Standard yield curve for oil palm

Analysis of responses to call for data

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1. Introduction

The EU **Renewable Energy Directive recast** and **Delegated Regulation 2019/807** give the possibility to certify biomass feedstocks as low indirect land use change (ILUC) risk by producing additional biomass above a business as usual scenario (i.e. by increasing yields). A crucial step for all low ILUC-risk certification is to for the farmer or plantation owner to determine a plot-specific “dynamic yield baseline”, which is the expected yield that would have been achieved on that plot in the absence of a low ILUC yield increase measure.

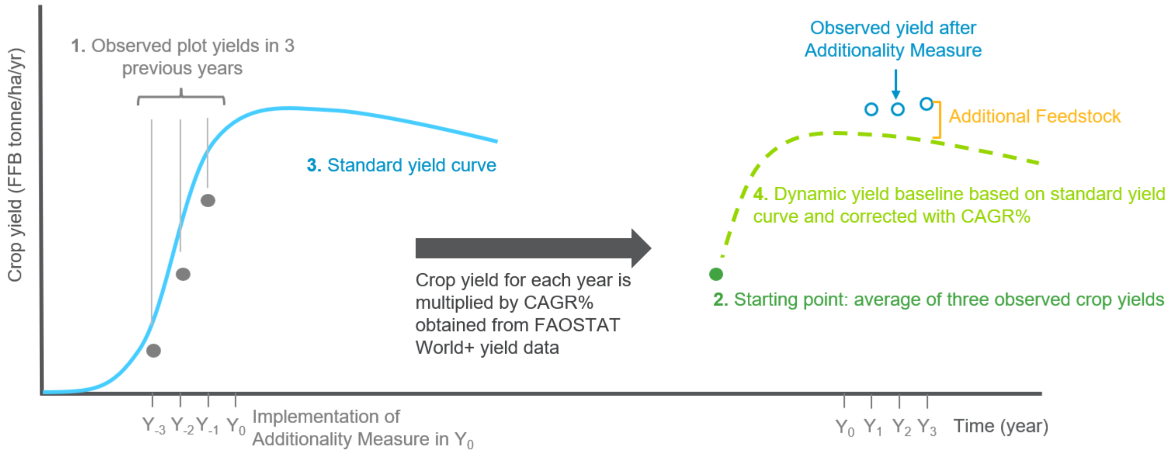
The dynamic yield baseline is designed to recognise that all farms have different contexts and therefore different starting points in terms of yield. The methodology to determine the dynamic yield baseline therefore combines the farmer’s yield starting point with the yield development trends seen globally, to define that farm’s “business as usual” yield. In the case of perennial crops, that baseline also needs to take into account the age of the crop as that is a key determinant of the expected yield.

The Delegated Regulation 2019/807 (Article 2(7)) defines dynamic yield baseline as, “the average yield from the delineated area where an additionality measure has been taken, calculated over the 3-year period immediately preceding the year of the application of such measure, taking into account the average yield increase observed for that feedstock over the previous decade and the yield curves over the lifetime in case of permanent crops, excluding yield fluctuations.”

While for annual crops a dynamic yield baseline is more straightforward, for a perennial crop such as oil palm, this is more complex, due to the different yields that can be expected depending on the age of the trees. Oil palm is a tree with a ~25 year non-linear yield growth curve, which needs to be taken into account in setting the dynamic yield baseline.

As illustrated in Figure 1-1 the methodology to determine the dynamic yield baseline for oil palm combines the existing yield from the plantation as the starting point (1, 2), with the shape of a standard yield curve for oil palm (3) to determine what the yield from that plantation would be in the absence of a yield increase measure (4). Note that the *shape* of the standard yield curve is important, rather than the *magnitude* of the standard yield curve, as the magnitude of the dynamic yield baseline is determined by the existing yield from the plantation in the 3 years prior to the yield increase measure.

Figure 1-1. How to determine the dynamic yield baseline for oil palm



1.1 Call for data

A standard yield curve has been developed based on a literature review. This curve was used to test the methodology to determine a dynamic yield baseline in Phase 1 of the **low ILUC pilot study for the European Commission**.

In July 2021, we published a **Call for data** request, aiming to gather more data on representative oil palm yield curves from agricultural ministries, research institutes, and other stakeholders in key palm oil producing countries and regions.

This aim of the call for data is to further develop and validate a "standard oil palm yield curve" that can be used in the methodology to certify biomass from oil palm plantations included in the **draft Implementing Act** on "rules to verify sustainability and greenhouse gas emissions saving criteria and low indirect land-use change-risk criteria".

Figure 1-2 Call for data

Guidehouse

Call for Data: Standard yield curve for oil palm

Introduction

The EU Renewable Energy Directive recast and Delegated Regulation 2019/807 gives the possibility to certify biomass feedstocks as low indirect land use change (ILUC) risk by producing additional biomass above a business as usual scenario (i.e. by increasing yields). To do this, a farmer or plantation owner needs to determine a "dynamic yield baseline", which is the expected yield that would have been achieved in the absence of a yield increase measure.

