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 #1:

General Comments:

Comment #1

The article presented the first annual oil palm plantation maps in Malaysia and Indonesia and demonstrate the accuracy of the maps through various comparisons with existing statistic dataset and regional maps. It's an interesting paper that exhibits the efficiency of fusing optical and radar data in over coming data gaps to produce consistent annual maps. However, there are quite a few details in the abstract and introduction session that need to be checked. Some statement are lacking adequate references. More detail needs to be given on the methods, especially validation approach. Some of the conclusions in the discussion section need to be backed up, either by reference or by results. I'm not very convinced by the results due to limited information was given to the independence validation approach.

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

Specific Comments:

Comment #1

Abstract/Introduction:
Line 12: The land convention to oil palm plantations not always lead to deforestation.

Response #1

Oil palm conversion takes places not only in forest but also agroforests, agricultural fallows, bare lands and etc. So we changed the original sentence to "The land conversion to oil palm plantations poses risks to deforestation (50% of the oil palm was taken from forest during 1990-2005, Koh and Wilcove, 2008), loss of biodiversity, and greenhouse gas emission over the past decades." **(Abstract, Lines 12-14)**.

Comment #2

Line 26: Current discussion is not strong enough to support the conclusion that the higher trend in this study is due to the inclusive of smallholder farmers. (more comments in the Results part, section 3.3)

Response #2

We totally agree with this. The inclusive of smallholder farmers is one of the potential reasons of the higher trend in this study. We rewrote the conclusions and excluded it in the abstract **(Abstract, Lines 26-28)**: "The higher trends from our dataset are consistent with those from the national inventories with limited annual average difference in Malaysia (0.2 M ha) and Indonesia (-0.17 M ha)." And we also discussed more possible reasons in the Result and discussion part (Please see the reply to comment#19).

Comment #3

Line 36: Corley, 2009- any more recent ref to support the expected growing rate from 2003?

Response #3

We updated the growing rate of oil palm fruit production in Malaysia and Indonesia to 2017 according to FAO statistics and added a new reference projecting a considerable expansion of oil palm cultivation worldwide in the future in **Section 1, Lines 35-37** :"According to the Food and Agriculture Organization (FAO), Malaysia and Indonesia account for 81.90% of the global oil palm fruit production in 2017, an increase by 179.72% from 2000 to 2017 (see http://faostat.fao.org) that is projected to continue in the future (Murphy, 2014). "

Reference:

Murphy, D. J. (2014). The future of oil palm as a major global crop: opportunities and challenges. J Oil Palm Res, 26(1), 1-24.

Comment #4

Line 38:"forest cover dropped from 76% to 9% since 1990 in Malaysia and Indonesia". Please double check these numbers, and cross reference with other sources.

Response #4

Sorry for the mistake. The peat swamp forest dropped from 76% to **2**9% since 1990 in Malaysia and Indonesia according to the reference. We also added references to show the deforestation caused by oil palm expansion on **Section 1 Lines 38-41**:" In Malaysia and Indonesia, more than 50% of the oil palm plantation was converted from forest during 1990-2005 (Koh and Wilcove, 2008) and industrial plantations dominated by oil palm (72.5% of all plantations) caused a 60% decrease of peatland forest from 2007 to 2015 (Miettinen et al., 2016)."

Comment #5

Line 43: There are quite a few existing dataset/report that are providing continuous information about the expansion of oil palm in Indonesia and Malaysia. E.g. https://theicct.org/sites/default/files/publications/ICCT_palm- expansion_Feb2012.pdf

Response #5

We thank the reviewer for this information. We added the references of the continuous mapping of oil palm on **Section 1, Lines 50-52**: "The continuous mapping of oil palm on peatland in 1990, 2000, 2007 and 2010 described the dynamic change of oil palm on peat during the past 30 years (Miettinen et al., 2012)." Here we also modified the text from continuous to annual mapping in **Section 1 Line 45**: " However, annual information on the expansion of oil palm plantations is poorly documented in Malaysia and Indonesia."

Comment #6

Line 59: There are quite a lot of Machine learning or Deep Learning based methods for automatic identification of oil palms.

Response #6

We added the recent deep learning based automatic identification references here as suggested on **Section 1, Line 63-66**: "3) interpretation methods from manual to semi- and fully automatic identification (Baklanov et al., 2018; Cheng et al., 2019; Li et al., 2017a; Mubin et al., 2019; Ordway et al., 2019), 4) products going from oil palm land cover maps to more detailed datasets on plantation structure, e.g. tree counting (Li et al., 2019; Cheang et al., 2017)."

