profile and technological progress factor (proxied by clonal improvement).

ESTIMATION OF AGE COMPOSITION OF EXISTING PALM STANDS

Estimation of the age profile of palms rests on a few fundamental equations involving the relationships between areas.

The first relates the areas between two successive time periods:

$$a_t = a_{t-1} + n_t - d_t \quad (1)$$

where:

- a_t = area in current period;
- a_{t-1} = area in previous period;
- n_t = new planting in current period; and
- d_t = discarded area in current period.

It should be noted that this relationship applies to a particular vintage, which as explained earlier refers to the year of planting. This could be indicated in the above equation as a second subscript, say 's', in addition to the subscript representing time. However, this has been omitted here to avoid clutter and for convenience. New planting refers to plantings in areas not previously under oil palm. Discarded area is an area taken out of growing oil palm. In other words, the current period's area must be equal to the last period's area plus additions and minus removals made between the two periods.

Note that replanting involves uprooting existing stands, not dissimilar to uprooting for discards. If information regarding replanting is available, the second equation takes this relationship as:

$$u_t = r_t + d_t \quad (2)$$

where the additional symbols:

- u_t = uprooted area; and
- r_t = replanted area.

In other words, this equation implies that the total area for uprooted palms must be equal to the areas uprooted for the purpose of replanting as well as for discarding.

The third and final equation assigns both replanting and new planting into:

$$tnp_t = n_t + r_t \quad (3)$$

where:

tnp_t = total new planted area.

To repeat, the area indicated above relates to a particular vintage, the year the palms were planted, and could have been written as (a_{ts}). As the year of planting is fixed and regarded as time period 0, ${}^a2010, 1980$ clearly indicates the area for 30-year old palms. Similarly, if the palms were replanted in this year, ${}^a2013, 2013$ represents the area of new plantings, *i.e.* 0-year old palms.

The next concept of critical importance in the vintage approach is the movement of a particular vintage over time. It is easy to grasp that palms planted in 1980 (age=0) will be one-year old palms in 1981, two-year old in 1982, and subsequently increasing in age as time moves on. However, it is important to note that not all palms will survive over time. A reduction in the number of palms is usually characterised by a discarding function.

The discarding function used in this analysis, f_{ts} , was adopted from Smit (2010). It is represented as:

$$f_{ts} = \frac{1 + e^{-\left(\frac{1}{r\mu_t}\right)}}{1 + e^{-\left(\frac{u_t - (t-s)}{r\mu_t}\right)}} \quad (4)$$

where:

s = year planted;

t = current year;

r = the speed at which discarding reaches half the maximum; and

μ = the average percentage discards or age at which discarding reaches half the maximum.

This discarding function multiplied by the area in the previous period is the area uprooted in the current period:

$$u_{t,s} = f_{t,s} * a_{t-1,s} \tag{5}$$

It may be recalled that the above is the uprooted area for a particular vintage. In any given year, the total area is made up of palms of various ages, (i.e. planted in different years) or vintages. Thus, the total area uprooted in any given year can be represented as:

$$u_t = \sum_s \frac{1 - e^{-(1/r)\mu t}}{1 + e^{(\mu_t - (t-s))/r \mu_t}} * a_{t-1,s} \tag{6}$$

Note the roles of r and μ in the discarding function. *Figure 1* shows the influence of μ on the discarding function. To reiterate, μ is a parameter that represents the inflection point of the curve. In other words, this is the point (year) where the discarding fraction is half the maximum. Notice that with greater μ the inflection point is delayed and the maximum discarding fraction is lowered. In other words, the curve is shifted to the right. For any given year when the discarding fraction is lower, the uprooting value is reduced and the life of the palms is extended because less is removed in each year.

Figure 2 clearly shows the influence of r on the discarding function. Remember that r is the speed at which the discarding fraction approaches half the

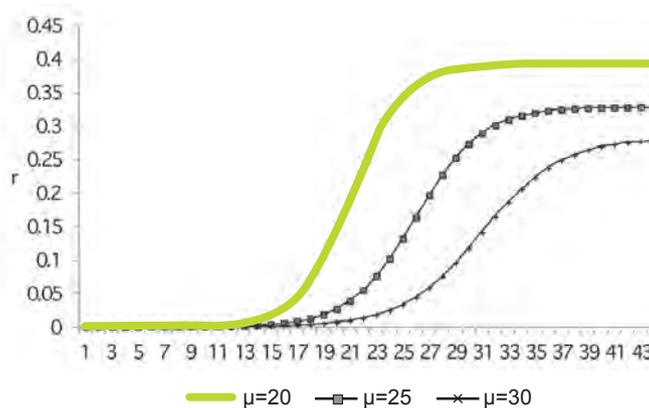


Figure 1. Influence of μ on the discarding function.

maximum. Notice that the slope is flatter with a greater r value as the curve approaches the inflection point. To the right of the inflection point the slope is steeper for a smaller r value, and the maximum fraction is lower for a larger r .

The above discussion focussed only on what can be called the ‘natural’ rate of discard. In reality, management policies, replanting policy being the most obvious, will affect the uprooting of palm stands. Thus, using the discarding function, the total area consisting of palms of different ages, or age profile, in any given year can be used to project the age profile of the succeeding year, or the previous year.

ESTIMATION OF PRODUCTION

An extended gestation period with no yield is a characteristic of perennials such as oil palm. Furthermore, yield is not constant over the life of the palms. It is usual for yield to increase after the gestation period, reaching a maximum, and then begin to decline with increasing age. This relationship between age and yield is referred to as the age-yield profile. Note that different vintages may have different age-yield

profiles. Production is estimated by multiplying the age profile of stands with the age-yield profile.