While for annual crops a dynamic yield baseline is more straightforward, for a perennial crop such as oil palm, this is more complex, due to the different yields that can be expected depending on the age of the trees. The methodology to determine the dynamic yield baseline combines the existing yield from the plantation as the starting point, with the shape of a standard average yield curve for oil palm to determine what the yield from that plantation would be in the absence of a yield increase measure.

We are **seeking data on representative oil palm yield curves** from agricultural ministries, research institutes, literature, and other stakeholders. This data is needed to develop an "average" oil palm yield curve that can be used in the methodology to certify biomass from oil palm plantations included in the draft Implementing Act[1] on "rules to verify sustainability and greenhouse gas emissions saving criteria and low indirect land-use change-risk criteria". Note that the most important aspect for the methodology is the **shape** of the average yield curve, rather than the magnitude of the yield.

Draft Average Yield Curve

A draft average yield curve has been developed based on two sources from literature, as shown in **Figure 1** and **Table 1**. The determination of a dynamic yield baseline was tested in two low ILUC pilots on oil palm plantations, one in Malaysia and the other in Colombia.

Figure 1. Yield curve of oil palm by tree age

[1] Draft Implementing Act, Annex VIII, Part C, page 26

This paper describes the response to the call for data and the analysis of the yield curves received.

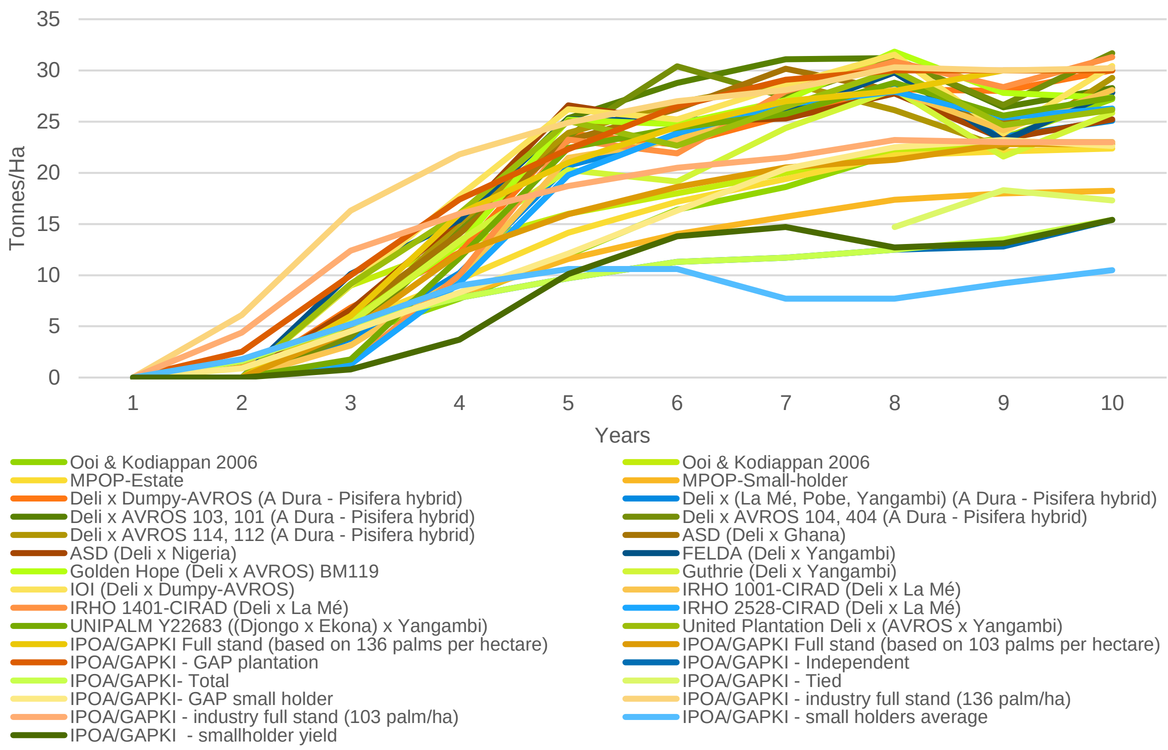
2. Overview of responses

Responses were received from six stakeholders (see Table 2-1), covering a range of different geographies. Key countries supplying palm oil to Europe sent representative data, namely Indonesia (IPOA/GAPKI), Malaysia (MBOP) and Colombia (Cenipalma). From those papers, 38 yield curves were derived, of which 31 were used in the analysis. The remaining 7 yield curves were theoretical calculations based on one of the other yield curves, and therefore were excluded from the analysis to avoid duplication.