Reference:

Baklanov, A., Khachay, M., and Pasynkov, M.: Application of fully convolutional neural networks to mapping industrial oil palm plantations, International Conference on Analysis of Images, Social Networks and Texts, 2018, 155-167,

Cheang, E. K., Cheang, T. K., and Tay, Y. H. J. a. p. a.: Using convolutional neural networks to count palm trees in satellite images, 2017.
Li, W., Fu, H., Yu, L., and Cracknell, A. J. R. S.: Deep learning based oil palm tree detection and counting for high-resolution remote sensing images, Remote Sensing, 9, 22, 2017a.
Mubin, N. A., Nadarajoo, E., Shafri, H. Z. M., and Hamedianfar, A.: Young and mature oil palm tree detection and counting using convolutional neural network deep learning method, Int. J. Remote Sens., 40, 7500-7515, 10.1080/01431161.2019.1569282, 2019.

Comment #7

Methods:
Any co-registration issue between MODIS and ALOS/ALOS2?

Response #7

We've checked there is no co-registration issues. And other analysis was also directly conducted in MODIS and PALSAR data in previous researches (Qin et al., 2017 and Zhang et al., 2019). We will further clarify this point in the revised manuscript.

Reference:

Zhang, Y., Ling, F., Foody, G. M., Ge, Y., Boyd, D. S., Li, X., Du, Y., and Atkinson, P. M.: Mapping annual forest cover by fusing PALSAR/PALSAR-2 and MODIS NDVI during 2007–2016, Remote Sens. Environ., 224, 74-91, https://doi.org/10.1016/j.rse.2019.01.038, 2019.
Qin, Y., Xiao, X., Dong, J., Zhou, Y., Wang, J., Doughty, R. B., Chen, Y., Zou, Z., and Moore, B.: Annual dynamics of forest areas in South America during 2007–2010 at 50-m spatial resolution, Remote Sens. Environ., 201, 73-87, https://doi.org/10.1016/j.rse.2017.09.005, 2017.

Comment #8

Line 149: Any other prove that no calibration is needed between ALOS and ALOS2 in Indonesia and Malaysia? The study site for the two referenced papers are not for these two coun-tries specifically (Thus with different incident angel, weather condition, etc).

Response #8

We randomly generated 250,000 points using ArcGIS 10.3 in our study area and compared the HH/HV values of these points during the 6 years following Qin et al (2016) and Cheng et al (2019)'s practice (**Figure S2**, reproduced below). According to the histogram, the backscattering value of PALSAR/PARSAR-2 are relatively stable in the study period. The reference which presented the stability of annual PALSAR/PALSAR-2 HH and HV values in Malaysia was also added (Cheng et al., 2019). Meanwhile, the HH and HV values for oil palm and forest is also shown in **Figure S3** (reproduced below) and indicate the separability between the two land cover types for both PALSAR/PALSAR-2 data. We will add these points in the revised manuscript. We produced the classification map using the training samples from each corresponding year, the influence of calibration differences between PALSAR/PALSAR-2 data will not influence the mapping results.

Reference:

Cheng, Y., Yu, L., Xu, Y., Lu, H., Cracknell, A. P., Kanniah, K., and Gong, P.: Mapping oil palm plantation expansion in Malaysia over the past decade (2007–2016) using ALOS-1/2 PALSAR-1/2 data, Int. J. Remote Sens., 1-20, 2019
Qin, Y., Xiao, X., Dong, J., Zhou, Y., Wang, J., Doughty, R. B., Chen, Y., Zou, Z., and Moore, B.: Annual dynamics of forest areas in South America during 2007–2010 at 50-m spatial resolution, Remote Sens. Environ., 201, 73-87, https://doi.org/10.1016/j.rse.2017.09.005, 2017.

Figure S2 Density distribution of PALSAR/PALSAR-2 (a) HH (dB) and (b) HV (dB) in study area for 2007, 2008, 2009, 2010, 2015 and 2016 based on 250000 randomly generated points. The mean and standard deviation (std) value for the six years were given (mean: -7.44~-6.98 of HH and -13.47~-13.01

of HV; std: 2.52~2.90 of HH and 3.05~3.76 of HV). According to the result, the backscatter signals are relatively stable for the given period (2007–2010 and 2015–2016).