Following Smit (2010), the age-yield profile can be characterised by three parametric values:

- start = the age when palms start to yield, i.e. bear harvestable fruit;
- top = the age of the palms when yield is at its maximum; and
- max = the value of the highest yield.

The equation for the age-yield profile can be written as:

$$\text{Estimated yield profile} = \frac{\text{max}(\text{start}) \left\{ \text{start-age} + \text{top}(\text{top}) \left(\frac{1}{\text{start}} - \frac{1}{\text{age}} \right) \right\}}{(\text{top}-\text{start})^2}$$

Figure 3 shows the age-yield profile used in the study. This is similar to the one used by Azman and Mohd Noor (2002).

As the name implies, the age-yield profile shows only the relationship between age and yield, other factors remaining constant. As mentioned before, it is ideally estimated from longitudinal studies. However, it is clear that over time factors other than age will influence production. For example, changes in cultural practices, improvements in harvesting technology, and

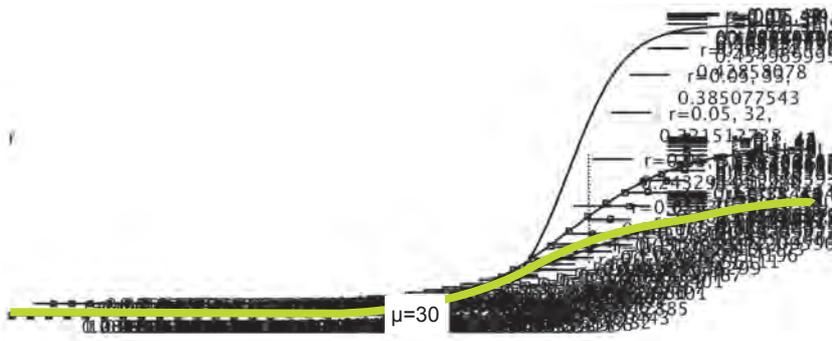


Figure 2. Influence of r on the discarding function.

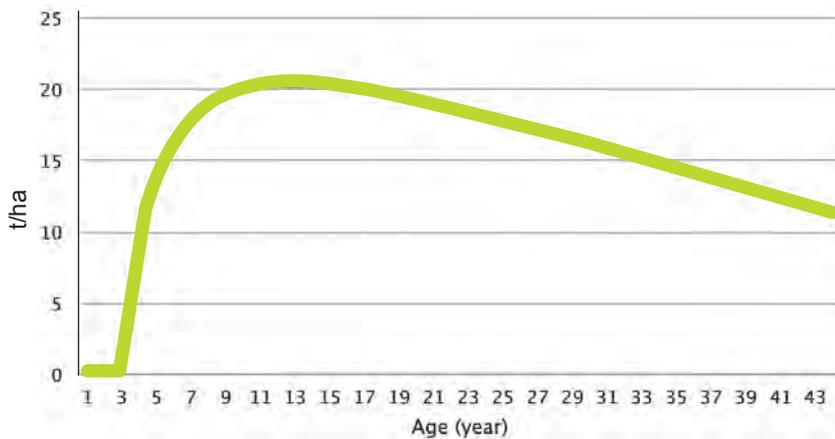


Figure 3. Standard age-yield profile of oil palm.

increased productivity of labour will contribute to increased output from a given stand of palms. Smit (2010) refers to this as technical progress. To take these influences into account, the time trend of yield was estimated and this index was used in the estimation of production. Thus, the estimation of production is written as:

$$qn_t = \sum_s f(s)y_{t-s}a_{ts} \quad (8)$$

Where:

- qn_t = normal production;
- s = year of initial planting;
- t = current year;
- $f(s)$ = embodied technical progress function;
- y_{t-s} = standard yield profile, age = $t-s$; and
- a_{ts} = area of vintage s still remaining in year t .

FINDINGS

The findings suggest that the vintage model developed was capable of projecting as well as simulating the impact on the palm oil sector if a change or shock was injected into the system. The model was able to characterise the essential dynamic elements of perennial crop production: the significant period between planting and harvestable output; and a relatively long but finite economic life, beginning with an initial period of increasing output but eventually followed by a period of declining productive capacity due to ageing palm stands.

The essence of the vintage approach is the estimation of the age profile of palms in a given year, which goes beyond the current

classification of immature and mature stands. This distribution of age is more important with a more pronounced age-yield profile. If the objective is just to estimate yield, an easier approach perhaps would be to estimate the ‘average’ production of mature oil palm which is then multiplied by the area of mature oil palm. However, if the objective is to study the impact of a policy such as replanting, then a much narrower classification of mature oil palm is needed, as demonstrated by this study.

There was a temporal relationship between total new plantings in a particular year (which is the sum of new plantings on land previously not under oil palm and replanting of old palms on existing oil palm area) and the age profile of palms in subsequent years. Additionally, the discards (which are the removal of existing palms and switching the area to non-oil palm use) also affected the future age profile of palms. Hence, uprooting palms, either for replanting or discards, was a significant factor in palm oil production.

