Response to the Comments from Editors and Reviewers

Editor comments

Dear Authors,

While you have addressed some reviewers' concerns, I find myself in agreement with the comments put forth by Reviewer #3 and Reviewer #4. Particularly, their significant concerns regarding the lack of acknowledgment for existing methodologies and the absence of uncertainty analysis stand out.

Response: Dear Dr. Sasaki, We appreciate your time and efforts to help improve this manuscript. According to the comments from you and four reviewers, we made careful improvements to this manuscript in this third round of revision. We (1) added the detailed method description for forest cover and evergreen forest cover mapping in the Methods section and (2) added the error matrices (Table S1) based on two independent reference datasets and the comparison of very high spatial resolution images, PALSAR/MODIS forest cover maps, and MODIS evergreen forest cover maps at three selected sites (Fig. 8) in the Brazilian Amazon.

Additionally, I would like to raise the following points:

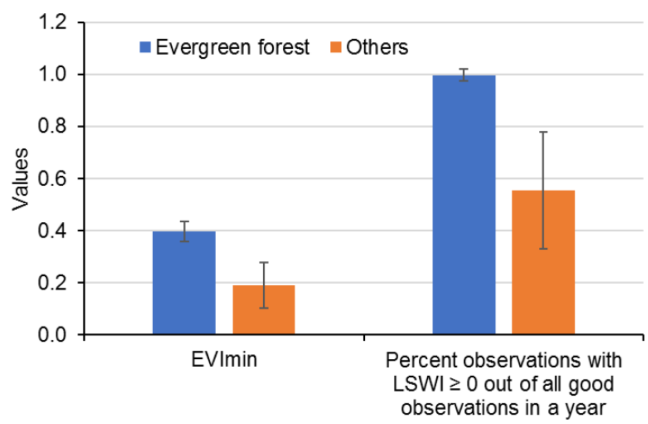
1) The terminology "annual forest cover" and "evergreen forest cover maps" as used in your manuscript remains ambiguous. If your study region encompasses X types of forest cover, it's crucial that the term "forest" adequately reflects those X types. To illustrate, at L155, you mentioned, ""The two major biomes in Brazil are the Amazon evergreen forests in the north and west, and the Cerrado, i.e., a vast ecoregion of tropical savanna, in the south and east." Based on this description, your annual forest would comprise both Amazon evergreen forests and tropical savannas. However, your paper seems to predominantly focus on the evergreen forest. If this is the intent, I suggest amending your title, abstract, and pertinent sections accordingly.

Response: For the long term, forest cover maps in the Brazilian Amazon were produced mainly based on optical remote sensing images from multiple years to get enough cloud-free images. Microwave remote sensing images are independent of frequent clouds in the tropics. The combination of microwave and optical remote sensing showed advantages in mapping annual tropical forest cover. Thus, we produced the annual PALSAR/MODIS forest cover maps in the Brazilian Amazon. These PALSAR/MODIS forest cover maps could include evergreen, deciduous, and mixed forests in the two major biomes. Evergreen forest cover is the dominant forest cover type in the Brazilian Amazon. Thus, PALSAR/MODIS forest cover and MODIS evergreen forest cover maps are important datasets. Besides the independent reference datasets at the site scales, the PALSAR/MODIS forest cover maps provided regional references for the area and spatial comparisons of MODIS evergreen forest cover maps. Generating annual forest cover type maps in the Brazilian Amazon is on our research schedule, which will need extensive time and effort for the field survey, collection and integration of high spatial resolution remote sensing images, algorithm calibration and validation, and accuracy assessment of forest cover type maps.

2) The definition of "forest" in your work doesn't distinguish between evergreen, deciduous, or mixed forests. Your rationale for embracing the FAO's definition for evergreen forests needs clearer elucidation.