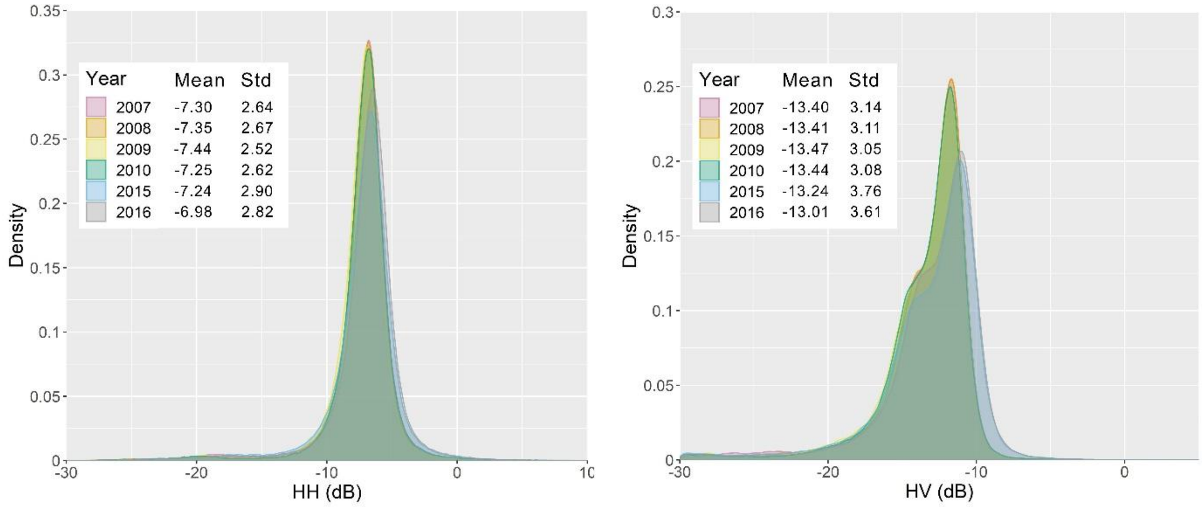
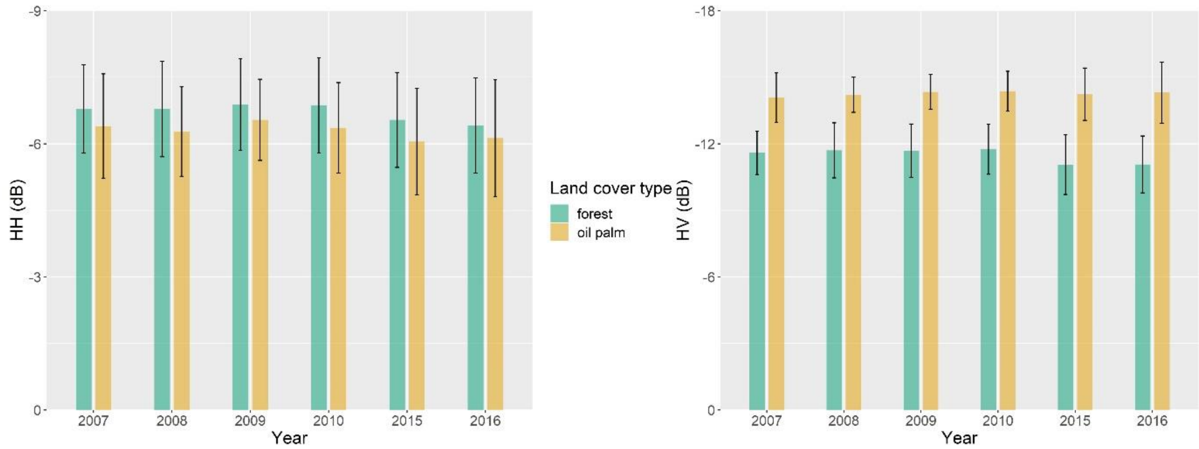


Figure S3 Comparison between PALSAR/PALSAR-2 (a) HH (dB) and (b) HV (dB) for forest and oil palm based on the training points. The HV (dB) for the forest and oil palm samples are differentiable during the given period (2007–2010 and 2015–2016).



Comment #9

Line 108: How dose 98.91% been calculated?

Response #9

We updated the number (96%) according to the reference (Petrenko et al., 2016) on **Section 2. 1, Line 113-115**: "Thus, we chose as a study area the whole Malaysia, Sumatra and Kalimantan in Indonesia, encompassing 96% of the total oil palm production in Indonesia (Petrenko et al., 2016)."

Reference:

Petrenko, C., et al. (2016). "Ecological impacts of palm oil expansion in Indonesia." J Washington : International Council on Clean Transportation.

Comment #10

Why the NDIV information from MODIS is not used as input to the RF model for classification?