A stronger relationship between age and yield would produce a greater impact on the annual production in the subsequent years. The age-yield profile was characterised by the gestation period, which determined the year of first harvest. The next influencing factor was the rate at which the yield approached the maximum possible. In this study, this was approximated by the year of maximum yield, and the level of this maximum yield. A higher maximum yield attained in a shorter period between age of first harvest and age of maximum harvest indicates a greater rate of increase in yield. The next phase of the age-yield curve is the declining phase. The rate of decline during this phase will impact the yield from palms aged more than the

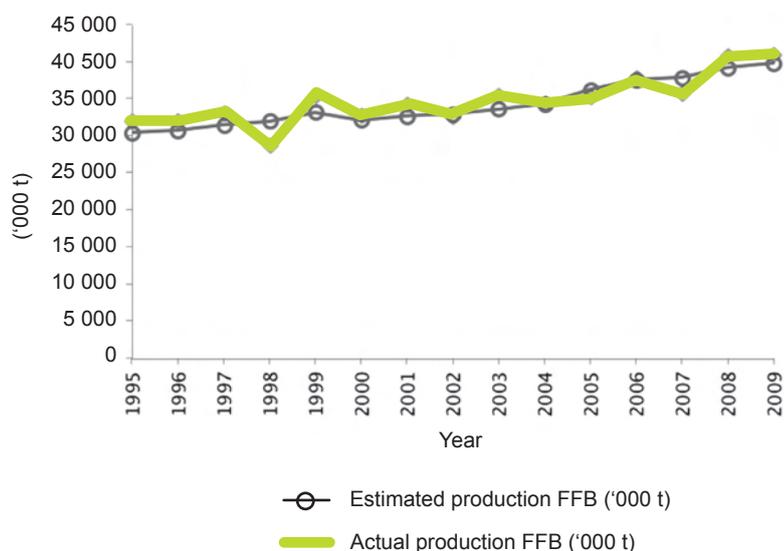


Figure 4. Estimated and actual total production of fresh fruit bunch (FFB) ('000 t) in Peninsular Malaysia, 1995-2009.

year of maximum yield. A slower rate of decline will reduce the impact of old age on reduction in yield, and *vice versa*. This feature implies a finite economic life for perennials such as oil palm. We can infer that, other factors remaining the same, a slower rate of decline will extend the economic life of the palms, and *vice versa*. In other words, at this stage the palms have to be uprooted and a choice has to be made as whether to replant old palms with those of a newer vintage, plant crops other than oil palm, or to put the land to non-agricultural use. The latter two choices are termed as 'discards'.

The actual decision, however, will be influenced by economic factors, net returns (which is influenced by expected prices of output and inputs), expected output of oil palm as well as of competing crops, and returns from other enterprises. The determination of the optimal age for replanting is usually done by studying a single vintage over time.

The simulation runs carried out involved:

- a normal base run or 'business-as-usual' run;

- a complete removal of palms more than 25 years old;
- removal of palms more than 25 years old within three years; and
- replanting with materials having a high yield profile.

The base run simulation gives a perspective of the age profile and fresh fruit bunch (FFB) production when replanting is carried out as usual without any new replanting policy imposed.

To date, there is a backlog of 274 000 ha of low yielding oil palm older than 25 years in Peninsular Malaysia. For the base run, the study assumed a replanting rate of 2% to 3% which was derived from historical data between 1995 and 2009.

BASE RUN SIMULATION

The base run simulation aims at showing the trend of age profile and FFB production between 2009 and 2021 when the standard yield profile (*i.e.* with a maximum yield of 23.25 t/yr/ha), normal replanting rate (*i.e.* 2% to 3%) and standard technological progress (*i.e.* 0.11% growth) are assumed. These assumptions were inferred

from the age profile and FFB production in 2009.

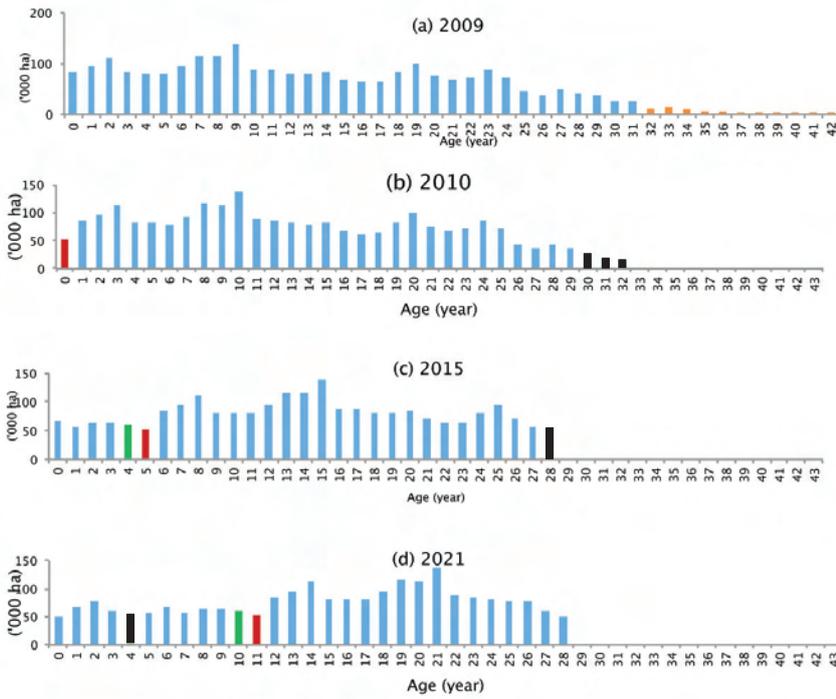
Uprooted oil palm from a planted area was followed immediately by replanting in a subsequent year. Again, in this simulation, it was also assumed that there was no new planting, as unused arable land in Peninsular Malaysia has almost reached its limit.

Replanting was estimated by summing the older palms first until the sum reached 2% to 5%. For instance, palms of vintage ages 32 to 43 years old in 2009 were uprooted for replanting in 2010, as the cumulative sum was 2.61% of the total area. This computation was repeated yearly till 2021.