Response: We investigated and quantified the threshold values for the evergreen forest mapping algorithm based on the training samples of evergreen forest in the Brazilian Amazon (Qin et al., 2019, Nature Sustainability). We modified the relevant description of the evergreen forest mapping in the section "2.7. Algorithm and data of annual MODIS evergreen forest cover maps during 2000-2021" as

"Based on the canopy phenology from analyses of time series water-related LSWI and greenness-related EVI calculated from all MOD09A1 data in each year, a novel, simple and robust algorithm was developed to generate annual maps of evergreen forests in the Brazilian Amazon using the FAO's forest definition as the reference and evergreen forest training samples (Xiao et al., 2009; Qin et al., 2019)."



Supplementary Fig. 14. Minimum Enhanced Vegetation Index (EVImin) and Percent observations with LSWI $\geqslant 0$ out of all good observations and their standard deviations for evergreen forest (using the FAO's forest definition as the reference) and other land cover types (Others). This analysis is calculated based on the Ground sample blocks from the Global Land Cover Validation Reference Dataset and EVI and Land Surface Water Index (LSWI) from MOD09A1 dataset in 2010. (Qin et al., 2019, Nature Sustainability.)

I kindly request that you address the aforementioned concerns and consider resubmitting the paper.

Sincerely,
Nophea Sasaki

Editor comments

by Svenja Lange

Notification to the authors:
Please ensure that the colour schemes used in your maps and charts allow readers with colour vision deficiencies to correctly interpret your findings. Please check your figures using the Coblis – Color Blindness Simulator (https://www.color-blindness.com/coblis-color-blindness-simulator/) and revise the colour schemes accordingly.

Response: Dear Dr. Lange, Thanks for your suggestions. We checked all the figures and we did not use green/red colour schemes. We also made Fig. 4 and Fig. 6 bigger to help readers to see them clearly.

Review #1

accepted as is

Response: Thanks!

Review #3

The authors have carefully addressed my concerns in the revised manuscript. I would like to recommend this manuscript to be published in the ESSD after a few of technical corrections which also can be carried out at the phase of proofreading.

Response: Thanks!

Reviewer #4

This paper presents the generation of annual forest and evergreen forest cover maps in Brazilian Amazon by combining PALSAR and MODIS data. The manuscript is well written and easy to follow. However, I have several major concerns. Firstly, the same method and data have been used in several previous studies (Qin et al., 2016a; Qin et al., 2017; etc.). From this perspective, this study lacks novelty. Secondly, during the validation of forest maps, only the overall accuracy of 91% was mentioned. It would be better to include error matrices based on two reference data to provide a more complete and reliable assessment of mapping accuracy. Thirdly, as mentioned by the other reviewer, this paper lacks useful statistical analysis. It is advised that the authors quantify annual change (loss, gain, and net change) in forest cover in Brazilian Amazon and identify the hotspots of forest cover change. Additionally, apart from comparing the annual forest area from different forest products in Figure 10, it would be beneficial to perform more localized visual comparisons of forest cover from current forest maps. Lastly, this project produced 50m forest maps from 2007 to 2010 using PALSAR and MODIS data. Since these two data sources have different spatial resolutions, how these multi-scale data were fused?

Response: Thanks for your time and efforts to improve this manuscript. We previously made two rounds of revisions to this manuscript. According to your valuable comments and suggestions to the manuscript (after the first round of revision), we made careful revisions to the manuscript in this third round of revision.

Based on the method development and data investigation in the previous studies, PALASR/MODIS forest and MODIS evergreen forest cover maps showed improved performance in tracking the area, spatial distribution, and temporal changes of forest and evergreen forest cover in the Brazilian Amazon. Canopy height and canopy coverage are two critical variables in defining forest. However, the previous accuracy assessment of forest cover maps was mainly based on the canopy coverage without canopy height. In this data manuscript, we did additional accuracy assessment for PALSAR/MODIS forest and MODIS evergreen forest cover maps using the ICESat-1 canopy height and canopy coverage data product. The ICESat-1 data showed high accuracy of PALSAR/MODIS forest and MODIS evergreen forest cover maps in the Brazilian Amazon. We wrote this data manuscript to share the data and code of our forest and evergreen forest cover maps with the research community.