Table 2-1. Overview of respondents

Organisation	Data sent
International Sustainability & Carbon Certification (ISCC)	Foong et al., 2019
International Sustainability & Carbon Certification (ISCC)	Ooi & Kodiappan, 2006
Golden Agri-Resources (GAR)	Saragih, n.d.
Golden Agri-Resources (GAR)	GAPKI, 2017
Malaysian Palm Oil Board (MPOB)	Nazrima et al., 2018
Cenipalma (Colombian palm oil research centre)	Tupaz Vera et al., 2017
Indonesian Palm Oil Association (IPOA)/ Gabungan Pengusaha Kelapa Sawit Indonesia (GAPKI)	IPOA & GAPKI, n.d.
FEDOIL	Foong et al., 2006

Figure 2-1. Collected Yield Curves (10 years)



The main sources of yield curve data were Cenipalma (16) and IPOA/GAPKI (11), with the remaining 4 coming from different sources. Most of the yield curves represent industrial-scale plantations (24), with 7 representing small holders. All the collected yield curves are visualised in Figure 2-1.

3. Analysis of the curves

3.1 Statistical analysis of all oil palm yield curves

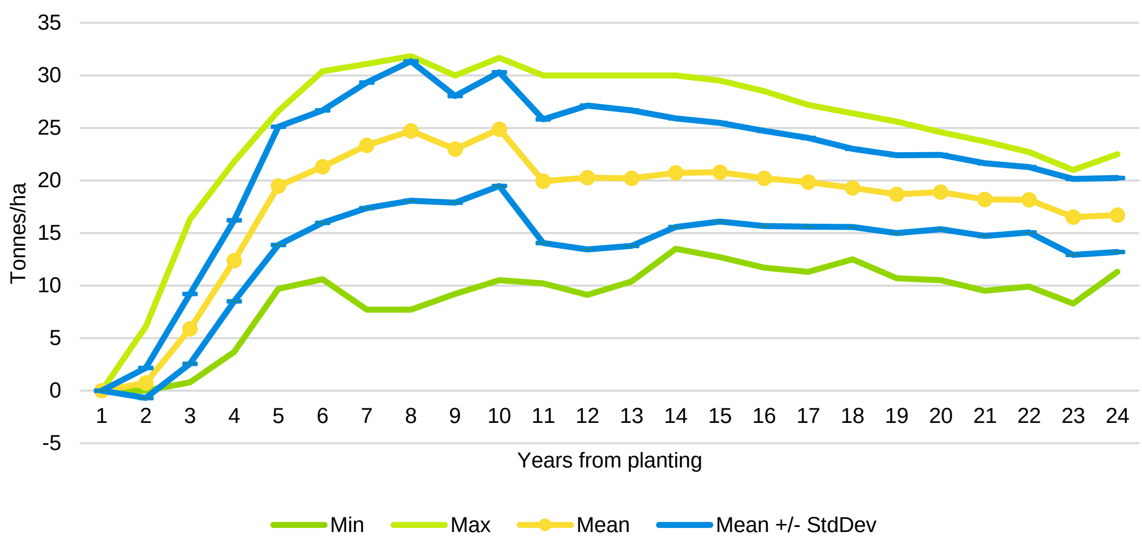
The first statistical analysis was a correlation analysis to assess to which degree the yield curves bear similarities. The correlation analysis helps us to understand the degree to which the yield curve shapes are similar over the lifetime of the oil palm trees, without regard to the magnitude of the yield. The correlation coefficient (R) signifies this, with 1.0 being a perfect correlation. In **Error! Reference source not found.** below, an R higher than 0.90 is coloured red, meaning a near perfect similarity of the curve shapes. The orange cells highlight an R higher than 0.70, which can still be considered a strong correlation. The analysis shows that yield curves are highly correlated and show a strong similarity.