Figure 5 shows the age profiles of 2009, 2010, 2015 and 2021. The green bars representing age profile 2009 indicate the vintages to be uprooted for replanting, resulting in vintage age zero for year 2010 (as shown by the single green bar in age profile of 2010). In year 2015, the green bar had shifted five years to the right again, and then six years to the right in year 2021. There was also a marginal decline in the total area from 2010 to 2021 which was not very obvious from the height of the bars. This is again evident in Figure 5a which shows the annual total planted oil palm area during the simulation period. The black line indicates the estimated total area whereas the green line is the actual planted area as reported by MPOB. Corresponding production is also shown in Figure 5b.

The reported total planted area was slightly higher than the estimate, and can be explained by:

- the assumption that there was no new planting in the forecast;
- the age-yield profile used could be somewhat dated, *e.g.* the current age-yield profile might be higher; and
- technological progress that was assumed was lower than in actual case.



Note: Replanting rate = 2% to 5%; standard yield profile was used.

Figure 5. Estimated age profile of oil palm in Peninsular Malaysia for base run simulation, 2009, 2010, 2015 and 2021 ('000 ha).

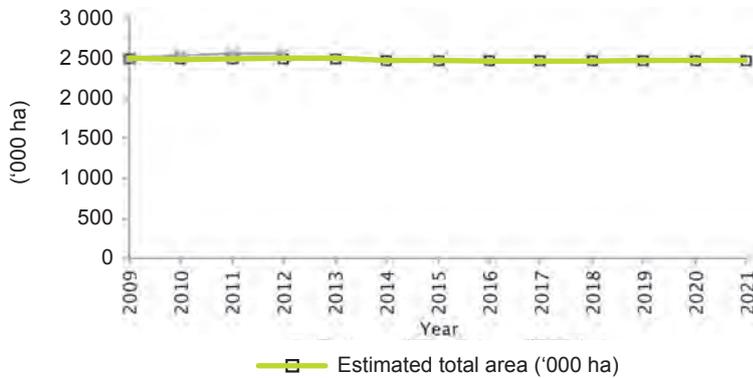


Figure 5a. Simulation results of total area ('000 ha) for base run simulation in Peninsular Malaysia, 2009-2021.

The production profile (FFB) in Peninsular Malaysia from year 2009 to 2021 was estimated based on the estimated age profile. FFB production in Peninsular Malaysia was projected to increase from 40 625 580 t in 2010 to 41 551 730 t in 2012. However, starting from year 2012 until 2021 the FFB production was projected

to decline from 41 551 730 t in 2012 to 39 239 290 t in 2021. Nonetheless, these changes were within a margin of 6%.

The base run simulation gave the perspective of age profile and FFB production when replanting was carried out as usual without any new replanting policy imposed. The subsequent subsections report

simulations based on different replanting policies; specifically the simulations involved:

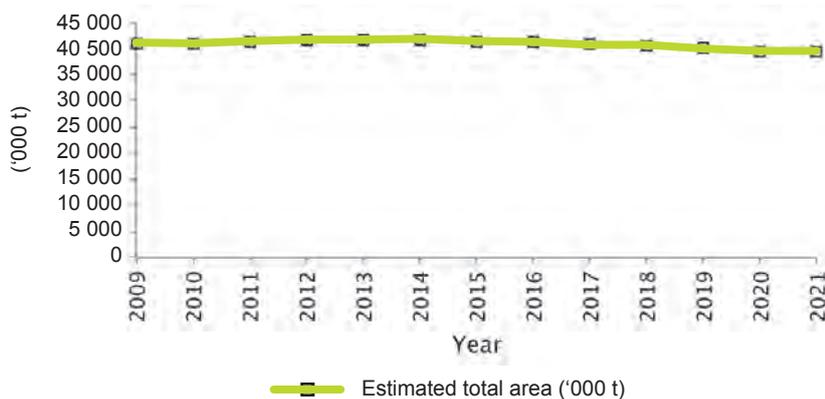
- simulation of complete replanting of palms more than 25 years old in 2010;
- simulation of PEMANDU's replanting plan, i.e. removal of palms more than 25 years within three years; and
- simulation of replanting with materials having a high yield profile.

Simulation 1: Complete Replanting of Oil Palm More Than 25 Years Old

The objective of this simulation was to project the impact of replanting all oil palm older than 25 years (except the mother palms) in 2009, on FFB production. To this end, 266 870 ha (10.8%) of old palms were assumed to have been replanted to give rise to a new vintage (age 0) in 2010.

In the year 2010, however, there were still 25-year old palms as 24-year old palms in 2009 would have turned 25 years in 2010, and therefore due for replanting. This holds true for all subsequent years.

Figure 6 shows the age profile histograms for year 2009 and after the radical replanting policy (years 2010, 2015 and 2021). Obviously, the radical replanting policy introduced a very tall bar in the age profile 2010, representing a new vintage of age 0. Note that the red bar at age 0 was derived from the trailing red bars in the age profile 2009. In this way, the total area can be maintained almost constant apart from marginal inevitable natural mortality of approximately 1% deducted from the estimated discarding fractions. The annual total area of oil palm planted area for the forecast period is shown in Figure 6a which is simulation results of total area ('000 ha) with complete removal of palms



Note: Replanting rate = 2% to 5%; standard yield profile was used.

Figure 5b. Estimated total production ('000 t) of fresh fruit bunch (FFB) for base run simulation in Peninsular Malaysia, 2009-2021.

more than 25 years old in Peninsular Malaysia, from 2009-2021.

This radical replanting policy introduced a relatively big area of vintage 2010 represented by the same tall red bar shown in Figure 6 in years 2010, 2015 and 2021. Note again that vintages shifted to the right in the age profile histogram over time. The immediate impact of this radical replanting policy can be seen in the FFB production in the next few years. FFB production was projected to decline immediately from 40 625 580 t in 2009 to 38 028 620 t in 2010. The decline accounted for approximately 6.4% of the total area and was maintained almost constantly lower for two more years.