Response #10

The use of coarse resolution MODIS information in RF may negate the benefits of our classification based on higher spatial resolution PALSAR data, keeping in mind that the change detection results during the gap years is based on the results from that classification. Second, we also found that the spectral information used to derive NDVI is quite similar between a tropical forest and a mature oil palm plantation, which induces confusion in the classification (Razak., 2018). Some studies used the fusion method (such as super-resolution mapping) to fusing coarser resolution MODIS with higher resolution PALSAR data, but these algorithms require large computational cost and were always applied to small scenes. For these two reasons, we didn't include the MODIS NDVI in the RF model. We will further add these points in the revised manuscript.

Reference:

Razak, J. A. B. A., Shariff, A. R. B. M., Ahmad, N. B., & Ibrahim Sameen, M. (2018). Mapping rubber trees based on phenological analysis of Landsat time series data-sets. Geocarto international, 33(6), 627-650.

Comment #11

Line 213: How many MODIS time series are used exactly? How many are actual data and how many are interpolated? As the author explained, Indonesia and Malaysia are heavily affected by clouds, so as MODIS NDVI as well.

Response #11

We used MODIS NDVI images (23 scenes per year) from 2000 to 2007 (P1) and from 2010 to 2015 (P2), with 181 and 138 scenes in the two periods, respectively. During the whole study period, 53.64% of the observations have good quality while 46.36% were interpolated. For those pixels with less than 30 good-quality observations (4.79% in P1 and 9.64% in P2), we didn't apply the BFAST algorithm. For the remaining area, 61.67% (P1) and 58.24% (P2) of pixels had 12 (~50%) good-quality observations annually. We will further clarify it in the revised manuscript.

Comment #12

Eq 4, 5 and 6: some errors in explanation.

Response #12

We modified the statements on **Section 2.4.2 Lines 257-268**: " An ordinary least square residuals-based moving sum test (Zeileis 2005) was used to test whether breakpoints occurred in the trend or seasonal components. Then, test was conducted to determine the number and optimal position of the breaks using Bayesian Information Criteria and the minimum of the residual sum of squares. The trend and seasonal coefficients were then computed using a robust regression. A harmonic seasonality model (with three harmonic terms) was used to describe the seasonality of the satellite data (Eq. 6) (Verbesselt et al. 2010). For each piecewise linear (T_t) from t_i^* to t_{i+1}^* where $t_1^*, \dots, t_p^*$ is the assumed break points which defines the p+1 segment, T_t can be expressed as follows:

$$T_t = \alpha_i + \beta_i t \; (i = 1, \dots, p) \tag{5}$$

where i is the index of the breaks, i=1, $\dots, q$. α_i and β_i are the intercept and slope of the fitted piecewise linear model.

For the $t_1^\#, \dots, t_m^\#$ seasonal break points, S_t is the harmonic model for $t_j^\#$ to $t_{j+1}^\#$:

$$S_t = \sum_{k=1}^{K} \alpha_{j,k} \sin\left(\frac{2\pi kt}{f} + \delta_{j,k}\right) (j = 1, \dots, q) \tag{6}$$

where, $j = 1, \dots q$. k is the number of harmonic terms in the periodic model (default value = 3); $\alpha_{j,k}$ is the amplitude; f is the frequency; $\delta_{j,k}$ is the time phase. ".

Comment #13

More information is needed for the validation methods (2.5). E.g how many samples are there for each land use class for each year?

Response #13

We added the details and the number distribution of the validation sample set (Please see the **Table 2** (reproduced below) and the descriptions on **Section 2.5, Lines 311-315**: " Two sets of annual oil palm samples were used to validate the mapping results in Malaysia and Indonesia according to the sampling protocol of Gong et al. (2013). The independent annual sample set in Malaysia was from the previous studies (Cheng et al., 2019; Cheng et al., 2017). All pixel-based samples were randomly produced in equal-area hexagonal grid (95.98 km^2 for each grid cell), therefore the distribution of the samples among different land cover types has minimum bias with the real land cover composition." And **Lines 319-323**: " The second annual Indonesia sample set was developed following the protocol of Cheng et al. (2017). This sample set contains 7663 samples in total (601 were oil palms and the rest were non-oil palm types) during 2010 to 2016 (see the blue points in Figure 3). The details of the number and spatial distribution of validation samples is presented in Figure 3 and Table 2. More information on the randomized sampling method could be referred to Cheng et al., 2017 and Cheng et al., 2019."

Reference:

Cheng, Y., Yu, L., Zhao, Y., Xu, Y., Hackman, K., Cracknell, A. P., and Gong, P.: Towards a global oil palm sample database: design and implications, Int. J. Remote Sens., 38, 4022-4032, 2017.

