Response to comments

Paper #: essd-2019-137
Title: Annual oil palm plantation maps in Malaysia and Indonesia from 2001 to 2016
Journal: Earth System Science Data

Reviewer #2:

General Comments:

Comment #1

The manuscript is addressing the annual oil palm mapping in Malaysia and Indonesia from 2001 – 2016 by using PALSAR/PALSAR-2 imagery, and fill the PALSAR data gap (2011-2014) by using the MODIS data and the BFAST method. This study is well designed and the paper is very well written. But some parts should be further improved before its consideration for publication.

Response #1
We thank the reviewer for the comments and suggestions. Please see the detailed point-by-point responses below.

Specific Comments:

Comment #1

Effects of stand age. How the stand age could affect the identification of the oil palm plantation as well as the robustness of the BFAST approach? This study claims that the maps include young oil palm trees and smallholder oil palm plantations. What strategies have been considered to make sure the inclusion of young trees and smallholder plantations?

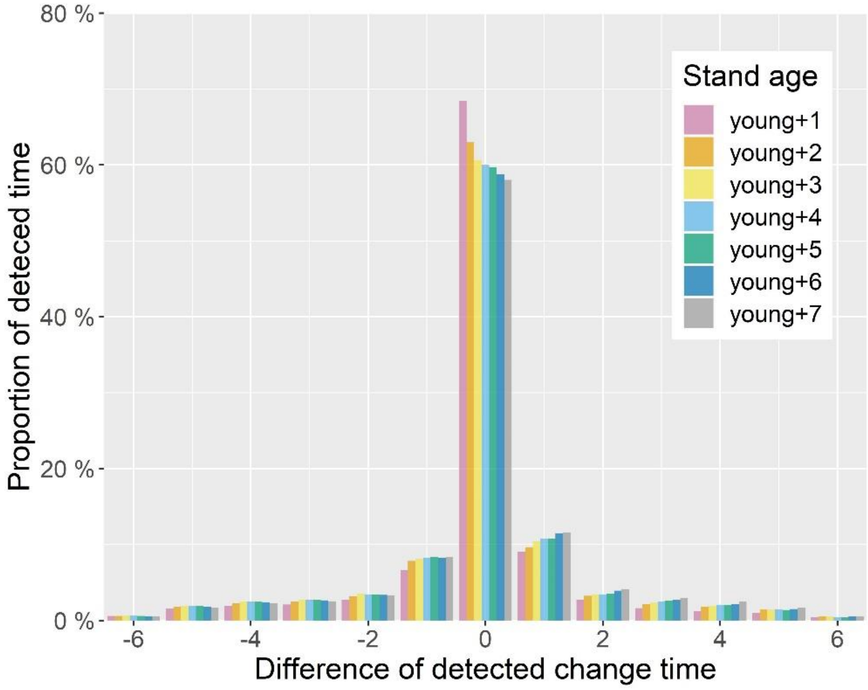
Response #1

We did a test to show the robustness of the algorithm at different age of oil palm plantation. Normally, the young oil palm (0-3 years old) was transplanted after the forest clearance, so the BFAST approach was applied to detect the conversion from forest to young oil palm at very young stage (the original planted age is referred as *young*). Here we manually moved forward the time-series NDVI after the break detected time to include older stand age and then re-applied the BFAST algorithm. For example, if the change year was detected at 2005, the subsequent 2006-2008 NDVI curves were replaced by 2007-2009 ones to show the effect of a one-year shift on the stand age (Here the age is referred as: *young*+1, if the 2008-2010 was used for two-year effect, the age is referred as *young*+2, etc.). Further, the break time detected by the new NDVI curves were compared with that of the original curves (differences of detected change time=break $year_{new}$ -break $year_{old}$). The differences among the different stand ages represented the effect of tree age and inform us about the algorithm's robustness. We applied the test for all the change pixels and **Figure S6** below shows the distribution of the differences between the new and original break time for all the results during 2000-2007. According to the result, the differences of detected change time were mostly concentrated on the values around zero (which mean there is no differences compared to the original detected change time) in all stand ages. In total, 79.69% (average result of the 7 stand ages) of the detected times show the agreement with the original result (76.73% of the detected years matched the original result while the rest were within one-year interval, **Figure S6**, reproduced below). This indicates the robustness of the algorithm under different stand ages and cloud conditions. With the increase of the stand age, the differences of the detected change time were increased (a 6.19% decrease of the agreement proportion presented if the tree is 6 years older than the other trees). However, the distribution pattern among the different stand ages is similar.
In the PALSAR mapping procedure, the training sample set used in the random forest classifier contains both young and mature oil palm samples (it could be identified by the canopy shape using very high-

resolution images from Google Earth in interpretation) therefore the outputs of the machine learning algorithm included young plantations. We will add these points in the revised manuscript.

