Response to Referee #2

Oil palm has received substantial mapping efforts, but up-to-date and accurate maps detailing both the extent and age of oil palm plantations are essential for monitoring impacts and informing concurrent debates. This study achieved global 10-meter resolution mapping of oil palm and confirmed plantation years from 1990 to 2021. Overall, the manuscript is well-written, but there are still areas that could be improved:

Response #1: Thank you for the positive assessment of the quality of the manuscript. We have now addressed your comments. Please see below a detailed response to all the comments.

1. In line 22, "We found oil palm plantations covering a total mapped area of 23.98 Mha," while in line 38, "30 Mha in 2022" is mentioned. It is recommended to explain the differences between these two data points in the subsequent discussions.

Response #2: Thank you for noticing this. We have now added a new figure that compares our oil palm area estimates with the statistics reported by FAO and USDA at the country level. We present these results and explain the differences with FAO and USDA statistics in the Results section (lines 271):

"*Our area estimates also align with national statistics for oil palm harvested areas reported by FAO and USDA (Figure A7). The largest discrepancy occurred in Nigeria, where we estimated 0.38 ± 0.13 Mha, compared to the 4.86 Mha and 3.00 Mha reported by FAO and FAS-USDA, respectively. This difference may result from the inclusion of semi-wild oil palms in the FAO and USDA statistics. Semi-wild oil palm, common in West Africa, is mostly omitted in our oil palm layer as these palms typically grow scattered across the landscape, making them difficult to map accurately with Sentinel-1.*"

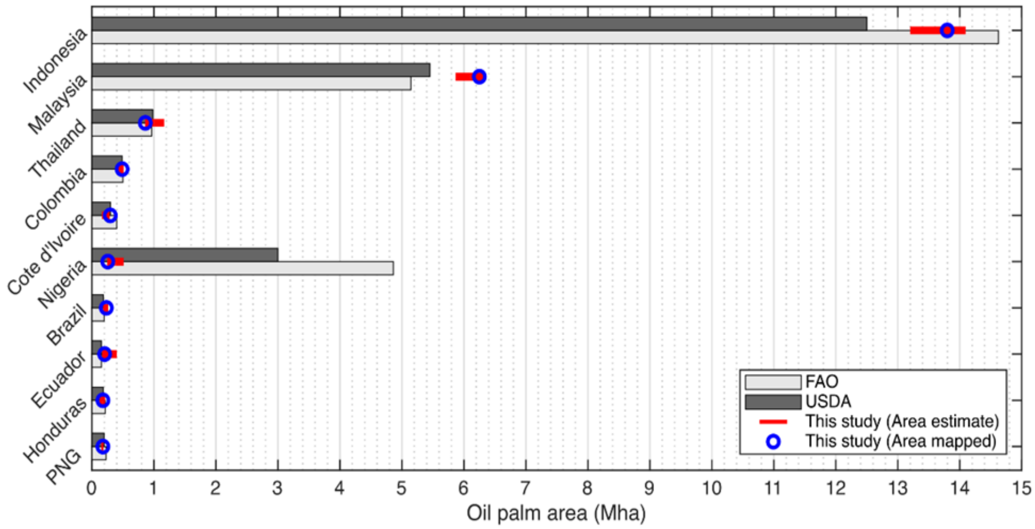

Figure A7: Oil palm area for the 10 highest producing countries according to the dataset presented in this study. The bars depict the oil palm area for 2021 according to official statistics (FAO and USDA), the blue circles represent the mapped oil palm area using the deep learning model, and the red line shows our oil palm area estimate with a 95% confidence interval.

The revised Discussion section also mentions the differences between our oil palm area estimates and the statistics from FAO and USDA (line 373):

"*Subsistence-level palm oil in Africa could add millions of hectares; areas of these unaccounted traditional oil palm plantations were estimated to be 6.66 Mha in Africa in 2013 (Carrere, 2010). The presence of unaccounted semi-wild oil palms likely explains the ~4.5 Mha discrepancy between our area estimates and FAO's oil palm area in Nigeria, as well as the difference between our global oil palm mapped area (23.98 Mha) and the FAO's reported global harvested area (29.62 Mha) for 2021. Despite this discrepancy, the comparison with official statistics supports the validity of our oil palm extent layer, as our area estimates closely align with the FAO and USDA-reported oil palm areas in other countries.*"

2. It is recommended to add descriptions for "closed-canopy industrial oil palm" and "closed-canopy smallholder oil palm". Additionally, using comparative charts to illustrate the differences between these land cover categories both qualitatively and quantitatively is advised, enabling readers to better understand the distinctions between these categories."