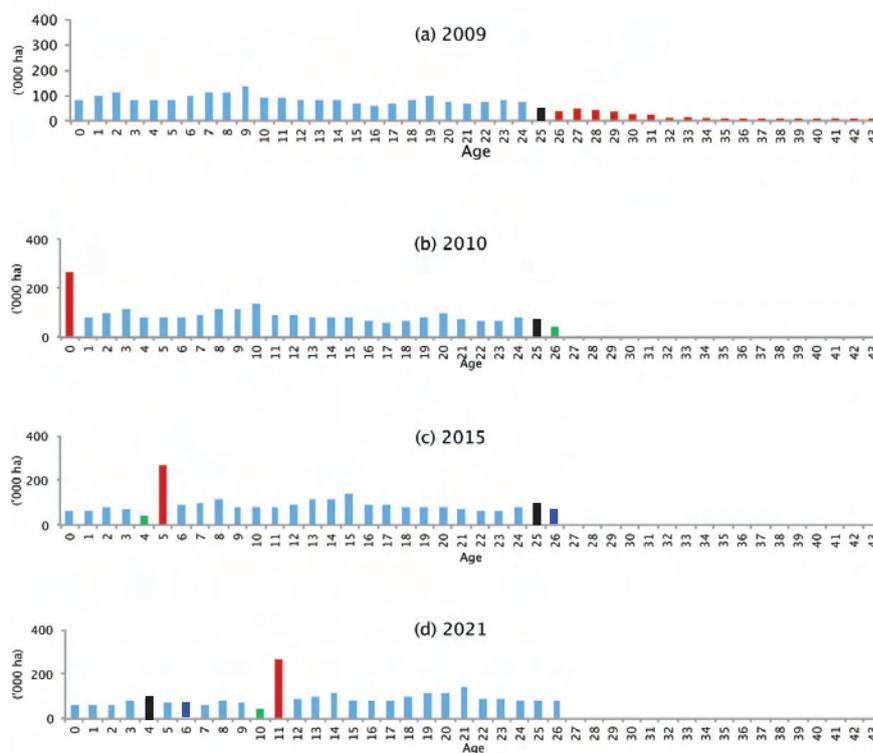
Nonetheless, FFB production was estimated to increase after the vintage 2010 matured. FFB production was estimated to peak after 10 years, i.e. in 2020, to a record of 42 825 120 t according to the standard yield profile and was expected to last for four to six years after that. Theoretically, the production would again decline to its lowest when this vintage was due to be replanted again which would happen beyond the forecast period.

This radical replanting policy was obviously able to clear off the backlog within three years as targeted by PEMANDU. However,

it also introduced a shock to palm oil production as a side effect.

Simulation 2: Replanting All Oil Palm More Than 25 Years Within Three Years

According to PEMANDU (2011), there is a backlog of 365 414 ha of low yielding oil palm older than 25 years in Malaysia. According to MPOB (pers. comm.) 75% (274 000 ha) of this backlog is in Peninsular Malaysia. The replanting is to be conducted in a staggered manner to avoid any shock in FFB production as demonstrated by the radical replanting in Simulation 1. If this staggered replanting policy is to be implemented, approximately 91 000 ha need to be replanted yearly over three consecutive



Note: Removal of oil palm more than 25 years old in any one year.

Figure 6. Estimated age profile of oil palm in Peninsular Malaysia with complete removal of palms more than 25 years old in 2009, 2010, 2015 and 2021 ('000 ha).

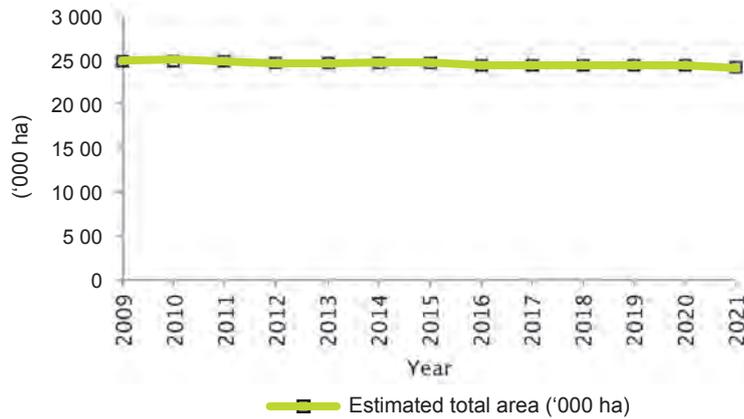


Figure 6a. Simulation results of total area ('000 ha) with complete removal of palms more than 25 years old in Peninsular Malaysia, from 2009-2021.

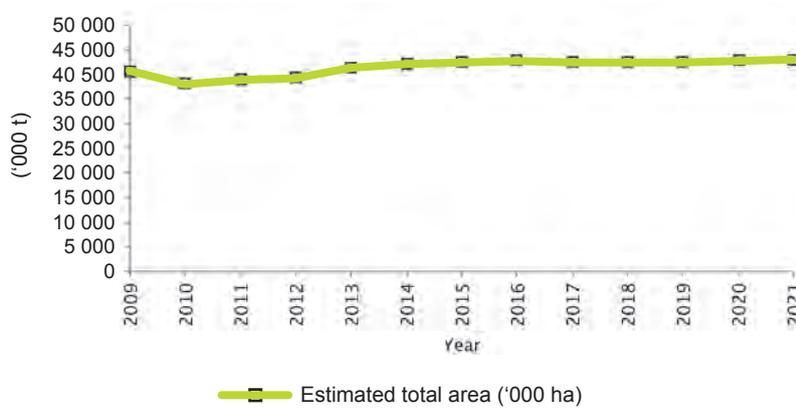


Figure 6b. Estimated total production ('000 t) with complete removal of palms more than 25 years old in Peninsular Malaysia, from 2009-2021.

years. With this replanting strategy, PEMANDU expects the average yield to increase to 26 t/ha/yr by 2020.