Cheng, Y., Yu, L., Xu, Y., Lu, H., Cracknell, A. P., Kanniah, K., and Gong, P.: Mapping oil palm plantation expansion in Malaysia over the past decade (2007–2016) using ALOS-1/2 PALSAR-1/2 data, Int. J. Remote Sens., 1-20, 2019

Table 2 The distribution of annual validation sample set for Malaysia and Indonesia (unit: pixel).

	Malaysia						Indonesia		
	Oil palm	Other vegetation	Water	Others	Total		Oil palm	Not oil palm	Total
2007	371	2,335	68	74	2,848	2010	547	7066	7613
2008	398	2,334	71	76	2,879	2011	559	7063	7622
2009	418	2,335	71	76	2,900	2012	568	7068	7636
2010	433	2,335	71	76	2,915	2013	575	7078	7653
2015	505	2,336	75	76	2,992	2014	588	7072	7660
2016	505	2,334	71	73	2,983	2015	594	7073	7667
						2016	601	7066	7667

Comment #14

Line 726: Fig 3: are all the 2986 annual distribution of validation dataset is very uneven. There is no annual sample set in Sumatra Indonesia at all.

Response #14

We added a new annual validation sample set in Indonesia for the period from 2010 to 2016 to validate our datasets on **Section 2.5, Lines 319-323**. The datasets included 7667 samples in 2016 (601 samples were oil palm and the remaining were others – see above). The blue points in **Figure 3** (reproduced below) shows the spatial distribution of validation sample set in Indonesia. And **Table 4** (reproduced below) shows the validation results using the Indonesia annual sample.

Figure 3 Spatial distribution of oil palm samples in the two validation datasets. The annual sample set contains 2986 (in 2016) samples in Malaysia which were interpreted for 2007, 2008, 2009, 2010, 2015 and 2016 and 7667 (in 2016) samples in Indonesia interpreted from 2010 to2016. These samples were used to validate the annual maps developed from PALSAR/PALSAR-2 data. Of the annual sample set in Malaysia, oil palm samples consist of 16.92% (505) while the forest, water and others consist of 78.16%, 2.48% and 2.44%, respectively. The Indonesian annual sample set contains 601 (7.84%) oil palm samples and the rest (92.16%) were other types. The change sample set includes 370 oil palm samples which were converted in the interpolated period (2001-2006 and 2011-2014). This sample set, with change year labelled, is used to assess the change detection result in the gap years.

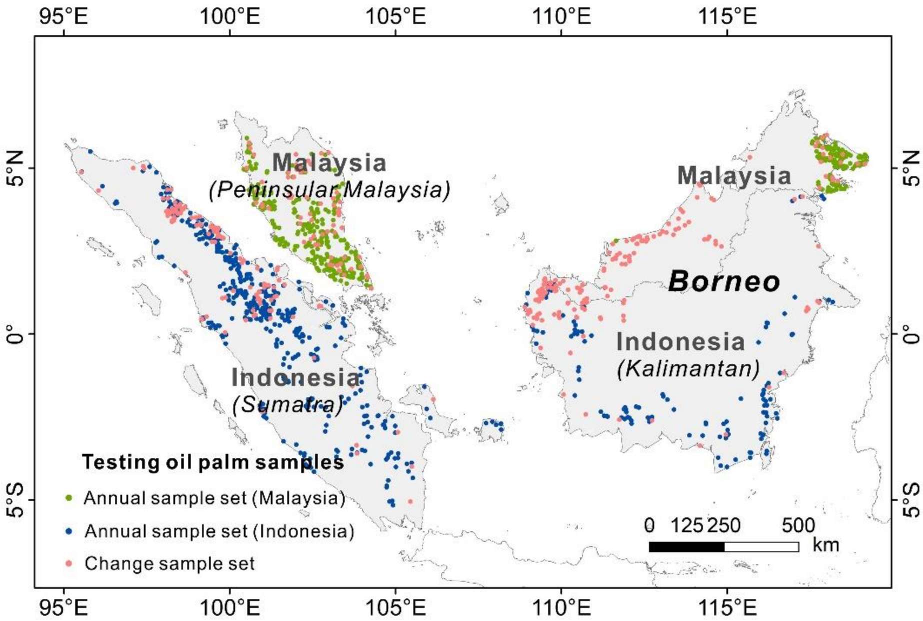


Table 4 The oil palm accuracy in Indonesia from 2010-2016. UA: User's Accuracy; PA: Producer's Accuracy

Year	Our results		
	F-score	UA (%)	PA (%)
2010	0.75	69.47	74.95
2011	0.75	70.38	74.83
2012	0.75	71.48	75.05
2013	0.75	72.39	74.79
2014	0.74	72.58	74.28
2015	0.72	68.46	71.83
2016	0.72	69.97	72.33

Comment #15

Line 300: How does the total number of validation points (5000) been decided? What's the ratio of the validation points to the total pixel been detected as change?