Response #3: Thank you for the suggestion. Initially, we omitted the description because this was explained in a previous study, but we agree with the reviewer that this current paper should also differentiate between the two classes. We have now added the description of "closed-canopy industrial oil palm" and "closed-canopy smallholder oil palm" in line 115:

"*In this study, we adopted the definitions of industrial and smallholder oil palm plantations from Descals et al., 2021. Industrial plantations typically span several thousand hectares, with uniform palm age and well-defined, often rectangular boundaries (Fig. A1). These plantations feature dense networks of roads or canals, designed during initial development of the plantation to optimize harvesting. On flat terrain, the roads are arranged in a rectilinear grid, while on hilly areas, they tend to curve. In contrast, smallholder plantations are usually less than 25 ha, though this threshold varies by country. Compared to industrial plantations, smallholder plantations are less organized and have more diverse palm ages, forming a mosaic landscape mixed with other land uses. Large clusters of smallholder plantations have sparser trail networks than industrial ones.*"

We have also added Fig. A1, which illustrates the differences between these two oil palm classes.

Figure A1: Sentinel-2 true color composite depicting industrial and smallholder plantations in a region in Riau province, Indonesia.

3. In line 92, it is suggested to briefly explain the data organization format, whether temporal information was used, whether monthly synthesis was employed, and if data stacking akin to multi-channel image data was implemented when inputting into DeepLabv3+.

Response #4: The revised Methods section now clarifies that only the annual aggregates were used, and no temporal information was extracted from the Sentinel-1 time series (line 97 in Section 2.2.1 Sentinel-1 compositing).

"*The daily Sentinel-1 images were aggregated annually from 2016 to 2021 using the median for ascending and descending orbits separately. Temporal information, such as seasonal variations in spectral backscatter, was not extracted from the Sentinel-1 time series.*"

We also clarified how the Sentinel-1 data was inputted into the deep learning model (lines 127 in Section 2.2.2 Deep learning classification):

"*Since the original model required an input image with three channels, we stacked the VV and VH spectral images along with a third image filled with zeros. In this way, we could use the existing deep learning model architecture without modification.*"

4. Due to regional distribution differences, it is recommended to increase the number of validation samples to better demonstrate the effectiveness of the method.

Response #5: Thanks for the recommendation. We have now included more sample points. Specifically, we have doubled the number of points for the classes 'smallholder oil palm' and ‘industrial oil palm’, respectively, using a stratified random sampling. All accuracy metrics have been updated accordingly. The accuracy metrics and area estimates in the revised version do not differ significantly from the submitted version.

5. In line 119, "manually digitized false positives, and subsequently reclassified these commission errors as class ‘other’", was it first masking and then checking all categories, followed by manually correcting misclassified information?

Response #6: Thank you for noticing this. It was first masking and then manual correction. This has now been clarified in line 133:

“*[...], we applied two amendments to reduce the occurrence of false positives. First, we masked oil palm pixels that overlapped with the classes ’cropland’, ‘built-up’, ‘water bodies’, ‘herbaceous wetland’, and ‘mangrove’ in the 10-m ESA WorldCover map v200 (Zanaga et al., 2022), given that oil palm is unlikely to be present in these land cover types. Second, we inspected the annual oil palm classification using high-resolution satellite imagery from Google Maps to remove any remaining false positives. We visually identified these false positives and reclassified them as the class 'other'.*”

6. In the figure on line 179, the author uses NDWI to determine the planting year and provides an example. It is recommended to explain the rationale for using NDWI.

Response #7: Thanks for the recommendation. We have now included a rationale for using NDWI (line 197):

“*We selected NDWI because it is less noisy than indices relying on visible spectrum bands. NDWI uses SWIR and NIR bands, which can penetrate thin clouds and are less affected by atmospheric conditions like water vapor, which is typically high in the tropics.*”

7. In line 228, "only represent the regions where oil palm was found worldwide in this study", did the study detect globally and then filter out these current regions, or was it based on previous research?

Response #8: The oil palm classification was mostly applied to regions delineated in a previous study, except few regions identified in this current study. We have now added this information in the main text (line 148):

“*These 100 x 100 km grid cells represent the regions where oil palm was identified in the 2019 version, presented in Descals et al., 2021, as well as grid cells where oil palm was omitted in the previous version (Fig. A4). The new regions mainly include an oil palm hotspot in the state of Andhra Pradesh in India, industrial plantations in the Congo basin, and scattered plantations in Thailand and Central and South America.*”

8. In Section 3.1, it is suggested to first present the global oil palm distribution map obtained in this study.

Response #9: Thank you for the suggestion. The Results section now starts with a figure depicting the global oil palm distribution map (Fig. 3). Please note that the 10-meter resolution map is too detailed and data-heavy for global display. For this reason, we included a global density map with lower resolution for efficient visualization and communication of the results.