To implement this staggered replanting policy, palms older than 29 years were replanted in the first year of the forecast period to give rise to vintage 2010. The vintage accounted for approximately 103 360 ha of planted area in the first year. Then, in the second year, palms older than 27 years would be replanted to give rise to vintage 2011 amounting to approximately 105 350 ha of palm oil planted area. Finally, palms older than 26 years were replanted to give rise to vintage 2012 planted on

approximately 72 160 ha. Clearly, even at this accelerated rate, it was still not possible to achieve the goal of clearing off all palms older than 25 years within three years.

Figure 7 shows the age profile histograms gained from the staggered replanting policy. Although replanting was accelerated to clear off the backlog of 274 000 ha of old palms within three years starting in 2009, there was no extremely high bar projected in the age profiles. In other words, no extremely big batch of a single vintage was produced from the policy. The replanting rates were recorded at 4.2%, 4.3% and 3.0%, respectively,

in the three consecutive years. These rates were around the upper limit of the replanting rate observed in the base run simulation.

Figure 7b shows the FFB production when the staggered strategy was used to implement PEMANDU’s plan to accelerate replanting. The figure projects that production declined immediately by 1% from 40 625 580 t in 2009 to 40 222 420 t in 2011. The decline in production was inevitable when the ratio of immature to mature planted area increased due to the accelerated replanting policy. FFB production started to pick up again after that when the replanted area started to produce yield.

This simulation shows that PEMANDU’s yield target of 26 t/ha was still not achievable as only a mere 17.5 t per yield was projected.

Simulation 3: Production with High Yield Profile

In this simulation, the previous simulation was redone by using a high yield profile, with the replanting strategy remaining exactly the same as in Simulation 2, i.e. implementing PEMANDU’s plan to replant the backlog of low yielding palms older than 25 years old within three years in the same staggered manner. The high yield profile was derived by using Equation (7). The maximum yield of the high yield profile was adjusted to 30.13 t/ha/yr instead of 25.34 t/ha/yr of the standard yield profile in all the previous simulations. The aim was to see the impact of high yield profile on FFB production during the forecast period, 2010–2021.

Figure 8 shows the resulting age profile simulated using a high yield profile. As the change was only with respect to the age-yield profile, the age profile showed exactly the same trend and pattern as in the previous simulation.

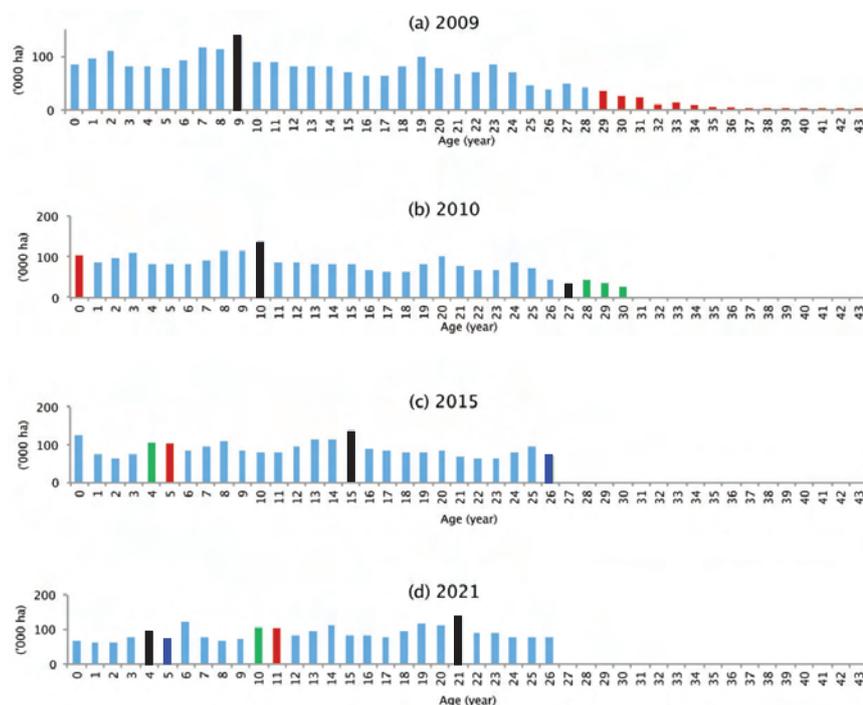


Figure 7. Estimated age profile of oil palm in Peninsular Malaysia following PEMANDU’s replanting policy, in 2009, 2010, 2015 and 2021 (‘000 ha).

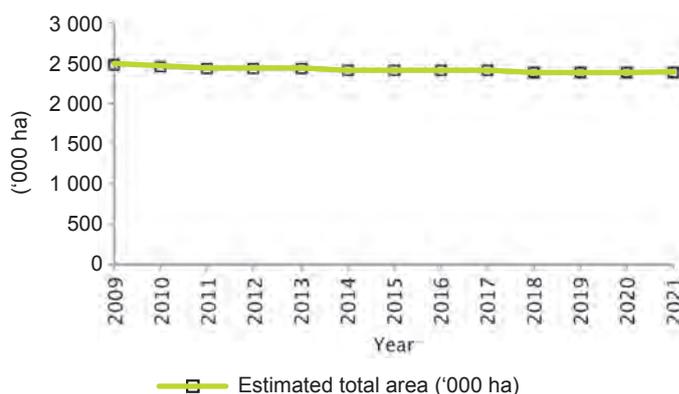


Figure 7a. Simulation results of total area (‘000 ha) for PEMANDU’s replanting policy in Peninsular Malaysia, from 2009-2021.