Response #15

We randomly generated 5000 samples in the change areas (which should all be changed area according to our results). However, as the lack of continuous high-resolution images from Google Earth and cloud-free Landsat time series, 370 samples were manually interpreted with actual change years and used as the change sample set. In total there are 370 changed oil palm samples in 1476 (25.07%) oil palm samples and 10500 total samples, whereas the ratio is 25.07% and 3.52%, respectively. We will further clarify this point in the revised manuscript.

Comment #16

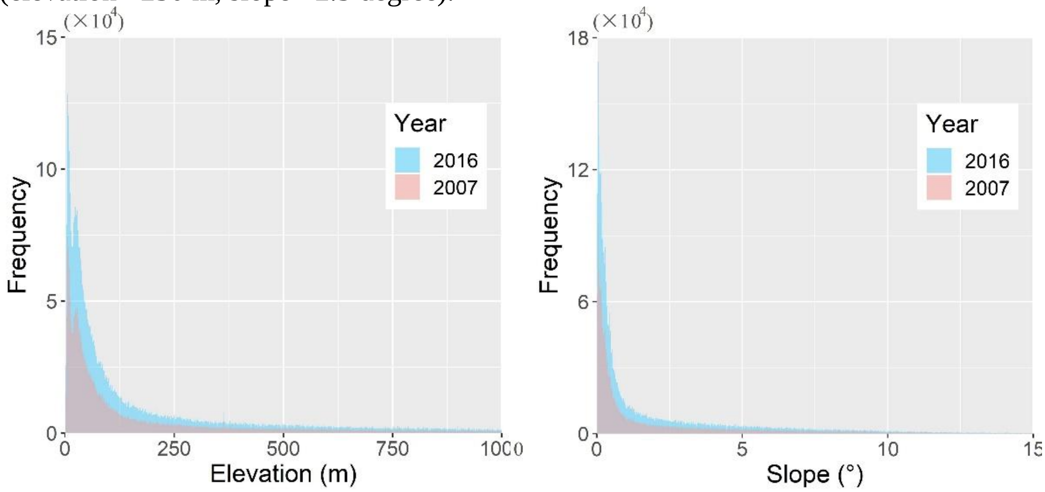
Results:

Paragraph 1 and 2: There is no other information/ref/map/graph/table provided to support many of the conclusions in these two paragraphs. Some of the sentences read like discussion rather than results.

Response #16

We added a SI figure (**Figure S5**, reproduced below) of the oil palm distribution according to elevation and slope topography and rewrote the unclear sentences in these two paragraphs: "In the study area, most oil palm plantations are located on lowland areas (elevation <250 m, slope <2.5 degree), and few are distributed in gently undulating hills (elevation >500 m, slope >5 degree) (Figure S5). The newly developed oil palm has similar elevation and slope distribution compared to the 2007 ones (slope: 1.97° in 2007/1.99° in 2016; elevation 228.98 m in 2007/230.10 m in 2016)" (**Section 3.1, Lines 334-337**) and "In Indonesia, rapid expansion first occurred in Sumatra and was then surpassed by Kalimantan (Gunarso, 2013; Petrenko et al., 2016). This can also be observed in our maps where more changes happened in earlier years in Sumatra (lighter colors in Figure 4 of the revised manuscript) and later in Kalimantan (darker colors)." (**Section 3.1, Lines 341-343**).

Figure S5: Frequency histograms of elevation and slope for oil palm distribution in 2007 and 2016 over the study area. According to the results, the oil palm is mainly distributed on the lowland areas (elevation <250 m, slope <2.5 degree).



Reference:

Gunarso, P., Hartoyo, M., Agus, F. & Killeen, T.: Oil palm and land use change in Indonesia, Malaysia and Papua New Guinea, 2013.

Petrenko, C., et al. (2016). "Ecological impacts of palm oil expansion in Indonesia." J Washington : International Council on Clean Transportation.

Comment #17

Section 3.3: Have you compared your results from Global forest watch, oil palm concession dataset 2014?