Figure 3-1. Correlation of all palm oil curves

Ooi & Kodiappan 2006 - 1	1.00																														
Ooi & Kodiappan 2006 - 2	0.98	1.00																													
Deli x Dumpy-AVROS (A Dura - Pisifera hybrid)	0.94	0.96	1.00																												
Deli x (La Mé, Pobe, Yangambi) (A Dura - Pisifera hybrid)	0.87	0.92	0.98	1.00																											
Deli x AVROS 103, 101 (A Dura - Pisifera hybrid)	0.82	0.89	0.97	0.99	1.00																										
Deli x AVROS 104, 404 (A Dura - Pisifera hybrid)	0.88	0.92	0.98	0.99	0.99	1.00																									
Deli x AVROS 114, 112 (A Dura - Pisifera hybrid)	0.82	0.86	0.97	0.98	0.99	0.99	1.00																								
ASD (Deli x Ghana)	0.85	0.90	0.98	0.99	1.00	0.99	0.99	1.00																							
ASD (Deli x Nigeria)	0.77	0.84	0.97	0.98	0.99	0.98	0.98	0.98	1.00																						
FELDA (Deli x Yangambi)	0.84	0.88	0.98	0.98	0.98	0.98	0.98	0.98	0.99	1.00																					
Golden Hope (Deli x AVROS) BM119	0.87	0.93	0.99	0.99	0.99	0.98	0.97	0.99	0.99	0.98	1.00																				
Guthrie (Deli x Yangambi)	0.89	0.93	0.98	0.99	0.98	0.98	0.97	0.98	0.98	0.98	0.99	1.00																			
IOI (Deli x Dumpy-AVROS)	0.84	0.88	0.98	0.98	0.98	0.98	0.98	0.98	0.99	1.00	0.98	0.99	1.00																		
IRHO 1001-CIRAD (Deli x La Mé)	0.90	0.94	0.99	1.00	0.99	0.99	0.98	0.99	0.97	0.97	0.99	0.99	0.97	1.00																	
IRHO 1401-CIRAD (Deli x La Mé)	0.93	0.96	0.99	0.99	0.97	0.97	0.96	0.97	0.95	0.95	0.99	0.98	0.96	0.99	1.00																
IRHO 2528-CIRAD (Deli x La Mé)	0.90	0.95	0.98	1.00	0.99	0.99	0.97	0.98	0.96	0.96	0.99	0.98	0.96	1.00	0.99	1.00															
UNIPALM Y22683 ((Djongo x Ekona) x Yangambi)	0.89	0.94	0.99	1.00	0.99	0.99	0.98	0.99	0.98	0.97	0.99	0.98	0.97	1.00	0.99	1.00	1.00														
United Plantation Deli x (AVROS x Yangambi)	0.84	0.90	0.98	0.98	0.98	0.97	0.97	0.98	0.99	0.99	0.99	0.99	0.99	0.97	0.96	0.96	0.97	1.00													
MPOP-Estate	0.98	1.00	0.99	0.98	0.96	0.97	0.95	0.97	0.94	0.95	0.98	0.97	0.95	0.98	0.98	0.98	0.98	0.96	1.00												
IPOA/GAPKI Full stand (based on 136 palms per hectare)	0.95	0.98	0.99	0.98	0.98	0.98	0.97	0.98	0.96	0.96	0.98	0.98	0.97	0.98	0.98	0.98	0.98	0.97	0.99	1.00											
IPOA/GAPKI Full stand (based on 103 palms per hectare)	0.95	0.98	0.99	0.98	0.98	0.98	0.97	0.98	0.96	0.96	0.98	0.98	0.97	0.98	0.98	0.98	0.98	0.97	0.99	1.00	1.00										
IPOA/GAPKI - GAP plantation	0.94	0.98	0.99	0.98	0.98	0.98	0.97	0.98	0.97	0.98	0.98	0.98	0.98	0.98	0.97	0.97	0.98	0.98	0.99	0.99	0.99	1.00									
IPOA/GAPKI- Total	0.99	0.98	0.98	0.95	0.94	0.96	0.95	0.96	0.94	0.96	0.95	0.96	0.96	0.95	0.95	0.95	0.95	0.95	0.98	0.98	0.98	0.98	1.00								
IPOA/GAPKI - Tied	0.50	0.96	0.18	-1.00	-0.99	-0.63	-0.31	-0.75	-0.99	-0.89	-0.93	-0.91	-0.80	-0.72	-0.61	-1.00	-0.95	-1.00	0.76	0.96	0.96	####	0.56	1.00							
IPOA/GAPKI - industry full stand (136 palm/ha)	0.95	0.99	0.96	0.93	0.94	0.94	0.94	0.95	0.95	0.97	0.95	0.95	0.96	0.93	0.91	0.92	0.93	0.97	0.95	0.96	0.96	0.98	0.97	-0.90	1.00						
IPOA/GAPKI - industry full stand (103 palm/ha)	0.96	0.99	0.96	0.94	0.94	0.94	0.94	0.95	0.95	0.97	0.95	0.95	0.96	0.93	0.92	0.92	0.93	0.97	0.96	0.97	0.97	0.98	0.98	-0.96	1.00	1.00					
IPOA/GAPKI - Independent	0.98	0.97	0.98	0.95	0.95	0.96	0.96	0.96	0.94	0.96	0.95	0.96	0.96	0.96	0.95	0.95	0.95	0.96	0.98	0.98	0.98	0.98	1.00	0.34	0.98	0.98	1.00				
IPOA/GAPKI- GAP small holder	0.97	0.99	0.97	0.96	0.94	0.95	0.93	0.95	0.91	0.93	0.96	0.96	0.93	0.97	0.97	0.97	0.96	0.94	0.99	0.98	0.98	0.97	0.97	0.80	0.93	0.94	0.96	1.00			
IPOA/GAPKI - small holders average	0.45	0.47	0.86	0.81	0.85	0.86	0.88	0.86	0.90	0.89	0.84	0.83	0.88	0.81	0.79	0.79	0.83	0.88	0.82	0.86	0.86	0.87	0.88	0.73	0.92	0.91	0.89	0.76	1.00		
IPOA/GAPKI - smallholder yield	0.90	0.92	0.97	0.98	0.97	0.98	0.97	0.97	0.94	0.93	0.96	0.94	0.93	0.98	0.97	0.99	0.98	0.93	0.96	0.96	0.96	0.96	0.94	0.49	0.90	0.90	0.94	0.95	0.80	1.00	
MPOP-Small-holder	0.98	1.00	0.99	0.97	0.96	0.97	0.95	0.97	0.94	0.95	0.98	0.97	0.96	0.98	0.98	0.98	0.98	0.96	1.00	0.99	0.99	0.99	0.99	0.86	0.96	0.96	0.98	0.99	0.83	0.96	1.00