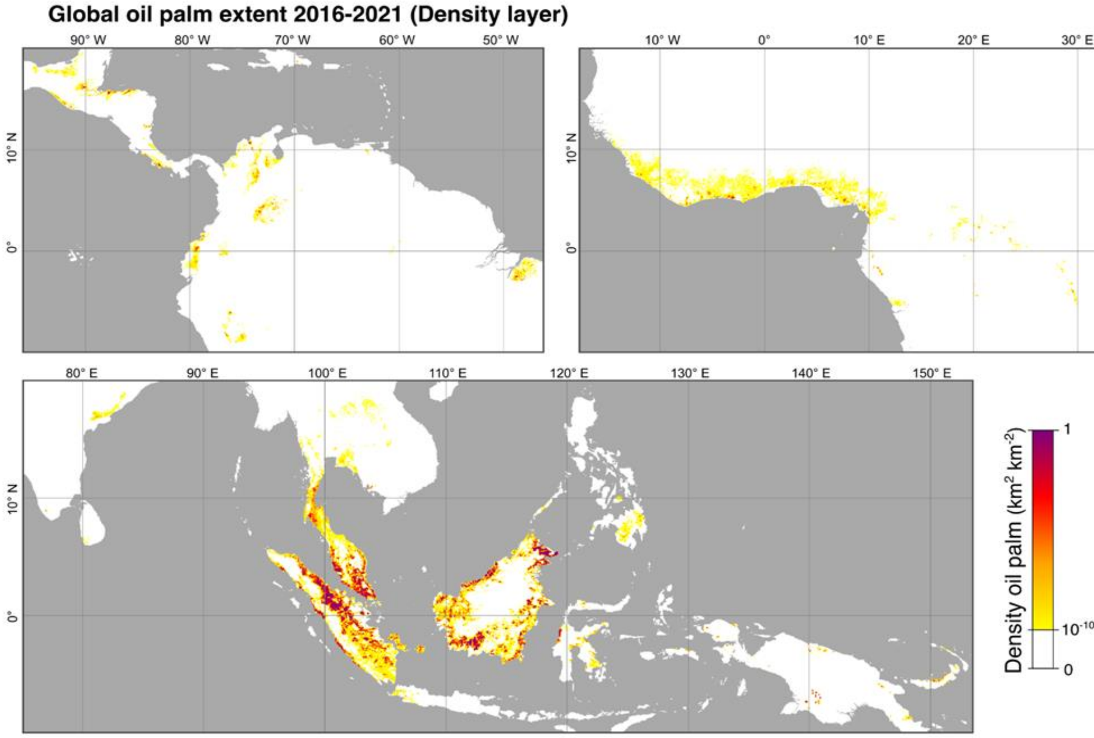

Figure 3: Global oil palm density map showing the density of oil palm at a 5 km resolution, derived from the 10 m global oil palm layer for the period 2016-2021.

9. In Section 3.3, consider increasing the number of sample points to assess validity further.

Response #10: We have now included more sample points. Specifically, we have doubled the number of points for the classes 'smallholder oil palm' and 'industrial oil palm', respectively, using a stratified random sampling. All accuracy metrics have been updated accordingly. The accuracy metrics and area estimates in the revised version do not differ significantly from the submitted version.

It is recommended to add comparative results with previous studies in Section 3.3 to visually demonstrate the effectiveness of the current research.

Response #11: We now compared our oil palm extent with official statistics from the FAO and USDA and with a previous study in Indonesia (Gaveau et al., 2022). Additionally, we assessed the improvements in this study over the previous version (Descals et al., 2021). For oil palm age, we validated our dataset using field measurements and inspection of Landsat time series. We did not compare our results with oil palm age layers from other studies for two reasons: (1) Other studies define the planting year differently. For example, Gaveau et al. (2022) defines the planting year as the year of conversion to oil palm, whereas we include oil palm rotations as the planting year. These differences introduce inconsistencies in the comparison, potentially undermining the accuracy of our age layer. (2) No reliable global reference dataset exists for oil palm age; other studies contain errors, making comparisons likely to produce misleading results. This is the reason why we produced a validation dataset extracted from Landsat to directly evaluate the accuracy of the planting year layer.