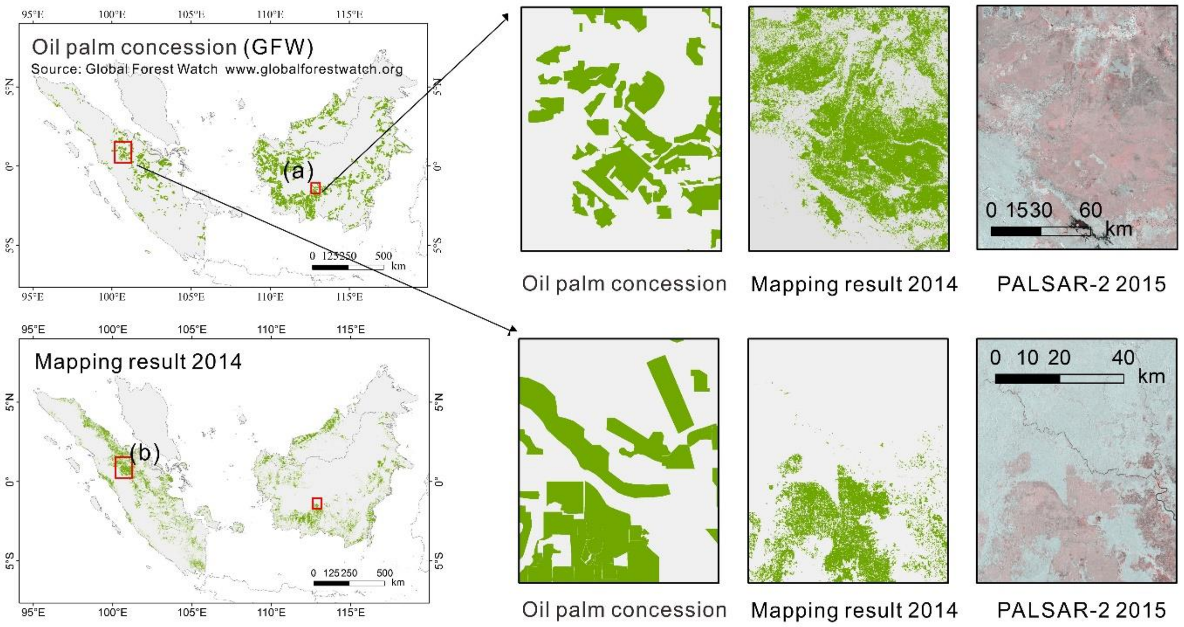
Response #17

Thank you for this suggestion. We added the comparison the spatial distribution with PALSAR data and area with oil palm concession from Global forest watch on **Section 3.3 Lines 451-460** and **Figure 9** (reproduced below): " The oil palm concession area for Indonesia and Malaysia (Sarawak) for 2014 from global forest watch (www.globalforestwatch.org) is also used in the comparison. This dataset indicated the boundaries of areas allocated by government to companies for oil palm plantation. The oil palm concession area in Indonesia and Malaysia (Sarawak) for 2014 is 12.98 M ha, which is slightly higher (8.7%) than our mapping results (11.85 M ha). However, since the concession data was compiled from various countries and sources (such as governments and other organizations) with different quality, some location of the existing concessions may be inaccurate (**Figure 9(a)**) or omitted. Another possible reason for the differences is the inclusion of very small oil palm plantations in our dataset of less than 50 ha, while most of the oil palm concessions (81.71%) were larger than 1000 ha."

Reference:

Slette, J. P., and I. E. Wiyono. 2011. Oilseeds and products update 2011. USDA Foreign Agricultural Service, Washington, D.C., USA. [online] URL: http://www.usdaindonesia.org/public/uploaded/Oilseeds%20and%20Products%20Update_Jakarta_Indonesia_1-28-2011.pdf

Figure 9 Comparison with oil palm concession from Global forest watch (GFW) for year 2014. The PALSAR-2 images were composited in RGB format (HH, HV, HV).



Comment #18

Section 3.3: There lacks adequate reference to support the linkage between oil palm expansion, price fluctuation.

Response #18

It is difficult to conclude the relationship between oil palm expansion and the price fluctuations since the plantation area is affected by multiple price-related factors such as land rent and production tax. We modified the texts on **Section 3.3, Lines 425-431**: "During the study period, the oil palm export price (total export value/export amount, data source: FAOSTAT) rapidly increased from 402.67 dollars/t in 2006 to the peak (1080.72 dollars/t) in 2011 (Figure S9, Figure 8 in the old version) but subsequently fell. The crop price is closely related to demand and may further impact the oil palm market and production (Turner et al., 2011). However, although there is a ~10-20% slowdown of the conversion rate, oil palm plantation area continuously increased after 2011. The land conversion to oil palm may also be affected by multiple factors such as agricultural rent, wages and market-mediated effects (such as tax) (Furumo and Aide, 2017; Taheripour et al., 2019), and the relationship between oil palm expansion and price fluctuation still requires further exploration." and put the price figure to supplementary (**Figure S9**).