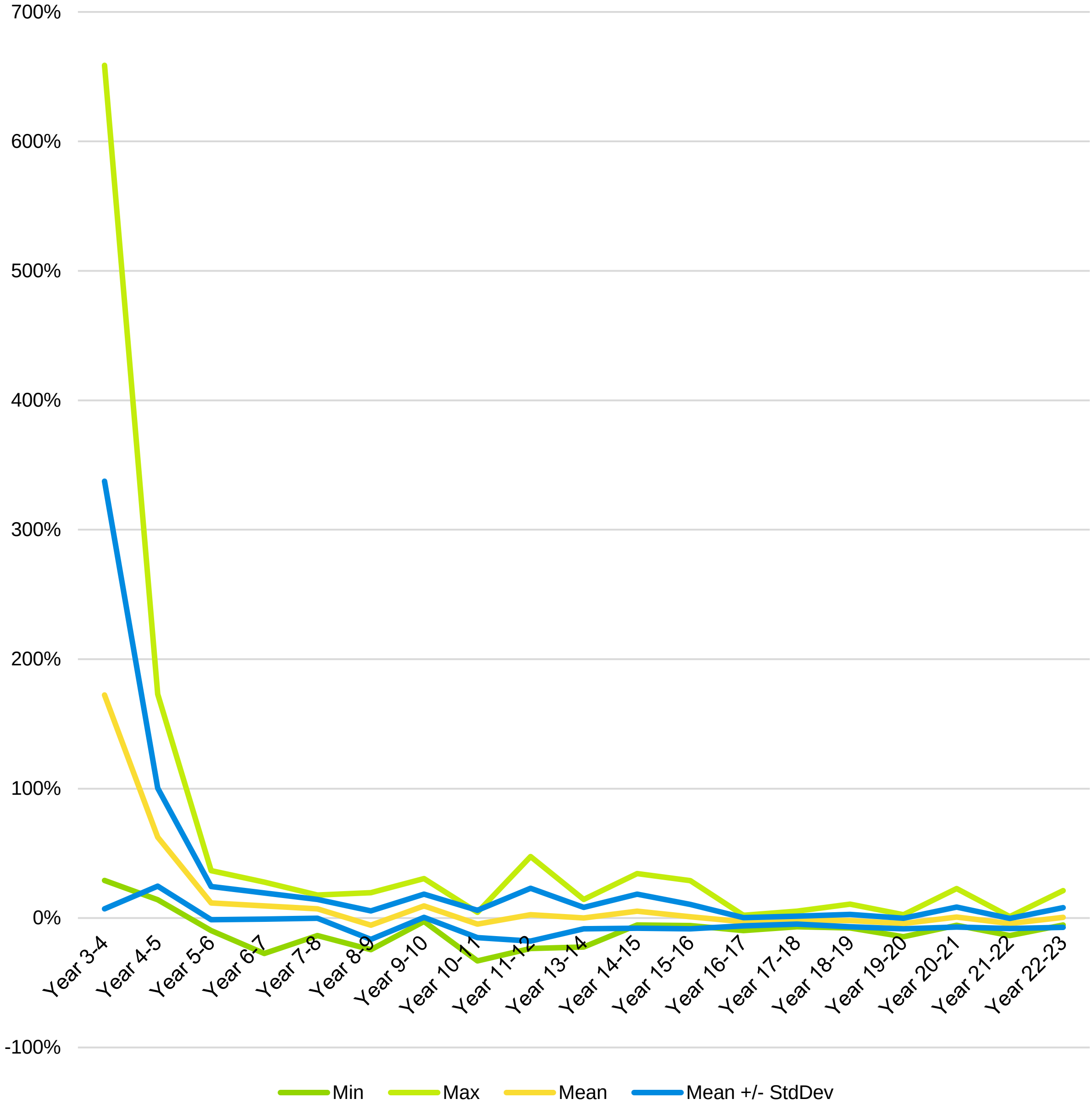
To analyse the 31 yield curves together, we calculated the minimum, maximum, mean and standard deviation for each year out of all the yield curves received. This was done for both the yield per hectare (Figure 3-2) and the growth rate (**Error! Reference source not found.**). This analysis shows that the mean and max yield curves have a similar shape, but the minimum yield – with datapoints coming mainly from a yield curve presented by a small farm – had a different shape, reaching maturity sooner and remaining at that (lower) level for most of its productive life.