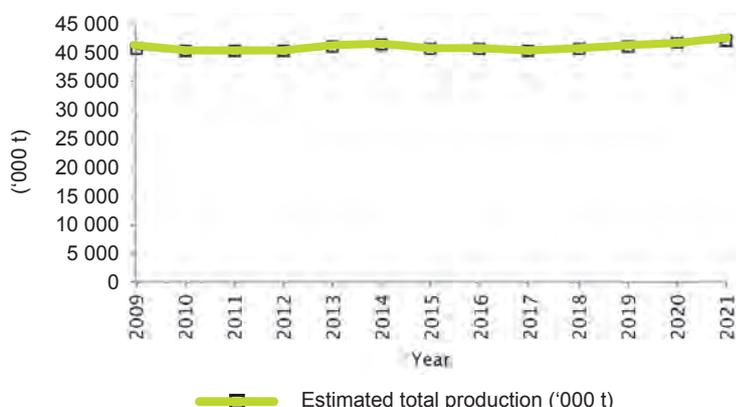


Figure 7b. Simulation results of PEMANDU’s replanting policy on production of fresh fruit bunch (FFB) (‘000 t) in Peninsular Malaysia, from 2009-2021.

There was also no exception to total oil palm planted area as shown in Figure 8a.

The effect of using a different age-yield profile was only shown in the FFB production (Figure 8b). The graph shifted upwards by a constant of approximately 20 000 000 t every year. That was 50% higher than the same implementation strategy using the standard yield profile. Due to this increase in total production, the yield per hectare was raised to 25.9 t/ha, which is very close to the targetted 26 t/ha expected by PEMANDU.

In conclusion, this section shows the impacts of different replanting policies on oil palm production. Figure 9 shows the FFB production from the different replanting policies simulated. The green line shows the FFB production from the base run simulation when replanting was conducted at the normal rate (2%-5%) without any additional policy intervention. Hence, the green line acts as the benchmark to gauge the impact of different replanting policies and strategies on FFB production.

The purpose of an accelerated replanting policy is to clear off the backlog of unproductive palms within a reasonably short period. However, radically accelerating replanting caused a greater shock to FFB production which is evident from the blue line. The shock to FFB production was almost immediate in the following year due to a higher percentage of immature stands in the oil palm planted area. It is worth noting that the impact recurred as the next ripple of decline was expected when the newly replanted vintage had to be replanted again after another 25 years.

To reduce the shock to production, a staggered replanting strategy is advisable, the resulting FFB production is shown by the

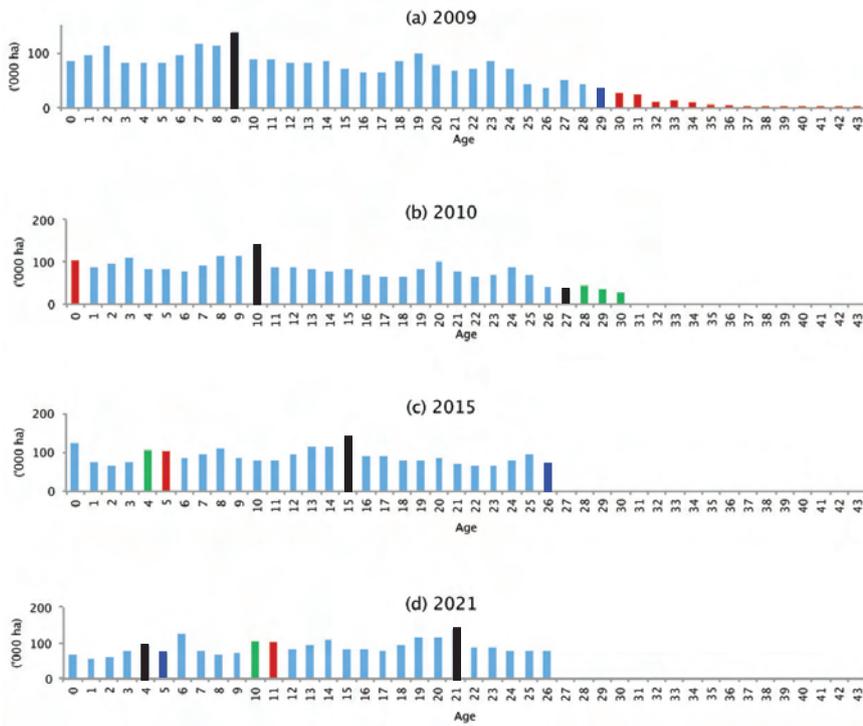


Figure 8. Estimated age profile of oil palm in Peninsular Malaysia with simulation of high yielding planting materials, in 2009, 2010, 2015 and 2021 ('000 ha).

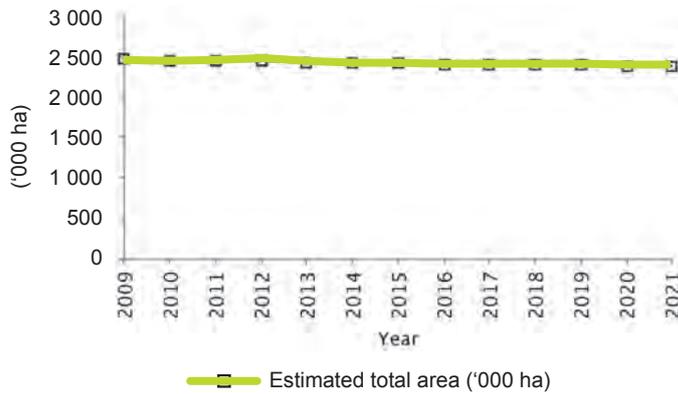


Figure 8a. Total area ('000 ha) in Peninsular Malaysia with simulation using high yield profile, from 2009-2021.

