Dear reviewer,

We are very pleased to finish a revised version of the manuscript essd-2023-1 entitled "**Spatiotemporally consistent global dataset of the GIMMS Normalized Difference Vegetation Index (PKU GIMMS NDVI) from 1982 to 2022**". In preparing this revision we have considered all your comments and incorporated most of the suggestions. **Temporal coverage of PKU GIMMS NDVI has been extended from 2020 to 2022.** We greatly appreciate your time and effort spent in reviewing this manuscript, which have improved the revised version of the manuscript.

Substantial improvements have been made based on your comments, including:

(1) We have provided more details on how we performed the time-weighted aggregation method to convert the temporal resolution of the MODIS NDVI product (MOD13C1) from 16 days to half-month.

(2) We have also elaborated the method used to splice the PKU GIMMS NDVI and MODIS NDVI

Below we provide point-to-point responses, each following the specific comment from the reviewer. All the changes have been marked by red in the revised manuscript.

Sincerely yours,

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[Comment 1] *Overall Comments:*

A reliable long-term vegetation time series is critical to understand the dynamic of vegetation and its feedback to the climate. This study by Li et al reconstructs a spatiotemporally consistent global NDVI dataset for 1982-2020 integrating Back Propagation Neural Network and a total of 3.6 million Landsat NDVI samples that well spread across the globe as input. This product, along with its predecessor (the GIMMS NDVI3g dataset), has been evaluated with the Landsat NDVI samples, showing substantial improvement. This study has originality and significance in uniqueness and usefulness.

[Response 1] We appreciate the reviewer for confirming the uniqueness and significance of the study. The idea of using massive high-quality Landsat NDVI samples ensures the spatiotemporal consistency and reliability of the PKU GIMMS NDVI dataset and eliminates the effects of NOAA satellite orbital drift and AVHRR sensor degradation. We hope that the PKU GIMMS NDVI could provide a more solid data basis for global vegetation dynamic studies.

[Comment 2] *Below are some comments that may help to further improve the manuscript. First, it seems that the golden truth of NDVI is Landsat NDVI samples. I recommend providing details in section 3.2.1 of Landsat NDVI samples to illustrate: 1) Why Landsat NDVI is more accurate than other products? 2) Does Landsat NDVI have any limitations (e.g. the influence of clouds)? 3) Adding a plot to show the distribution of these samples (time and space).*

[Response 2] We thank the reviewer for providing these recommendations. More details have been added in Section 3.2.1 of the revised manuscript. We hope the following questions have been answered:

1) Why Landsat NDVI is more accurate than other products?

The reason is that Landsat sensors have unparalleled radiometric and geometric accuracy and stability with the longest continuity, global coverage, and relatively high spatial resolution (Wulder et al., 2019; Wulder et al., 2016). This has been partially explained in the Introduction section. Now we further state it in the beginning of Section

3.2.1.

2) Does Landsat NDVI have any limitations (e.g. the influence of clouds)?

Landsat NDVI did have limitations. Because of the relative long revisit time and small field-of-view (see Introduction section), it suffers from influences from clouds, cloud shadows, water, snow, aerosols, etc. These limitations make Landsat NDVI unsuitable for global long-term vegetation trend analysis but could be an idea candidate as reference data. This study used a rigorous process that considered abovementioned factors as well as others such as the eruption of Mount Pinatubo and radiation performance to retain high-quality Landsat pixels only (see Section 3.1.1).

3) Adding a plot to show the distribution of these samples (time and space).

A new sub-figure has been added to Figure 3. Now the spatial, seasonal, and interannual distribution of the Landsat NDVI samples are presented.