Figure 3-2. Minimum, maximum and mean of all curves



The yield curves were adjusted to examine the yearly growth rates, and again to look at the minimum, maximum, mean and standard deviation (**Error! Reference source not found.**). This analysis shows there is a significant difference in the first six years of the life of a palm tree (most palms start fruiting at year 3), but from year 6 onwards, the growth rates from the different yield curves converge, resulting in standard deviations of below 10% for the remaining lifetime of the palm trees.

Figure 3-3. Minimum, maximum and mean yearly growth rate

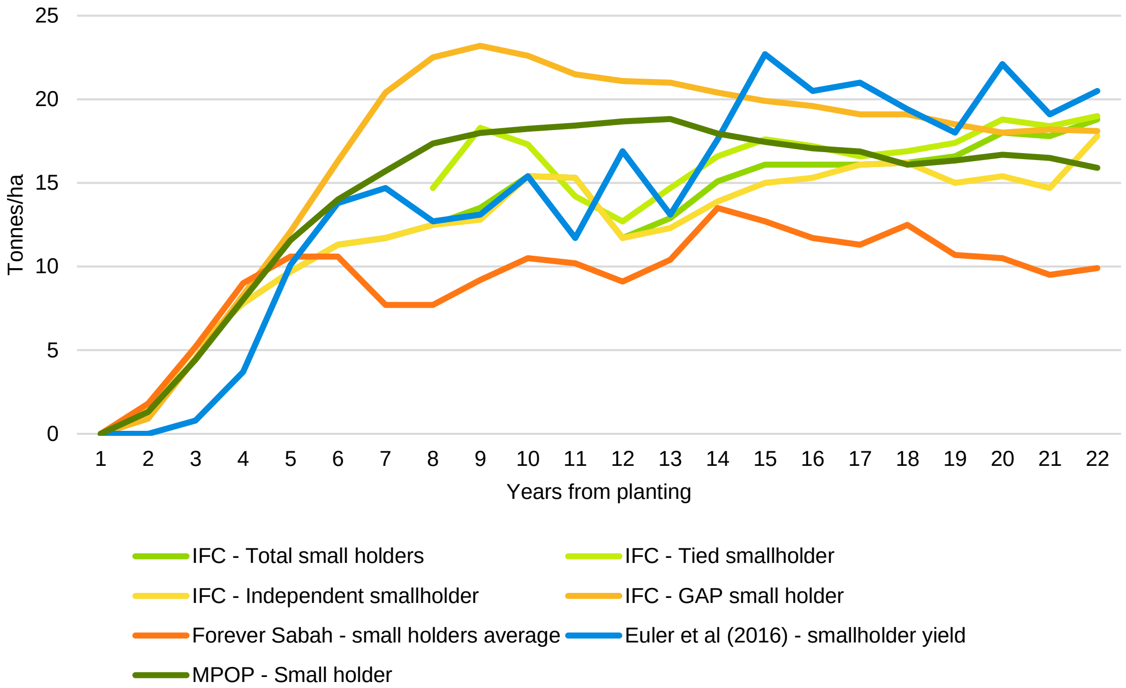


3.2 Analysis of the small holder data

The term ‘small holders’ in this paper is used when the original research paper labelled a farm as a small holder. This does not necessarily mean that the farm was a small holder in line with the definition in the Delegated Regulation 2019/807.[1]

When specifically looking at the small holder yield curves, the trendlines are more volatile for the different types of small holders (Figure 3-4) below. The data represents both small holders associated with schemes and plantations, and independent small holders. These studies conducted with small holders were located in Indonesia and Malaysia.

Figure 3-4. Small holder yield curves



The paper from IPOA/GAPKI included data from an International Finance Corporation (IFC) report, which distinguishes between ‘tied’ small holders that are contracted to a plantation company and ‘independent’ small holders that were not bound to a plantation company. The IFC report included 1069 small holders in Sumatra and Kalimantan (Indonesia) with 1509 plots in total, of which 487 were tied and 1022 independent. Furthermore, they compiled a Good Agricultural Practice (GAP) small holder curve to provide a benchmark. In their findings they reported a positive correlation between sustainability practices and productivity for the small holders’ yield.

[1] Article 2(9) ‘small holders’ means farmers who conduct independently an agricultural activity on a holding with an agricultural area of less than 2 hectares for which they hold ownership, tenure rights or any equivalent title granting them control over land, and who are not employed by a company, except for a cooperative of which they are members with other small holders, provided that such a cooperative is not controlled by a third party

Furthermore, IPOA/GAPKI submitted data from Euler et al. (2016), a study exploring small holder yield gaps, which consisted of a questionnaire sent to small holders in selected villages in the Jambi province in Sumatra. This study included 236 oil palm farmers and 363 oil palm plots, of which 170 independent small holders cultivating 241 plots and 66 supported farmers with 122 plots. The supported farmers in this study were either aided by a government programme or tied to a farmer group. The study found that there were large gaps between the potential yield and the actual yield of the small holders, mainly due to management practices such as fertilization and harvest frequencies. The data in Figure 3-4 is the actual yield achieved by the small holders surveyed. The paper also calculates a theoretical "exploitable" and maximum "potential" yield for the small holders in this region. Although these curves represent the expected shape of a palm yield curve, they were not included in this small holder analysis as they represent a modelled yield.