As you suggested, we added the error matrices (Table S1) based on the two reference data.

This manuscript is about data introduction, so we did not do much forest change analysis. We have shared the annual forest and evergreen forest cover maps. People can download these data products and investigate forest changes depending on their needs. We added three sites of localized visual comparisons of very high spatial resolution images, PALSAR/MODIS forest cover and MODIS evergreen forest cover maps (Fig. 8).

To match the 50-m PALSAR data, we resampled the 250-m MODIS NDVImax into 50-m spatial resolution using the nearest sampling approach. We added this data processing in the section "2.3. MODIS surface reflectance and vegetation indices".

Reviewer #5

General comments:

This study presented a datasets of forest map according to FAO's definition, which is of great importance to the sustainable development and biomass estimation in specific. From the results presented in this paper, the accuracy is of good performance, and it has a great contribution for large-scale forest mapping work. However, I recommend the authors to address the following issues before the manuscript can be considered to be published on ESSD.

Response: Thanks for your positive comments. We made careful revisions to this manuscript according to your comments and suggestions.

1. The description of method about forest mapping is not comprehensive enough, even was ignored. Please express this part fully. The detail of methodology is missing, which is not acceptable without further modification regarding the scope of ESSD journal. It is not easy for readers to know how they produced the datasets without further knowledge from the cited paper.

Response: We added more details about the method description of forest mapping. Please see section "2.6. Algorithm and data of annual PALSAR/MODIS forest cover maps during 2007-2010".

"Electromagnetic wave of PALSAR can penetrate the tree canopy and interact with the tree trunks and branches. Forests have higher volume backscatter signals in HH and HV compared to croplands, grasslands, and water bodies. Thus, PALSAR data are sensitive to forest structure and biomass. However, PALSAR data can be affected by local incidence angle and soil moisture as PALSAR data is acquired at a different date each year. We calculated the acquisition date (Fig. 2), the local incidence angle (Fig. S1), and HH and HV gamma-naught values for each year and their standard deviations (Fig. S2) during 2007-2010 in the Brazilian Amazon. PALSAR HH and HV data were mainly acquired in the dry season (from June to October) and the local incidence angle is stable. About 90% of the area has standard deviation values of less than 1 dB for PALSAR HH and HV data. PALSAR data have advantages in identifying and mapping the spatial and temporal changes of forests in the tropics with frequent clouds compared to optical satellite remote sensing. Using the FAO's forest definition as the reference, we developed a robust decision tree algorithm to identify and generate forest cover maps by ALOS PALSAR data: $-15 \leq HV \leq -9$, $3 \leq Difference \leq 7$, and $0.35 \leq Ratio \leq 0.75$, based on the forest and non-forest training samples (Qin et al., 2016a; Qin et al., 2015; Qin et al., 2017). Several land cover types (e.g., rocks and buildings) had high backscatter values of HH and HV, which were often confused with the forests when only HH and HV data were used. These land cover types usually have low vegetation coverage with $NDVImax < 0.5$ (Qin et al., 2016a; Qin et al., 2015; Qin et al., 2017). To reduce the commission errors from these land cover types, we combined both PALSAR and NDVImax from MOD13Q1 to produce annual forest cover maps (namely PALSAR/MODIS) at 50-m spatial resolution in the Brazilian Amazon during 2007-2010 using these threshold values: $-15 \leq HV \leq -9$, $3 \leq Difference \leq 7$, $0.35 \leq Ratio \leq 0.75$, and $NDVImax \geq 0.5$ (Qin et al., 2016a; Qin et al., 2017). We also carried out a three-year temporal consistency filter to reduce the effects of noise (Qin et al., 2016a; Qin et al., 2017)."

2. The availability of existing reference datasets needs to be further clarified, especially in the accuracy comparison part.