The smallholder oil palm plantations were defined as: " oil palm smallholders is defined as 50 hectares or less of cultivated land producing palm oil controlled by smallholder farmers (the definition used by the RSPO) with an average of 2 ha (World Bank, 2010) " (Section 1, Lines 102-103), whereas our 1-ha mapping unit is able to depict some of the smallholder plantations between 1-50 ha.

Figure S6 Effect of stand age. The values in x-axis is the difference between the detected change years using the replaced MODIS NDVI fragments (refer to older stand age) and the original NDVI curves (refer to young age). Negative values in x-axis refer to the detected change year using the older stand age is earlier than the original detected change year.



Comment #2

Effects of multiple data resolutions. Why does the resolution of 100m perform better to estimate oil palm planting area, not the 50m or other resolution? Is resolution of 100m sufficient to depict the smallholder details? Which resample technique did you use to resample 25-m PALSAR to 100-m? How did you integrate your 100-m oil palm maps with the 250-m land cover change maps?

Response #2

PALSAR data has a lot noise which may conceal the true land surface information. Filter analysis (Enhanced Frost, Enhanced Lee, Frost and Gamma filter) was compared with the resampling method at different resolution (25m, 50m, 100m, 250m, 500m, 1000m) in Cheng et al., (2018). The nearest neighborhood resampling at 100-m resolution showed the best mapping accuracy compared to the other filter methods and spatial resolution. Thus, we chose 100-m as the trade-off resolution of retaining the most land surface information as well as reducing noise.
Smallholders oil palm plantations are defined on an average of 2 ha and ranged up to 50 ha which is hold by family-based enterprises (Vermeulen and Goad, 2006; Lee et al., 2014 and World Bank 2010). Our results are able to capture part of the small oil palm plantations which are larger than 1 ha (100 m ×100 m).
We first identified the change area and “from-to” types in the 100-m land cover change maps. Then the MODIS product was resized to the same resolution as of 100-m land cover maps as described in **Section**

2.4.1 Lines 222-224: "All the MODIS images were projected from its original sinusoidal projection to a geographic grid with a WGS 1984 spheroid and resized to 100 m to match the resolution of the oil palm maps using the nearest neighbor resampling approach.)". Next, "We then sought the exact change year within the intervals in the next step (Section 2.4.2) using temporal NDVI files extracted from each change pixel. "as described in **Section 2.4.1, Lines 230-231**. Finally, "Change detection analysis was conducted in the change pixels derived from the last step to identify the exact change time within the two periods (2011-2014 and 2001-2006) based on the time-series MODIS NDVI from 2010 to 2015 and 2000 to 2007, respectively. " **(Section 2.4.1, Lines 238-240)**.

Reference:

Cheng, Y., Yu, L., Xu, Y., Lu, H., Cracknell, A. P., Kanniah, K., and Gong, P.: Mapping oil palm extent in Malaysia using ALOS-2 PALSAR-2 data, Int. J. Remote Sens., 39, 432-452, 2018.

Vermeulen, S., & Goad, N. (2006). Towards better practice in smallholder palm oil production. Iied.

Lee, J. S. H., Abood, S., Ghazoul, J., Barus, B., Obidzinski, K., & Koh, L. P. (2014). Environmental impacts of large-scale oil palm enterprises exceed that of smallholdings in Indonesia. Conservation letters, 7(1), 25-33.

World Bank. (2010) Improving the livelihoods of palm oil smallholders: the role of the private sector. International Finance Corporation, World Bank Group, Washington, DC, USA

Comment #3

How many types of land cover were got with the RF classification? Is the multi-class classification consistent with Table 1? Or the binary classification (oil palm; non-oil palm)?