Reference:

Furumo, P. R., and Aide, T. M. J. E. R. L.: Characterizing commercial oil palm expansion in Latin America: land use change and trade, 12, 024008, 2017.

Taheripour, F., Hertel, T. W., and Ramankutty, N.: Market-mediated responses confound policies to limit deforestation from oil palm expansion in Malaysia and Indonesia, Proceedings of the National Academy of Sciences, 116, 19193, 10.1073/pnas.1903476116, 2019.

Turner, E. C., Snaddon, J. L., Ewers, R. M., Fayle, T. M., and Foster, W. A. J. E. i. o. b.: The impact of oil palm expansion on environmental change: putting conservation research in context, 10, 20263, 2011

Comment #19

Section 3.3: There are potentially more reasons to explain the higher estimated oil palm area in this study compared to existing dataset. More evidence is needed to exclude other reasons and draw the conclusion to smallholders' oil palm plantation. Especially the minimum mapping unit in this paper is 1ha.

Response #19

We added more discussion about the higher estimation in **Section 3.3**: "The higher estimation may be induced by the confusion in other woody plantations such as coconuts and pulp. Although there is high separability between rubber, wattles and palms in PALSAR data (Miettinen and Liew, 2011), the coconuts which belongs to palm trees and have a fan-like shape showed less differences with oil palm compared to other plantations" (**Section 3.3**, **Lines 419-422**), " We should also note that the uni-directional version would have a higher estimation of oil palm plantation area since the assumption of one-way growth" (**Section 3.3**, **Lines 426-427**), " The oil palm concession area in Indonesia and Malaysia (Sarawak) for 2014 is 12.98 M ha, which is 8.7% higher than our mapping results (11.85 M ha). However, since the concession data was compiled from various countries and sources (such as government and other organizations) with different quality, some location of the existing concessions can be inaccurate (Figure 9(a)) or may be omitted (Figure 9(b)) comparing the concessions and our mapping results with PALSAR-2 data. Many concessions are not fully developed and the number reached more than 11 M ha (more than half) in 2010. Another possible reason for the differences may be the inclusive of oil palm plantations less than 50 ha in our results, while most of the oil palm concessions (81.71%) were larger than 1000 ha." (**Section 3.3**, **Lines 451-460**). And we also explained the uncertainty of the datasets in discussion part, "…but confusion may occur in some impervious area and plantations of other species such as coconuts. As a result, the accuracy of the change detection in the second step was also influenced by the oil palm maps generated from PALSAR/PALSAR-2 data in the first stage... inaccurate inputs in some pixels may lead to cumulative errors in the change detection during the PALSAR data gap years, particularly in Indonesia. " (**Section 4.1**, **Lines 482-487**), " … the use of moderate resolution MODIS data at 250 m may cause the loss of spatial information and false identification of the change times. … In addition to the satellite data, the change detection algorithm may also bring uncertainties. Because the accuracy of the detected change time by BFAST within a time series is influenced by the signal-to-noise ratio (Verbesselt et al., 2010b), cloud contamination and poor data quality in some regions from MODIS reduced the amount of valid information. And the bias may also be found in the gap years when no breakpoint could be found using BFAST algorithm and the errors were accumulated to years when switching to MODIS before and after PALSAR. " (**Section 4.1**, **Lines 490-500**)

As for the concern of mapping units and smallholders, on average, each farming household manages about 2 ha of land (ranged up to 50 ha), compared with private companies that manage about 4,000 ha (Daemeter Consulting 2015, Vermeulen and Goad, 2006; Lee et al., 2014). Compared to the existing industrial oil palm plantation datasets (81.71% are larger than 1000 ha in GFW oil palm concession), our datasets included oil palm plantation larger than 1 ha which contains some of the small-scale family-based enterprises. But the spatial resolution still limits the detection of smallholder less than 1 ha. We believe it is reasonable to attribute part of our higher estimated oil palm area to smallholder land but not all the differences. Therefore, we also modified the statements in the manuscript: "Our higher estimation of oil palm plantation area is possibly because some of the smallholders oil palm plantations (1-50 ha in size) is captured in our results whereas only industrial plantations were visually interpreted in Gaveau's results. Misclassification (commission errors) in our results may however also contribute to our estimation being higher. " (**Section 4.1**, **Lines 447-450**)

Reference:

Daemeter Consulting (2015): Indonesian Oil Palm Smallholder Farmers: A Typology of Organizational Models, Needs, and Investment Opportunities. Daemeter Consulting, Bogor, Indonesia

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.

Comment #20

Line 435: what does 'limited bands in ALOS/ALOS 2 mean?

Response #20

Here we mean there is two bands (HH HV) in the original data. We deleted the inaccurate description.