Response: We added the description of the availability of existing reference datasets in the revised manuscript (3.1. Annual PALSAR/MODIS forest cover maps during 2007-2010) as "The

Global Land Cover Validation Reference Dataset was produced from very high spatial resolution commercial remote sensing data acquired around 2010 and is freely available at the https://web.archive.org/web/20161209205946/https:/landcover.usgs.gov/glc/SitesDescriptionAndDownloads.php. The TREES-3 dataset was produced from Landsat images and is freely available at https://forobs.jrc.ec.europa.eu/trees3/data."

3. For the statistical accuracy analysis, the authors used 5km as the pixels' resolution. Why not conduct such analysis on a higher resolution? The resolution of the cartographic results in this paper is already very low (e.g., 50 m, 250 m, 500 m). Using a lower resolution to is actually much more friendly to a better accuracy, but it's fake. Please reconduct the uncertainty analysis to make it more convincible like previous studies [1-4].

Response: Thanks for sharing these four previous studies. We added the reason that we selected 5-km spatial resolution as an optimal scale to aggregate the 50-m SAR and 500-m MODIS images in the second round of revision: "For the spatial comparison, to avoid the bias caused by different spatial resolutions, we aggregated the 50-m annual PALSAR/MODIS forest cover maps and 500-m (463-m) MODIS evergreen forest cover maps into 5-km pixels and calculated their average forest area fraction values within individual 5-km pixels.". Please see section "2.8. Spatial and statistical analysis".

We added three sites of zoom-in windows of very high spatial resolution images, PALSAR/MODIS forest cover maps, and MODIS evergreen forest cover maps using these previous studies as the reference.

4. Did the forest map from 2007 to 2010 (Fig. 5) also combine PALSAR data and MODIS? Please clarify it, because the "or" in the caption is not consistent with the description in the text. For 2007-2021 evergreen forest mapping, only MODIS data were used only, which is clear. Similar mistakes are quite often in the manuscript, such as Sections 3.1 and 3.2. Please recheck the manuscript thoroughly.

Response: The PALSAR/MODIS forest cover maps from 2007 to 2010 in Fig. 5 (in the manuscript after the first round of revision) are generated based on PALSAR and MODIS images. As we moved some figures from the main text to supplementary materials in the second round of revision, this Fig. 5 became Fig. 3. In this third round of revision, we highlighted the meaning of the "PALSAR/MODIS forest cover maps" in the section "2.6. Algorithm and data of annual PALSAR/MODIS forest cover maps during 2007-2010".

5. Please add zoomed images (e.g., optical images) for details analysis to prove your results is corrected. Please refer to the existing research analysis [1-4].

Response: As you suggested, we added the zoomed very high spatial resolution images, PALSAR/MODIS forest cover, and MODIS evergreen forest cover maps at three sites (Fig. 8).

6. Section 3.4 should be placed in the introduction instead of "Results and discussion" since section 3 described the advantages satellite lidar data for result assessment.

Response: We made this change in the second round of revision.

7. The comprehensive discussion of the results is inadequate in the manuscript, such as the possible reasons for misclassifications.

Response: We added one section in the revised manuscript.

"3.3. Uncertainties in the accuracy assessment of PALSAR/MODIS forest cover maps and MODIS evergreen forest cover maps

The Global Land Cover Validation Reference and TREES-3 land cover datasets were produced from optical remote sensing images, which were sensitive to canopy coverage instead of canopy height. Thus, our PALSAR/MODIS forest cover maps had high user's and producer's accuracy for forest cover type, while the non-forest cover type had relatively low user's or producer's accuracy (Table S1), which may be attributed to the uncertainties in the reference maps. Different from the optical remote sensing image, the ICESat-1 data used in this study had not only the maximum canopy coverage data but also the maximum canopy height from 2003 to 2007 (Tang et al., 2019a). As the Brazilian Amazon had high annual primary forest loss rates of 17,654 km^2/yr in the 2000s (INPE, 2023), the maximum canopy height and canopy coverage of ICESat-1 data may not include the impacts of deforestation. Thus, ~94% of PALSAR/MODIS forest cover pixels and MODIS evergreen forest cover pixels meet the forest definition."