Response #3

We got 4 land cover types (water, other vegetation, oil palm and others) from the RF classification. The result is consistent with multi-class classification. Here we presented the oil palm accuracy in the multi-class classification. As for the binary classification results, the average score of oil palm is 0.87/0.74 while the non-oil palm is 0.98/0.98 in Malaysia / Indonesia, respectively. For the newly added Indonesia validation sample set, we only have oil palm and non-oil palm types as described in **Section 2.5, Lines 321-322**: "This sample set contains 7663 samples in total (601 were oil palms and the rest were non-oil palm types) during 2010 to 2016."

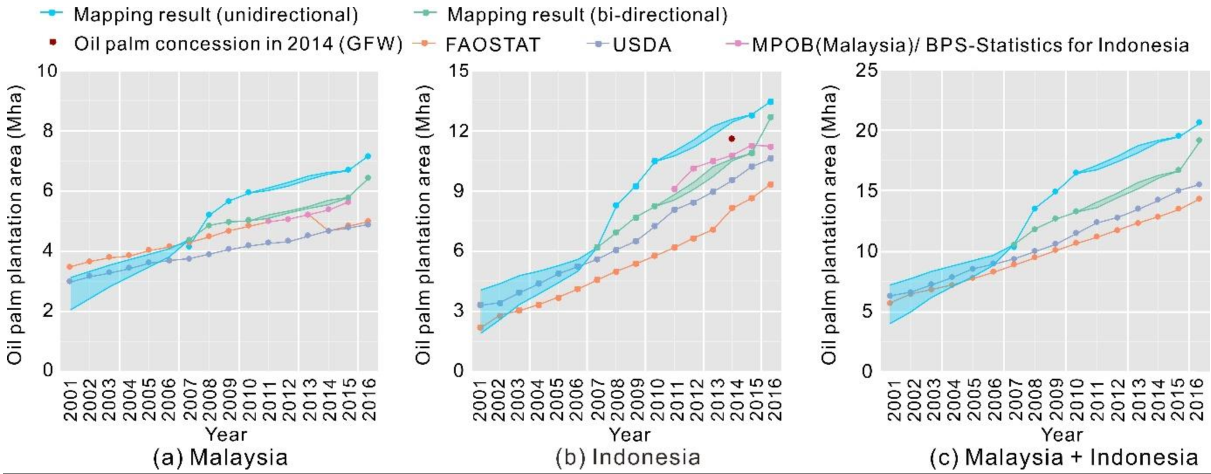
Comment #4

You provided two version of oil palm datasets: one considers the oil palm expansion (unidirectional change) and the other one considers oil palm shrinkage (bi-directional change). Which version is more consistent with statistics? Which version is more accurate based on your validation samples? In Figure 5, the oil palm change in 2001-2007 is also unidirectional, thus the color of line might be blue, not green.

Response #4

The bi-directional version is more consistent with statistics. According to the validation sample, the unidirectional version is however more accurate (with an average 0.034 increase of *F*-score for each year). We changed the color in **Figure 5** (reproduced below) according to the suggestions.

Figure 5: Comparison of the annual oil palm plantation area among FAO and USDA statistics, MPOB records for Malaysia, BPS-Statistics and oil palm concessions from GFW for Indonesia and our mapping results in a) Malaysia, b) Indonesia and c) Malaysia and Indonesia from 2001 to 2016. The blue lines represent the gross gain (unidirectional expansion) while the green lines show the net changes of oil palm from 2007 to 2016. The shaded area within the two boundary lines are the uncertainty range of the oil palm area. The upper boundary lines represent the upper limit area of oil palm within the two periods (2011-2014 and 2001-2006), whereas the lower boundary lines are the lower limit according to our results. Note that during the gap between the two periods, no uncertainty could be derived, which does not mean that the uncertainty was small.



Comment #5

If there were more than one change time in 2011-2014 or 2001-2006, how did you allocate land cover types?

Response #5

We supposed more possibility of one-time change during such a short period other than the multi-time changes. For example, there is a long lead time (at least 2-4 years) between planting and productive harvest of oil palm and it is unlikely to do planting-cutting-replanting very often in such a short period, as described in **Section 2.4.1, Lines 231-232**: "Frequent changes such as two or three shifts during the gap years were assumed to be of low probability and thus not considered in this study." Therefore, we only consider the one-time change during the two time periods. We added the uncertainty caused by multiple changes in **Section 4.1, Lines 504-506**: "However, multiple changes may occur in the deforestation area when the logging activity is applied first and followed by the replantation of oil palm several years later.