The last data included in the IPOA/GAPKI submission regarding small holders was the study done by Forever Sabah, on 134 oil palm small holders in Sabah, Malaysia. The villages this study focussed on were 20 isolated villages with lower yields than more often studied small holders that are affiliated with settlement schemes. The main contributor to the lower yields were shortcomings in management practices. The other data on Malaysian small holders were sent by MPOB, however it was not specified how many small holders were included in the study or the type of small holders.

The correlations between the yield curves of the small holders are strong (r>0.75), albeit lower than the results from all the yield curves, see Figure 3-5. The small holders that were tied to an estate did not have a strong correlation with the other small holder data.

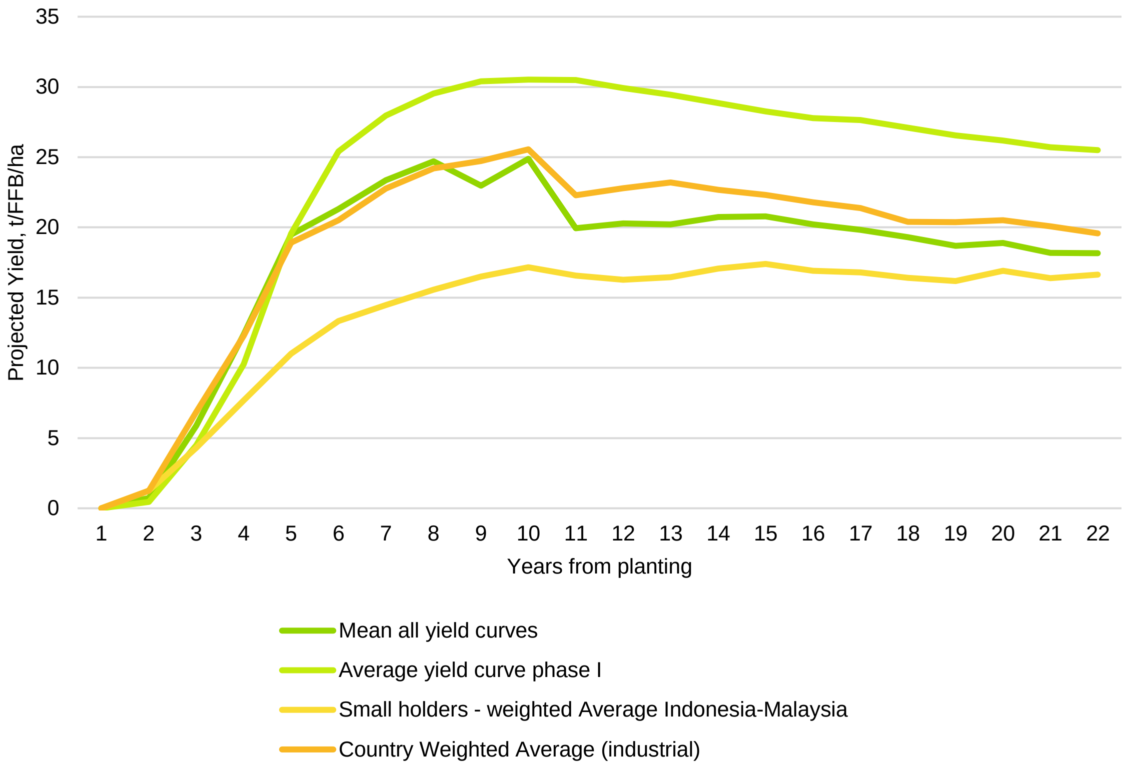
Figure 3-5. Correlation of the small holder curves

IFC - Total small holders	1.00						
IFC - Tied smallholder	0.79	1.00					
IFC - Independent smallholder	0.99	0.62	1.00				
IFC - (GAP) small holder	0.85	-0.48	0.88	1.00			
Euler et al (2016) - Small holders average	0.85	0.25	0.87	0.78	1.00		
Forever Sabah - Small holder yield	0.93	0.56	0.92	0.81	0.81	1.00	
MPOP - Small holder	0.89	-0.67	0.91	0.99	0.83	0.85	1.00

3.3 Analysis of the combined yield curves

To combine the yield curves for comparison, the weighted averages per type of plantation (small holder or industrial) were distinguished and then compiled per country, see Figure 3-6 below. The standard yield curve from Phase I of the low ILUC pilots was included for further analysis as well as the mean of all yield curves. The figure below shows that the curves follow a similar path, despite some deviations between year 7 and year 11 in the mean of all yield curves.

Figure 3-6. Combined yield curves



The correlation matrix below (Figure 3-7) demonstrates that the shapes of the combined curves are highly correlated (all R>0.9) and behave in a similar manner, despite their magnitude differences. The yield curves collected and analysed were highly correlated (R>0.98) with the "standard yield curve" developed for the Phase 1 low ILUC pilots. This suggests the existing "standard yield curve" is a good *shape* to use to determine the baseline yield from a plantation, confirmed by the data sent in.