8. Generally speaking, the source data used in this paper are quite outdated. (e.g.,? This deficiency leads to a much lower significance of this study. Why not use more modern data like Sentinel, ICESat-2, ALOS-2? This should be answered seriously, as well as in the text.

Response: In our opinion, each data product has its own advantages and disadvantages in forest cover mapping. Frequent cloud cover is a major challenge for forest cover mapping in the Brazilian Amazon. Although the 8-day MOD09A1 data product has a spatial resolution of 500m, it is generated based on daily observations and has a high opportunity to get cloud-free observations. Besides, MOD09A1 has data collection since 2000, which could track long-term forest cover changes due to frequent policy and environmental changes in the Brazilian Amazon, especially the different phases of deforestation. The ICESat-1 canopy height and canopy coverage percentage data products were generated by Tang et al (2019, Remote Sensing of Environment). ICESat-2 has the canopy height data product but its canopy coverage data product was not calculated from LiDAR observations instead of Landsat vegetation coverage fraction. Sentinel has data observations for about 10 years. The combination of Sentinel and Landsat could provide land surface observations about every 3-4 days. ALOS PALSAR-2 and Global Ecosystem Dynamics Investigation (GEDI) canopy height and canopy coverage data products have been updated recently. Combining Sentinel, ALOS PALSAR-2, Landsat, and GEDI to generate annual forest cover maps is on our to-do list. We added the relevant description in the section "2.3. MODIS surface reflectance and vegetation indices".

10. The topic of this study, which is "annual forest" and "evergreen forest", as we can see in the title and abstract. But as I know, and as we can know from the results, these two types of forests are almost the same in Amazon. So why separate them apart if the difference is not significant (see Section 3.3 and Fig. 9)? Or, what's the difference between them and how we can tell it from the results?

Response: To assess the accuracy and uncertainty of MODIS evergreen forest cover maps, we used multiple independent reference datasets at the site scales, including land cover maps at the 2-m spatial resolution, land cover maps at the 30-m spatial resolution, and ICESat-2 canopy height and canopy cover percentage data products. These site-level reference datasets are sampling datasets, which did not cover the whole Brazilian Amazon. The major forest type is the evergreen forest in the Brazilian Amazon. Thus, we used the PALSAR/MODIS forest cover maps, which had little impact from frequent clouds, as the reference to assess the uncertainty of MODIS evergreen forest cover maps.

Reference:

[1] Shimada, Itoh, Motooka, et al. New Global Forest/Non-Forest Maps from ALOS PALSAR Data (2007-2010) [J]. Remote Sensing of Environment, 2014, 2014,155(-): 13-31.DOI:10.1016/j.rse. 2014.04.014.

[2] Martone M, Rizzoli P, Wecklich C, et al. The global forest/non-forest map from TanDEM-X interferometric SAR data[J]. Remote Sensing of Environment, 2018, 205:352373.DOI:10.1016/j.rse.2017.12.002.

[3] Mazza A, Sica F, Rizzoli P, et al.TanDEM-X Forest Mapping using Convolutional Neural Networks[J].Remote Sensing, 2019, 11(2980).DOI:10.3390/rs11242980.

[4] Pulella A, Santos R A, Sica F, et al. Multi-Temporal Sentinel-1 Backscatter and Coherence for Rainforest Mapping[J]. Remote Sensing, 2020, 12(5):847-.DOI:10.3390/rs12050847.

Specific comments:

1. Line 262: 0.03×106 -> 3×104; Line 248: 0.75×106 -> 7.5×105; please check such representation.

Response: We used the multiplication step for increments of the base-10 exponent of three to match thousand, million etc.

2. Line 165, Fig.1(a) and (b): The legend should be included in the figure.

Response: We included the legend in Figure 1(a) and (b).

3. Line 199, Fig.4(c) and (d): The label is too crowded to read.

Response: We made Fig. 4 bigger to be clear to read. We moved this figure into supplementary materials in the second round of revision.

4. Line 269, Fig.7: add a legend, like Fig. 5.

Response: We revised it as you suggested.