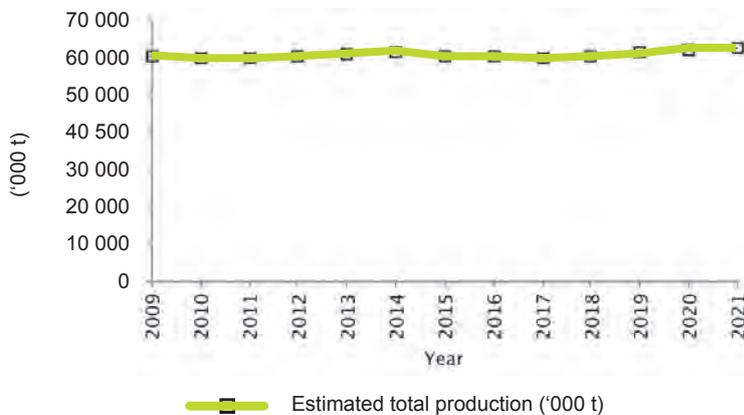


Figure 8b. Simulation results of high yield profile on production of fresh fruit bunch (FFB) in Peninsular Malaysia, from 2009-2021 ('000 t).

red line in which the decline was reduced by half. The yield profile used in this simulation was the standard yield profile that gives a maximum yield 25.34 t/ha/yr. The black line shows the resulting FFB production if a high yield profile was used in the simulation with the same staggered replanting strategy. By using a yield profile that can produce 20% more maximum yield, the FFB production can be increased consistently by 50%.

This simulation showed that PEMANDU's target to clear off the backlog of old palms (274 000 ha) is achievable. However, it would appear that it is not possible to replant all palms older than 25 years within three years. The simulated yield was recorded at approximately 25.9 t/ha which is close to the targetted 26 t/ha in 2020.

RECOMMENDATIONS

The obvious recommendation is that there is a need to collect systematic and periodic data on the age profile of palms. Similar to the collection of human population statistics, data collection need not be conducted annually. A census every five years would be sufficient with the data for the intervening years derived by statistical interpolations. However, data on replanting, new planting, and discards must be collected annually as is currently being done.

As the discard function and age-yield curve are important determinants of production obtained from any given stand of palms, further studies to refine the reliability of these estimates are crucial to the accuracy of the projections. It should be mentioned that the age-yield curve should ideally be estimated from longitudinal studies of specific vintages. Estimates based on cross-sectional studies have the potential of being biased from confounding

variables such as differences in vintage, in soil properties, and in management and cultural practices. A more accurate age-yield curve for different clones and locations is of utmost importance in studies to determine the optimal age of replanting of particular vintages for specific regions and under differing management arrangements (estates versus smallholdings).

Any optimisation study will involve the specification of the objective function to be optimised. Hence, behavioural characteristics of agents are equally important. This is especially true for smallholdings. The objective of profit maximisation with rational expectations is very much acceptable for estate management while the same cannot be said of smallholders.

Behavioural characteristics of agents are also important in supply response studies. Note that this study stopped short of estimating a supply relationship as prices did not enter any of the equations discussed. What was estimated here is referred to as 'productive capacity', 'normal production', etc.

To extend this analysis to a supply response framework, the influence of prices on new plantings, and the influence of prices on the actual usage of productive capacity or normal production, are needed. To use a simple illustration, the decision to harvest existing palms is influenced by the relative balance between FFB price and cost of harvesting.

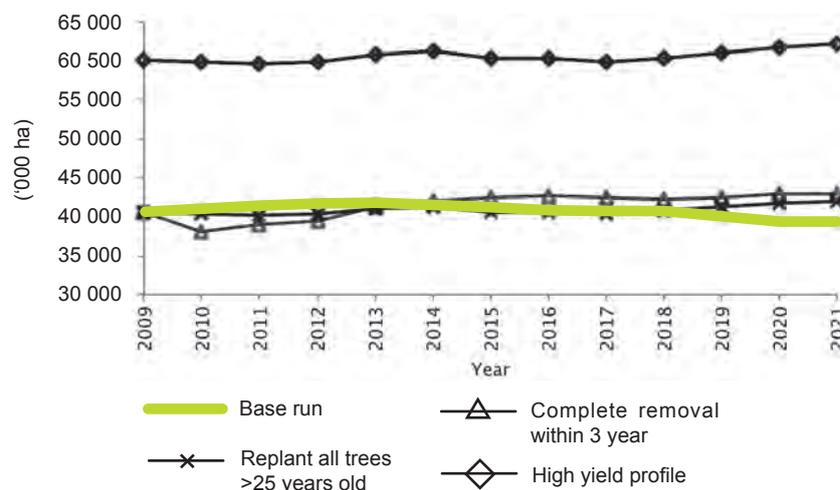


Figure 9. Simulation results of different replanting policies on production of fresh fruit bunch (FFB) in Peninsular Malaysia, from 2009-2021 ('000 t).

To conclude, the vintage approach is a rigorous and robust methodology for studying perennials such as oil palm. It has been well-tested on other perennials such as tea, coffee, cocoa and orchard trees, all of which are commodities that are available in Malaysia.

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