Figure 3-7. Correlation of the combined yield curves

Mean all yield curves	1.00			
Average yield curve phase I	0.96	1.00		
Small holders - weighted Average Indonesia-Malay	0.92	0.98	1.00	
Country Weighted Average (industrial)	0.99	0.98	0.96	1.00

4. Recommendation

The 31 yield curves were analysed, and confirmed through a correlation matrix that the normalised standard yield curve from Phase I of the low ILUC pilots is appropriate to use to determine the shape of a dynamic yield baseline curve. We recommend that the Commission uses this standard yield curve in the methodology to certify biomass from oil palm plantations included in the **Draft Implementing Act** on "rules to verify sustainability and greenhouse gas emissions saving criteria and low indirect land-use change-risk criteria". The standard yield curve from Phase 1 is normalised, to make it applicable for different yield starting points, see Figure 4-1, Table 4-1 and Table 4-2.

The analysis of the yield growth rates shows that the yield curve shape varies the most in the first 6 years from planting. However, these years are low yielding in general and hence, the risk of a farmer claiming substantial volumes of additional biomass in those years due to a dynamic yield baseline advantage is low. We recommend to the Commission to allow farmers using replanting as their additionality measure, to delay the start of their 10 year low ILUC validity period for up to 5 years, in the same way that it is suggested to allow all palm plantations to delay the start of their validity period by up to 2 years to recognise that it can take up to 2 years to see the effect of an additionality measure on a perennial crop such as palm.

After 25 years, the yield of an oil palm tree would be expected to continue to decline. However, as the typical lifetime of an oil palm tree is around 25 years, there is a lack of data to support the magnitude of the decline after 25 years. Therefore, if the dynamic yield baseline is required to extend beyond 25 years, we recommend that a conservative approach is taken, to assume that the yield curve would remain at the 25 year level.

Figure 4-1. Normalised standard yield curve oil palm

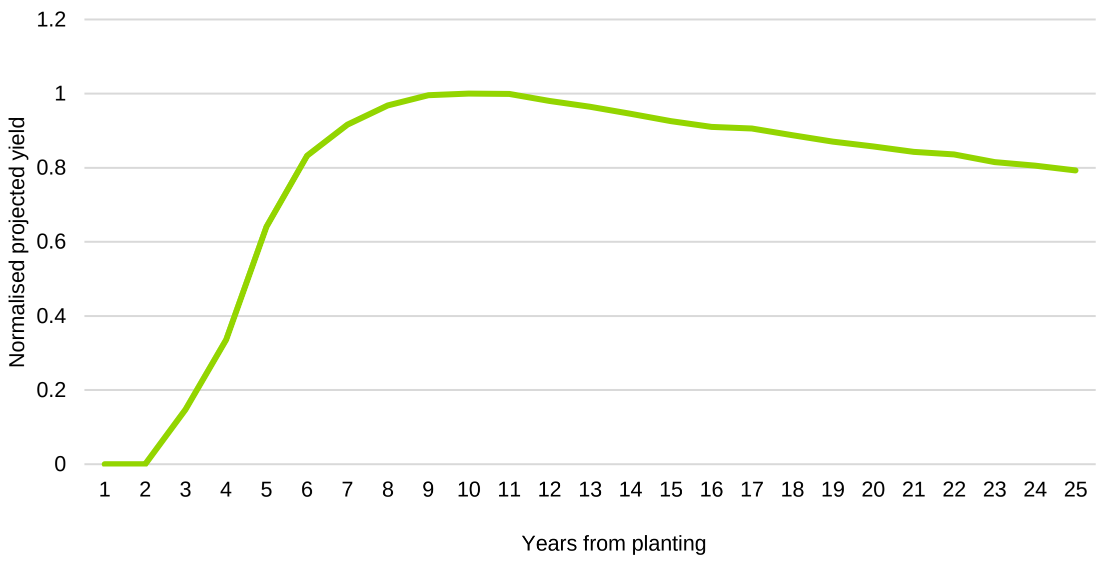


Table 4-1. Standard yield curve oil palm: data

Years after planting	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Normalised yield	0	0	0.147	0.336	0.641	0.833	0.916	0.968	0.996	1	0.999	0.980	0.965
Years after planting	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26+**
Normalised yield	0.945	0.926	0.910	0.906	0.888	0.870	0.858	0.842	0.836	0.815	0.806	0.793	0.793

Table 4-2. Standard yield curve oil palm: growth rate

Years after planting	**1 to 3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Annual percentage change	-	128.0%	90.6%	30.0%	10.0%	5.6%	2.9%	0.4%	-0.1%	-1.9%	-1.6%	-2.0%
Years after planting	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26+**
Annual percentage change	-2.1%	-1.7%	-0.5%	-1.9%	-2.0%	-1.4%	-1.8%	-0.8%	-2.5%	-1.1%	-1.6%	0%

Appendix A. References

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