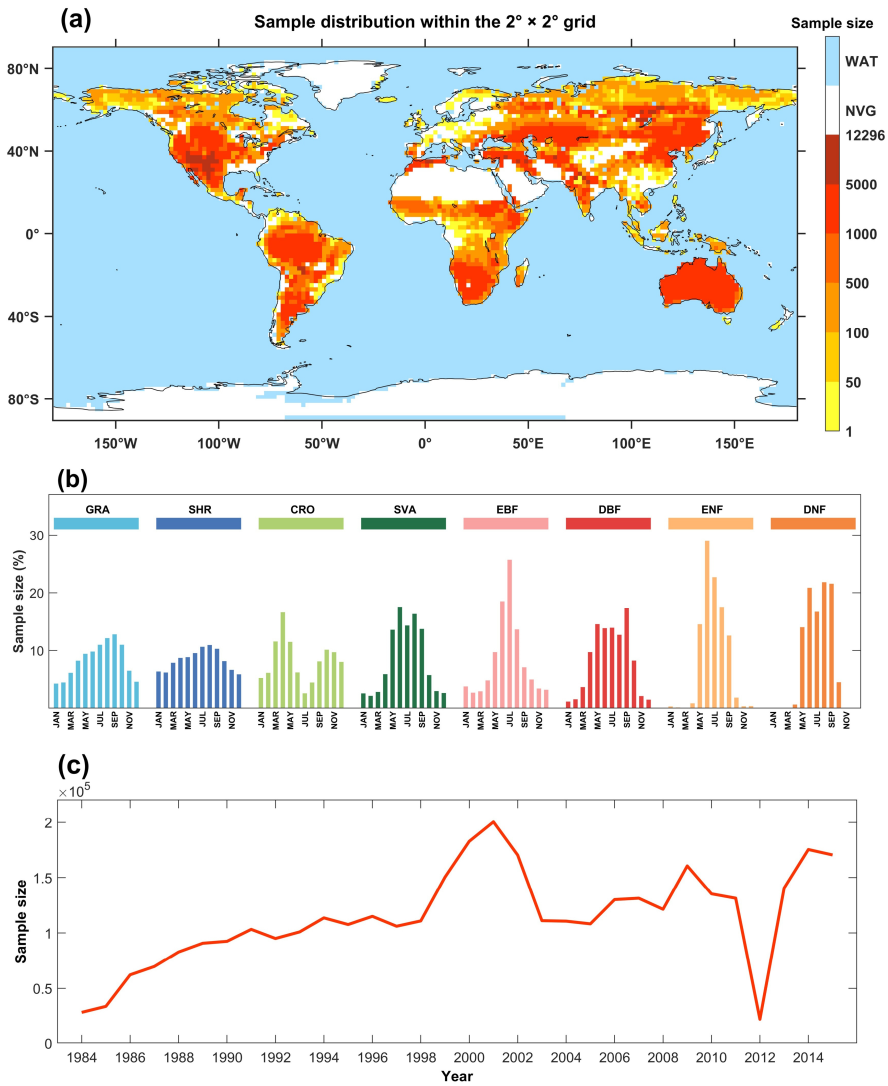

Figure 3. Spatial and temporal distribution of refined Landsat NDVI samples (3.6 million). (a) Distribution of Landsat NDVI samples within the 2° × 2° grid. (b) Percentage of samples among the eight vegetation biome types in each month. (c) Annual variation of Landsat NDVI sample size.

The following changes are made in the revised manuscript:

(a) Landsat NDVI sample selection in Section 3.2.1:

"Landsat data is known for its unparalleled radiometric and geometric accuracy and stability, as well as the longest continuity, global coverage, and relatively high spatial resolution (Wulder et al., 2019; Wulder et al., 2016)." (Page 8, Line 209-211)

(b) Spatiotemporal variations of Landsat NDVI samples in Section 4.2.1:

"During 1984–2015, the Landsat NDVI sample size generally increased from Landsat 5 to Landsat 7 and Landsat 8 except for two periods. Between 1999 and 2003, the sample size was significant larger as both Landsat 5 and Landsat 7 were available; and between November 2011 and May 2012, very few images were acquired when Landsat 5 was decommissioning (https://www.usgs.gov/centers/eros/science/usgs-eros-archive-landsat-archives-landsat-4-5-thematic-mapper-tm-level-1-data) and Landsat 8 was not available yet (Figure 3c).” (Page 13, Line 320-324)

[Comment 3] *Second, this dataset extends the time-span of 1982-2015 for its predecessor to 1982-2020, but there is no figure or analysis of this extension. It would be great to show more details of this extension (e.g. a long time series spanning from 1982 to 2015). In addition, it would be great to explain the results of consolidating the PKU dataset with MODIS NDVI data for the years after 2016. A comparison between MODIS and PKU NDVI datasets from 2017 to 2020 would be helpful (e.g. Figure 12).*

[Response 3] We thank the reviewer for this suggestion. In the revised manuscript, we have updated the Figure 12 to show the full time-span of 1982−2022 and to draw the time-series of all NDVI products involved in this study, i.e., PKU GIMMS NDVI before consolidation (1982−2015), PKU GIMMS NDVI after consolidation (1982−2022), MODIS NDVI (2003−2022), and GIMMS NDVI3g (1982−2015). Biome-specific version of updated Figure 12 has also been implemented in the Appendix. Anomalies and trends of the NDVI products have been compared and analyzed.

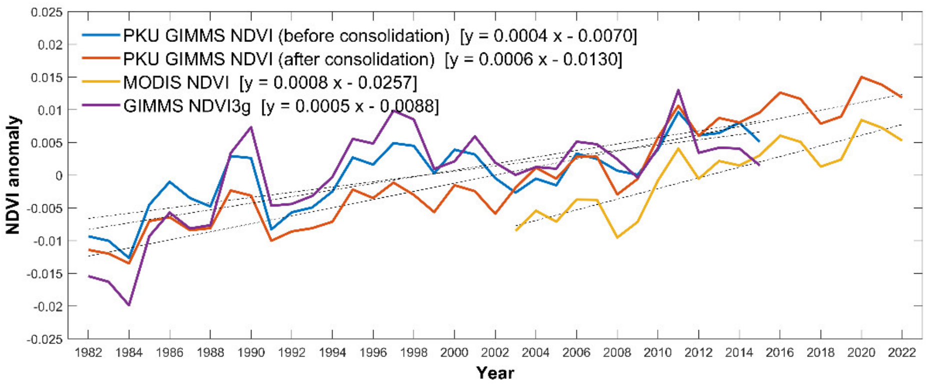

Figure 12. Annual anomalies and trends of PKU GIMMS NDVI (before consolidation), PKU GIMMS NDVI (after consolidation), MODIS NDVI, and GIMMS NDVI3g. The NDVI anomalies were calculated as area-weighted annual averages.

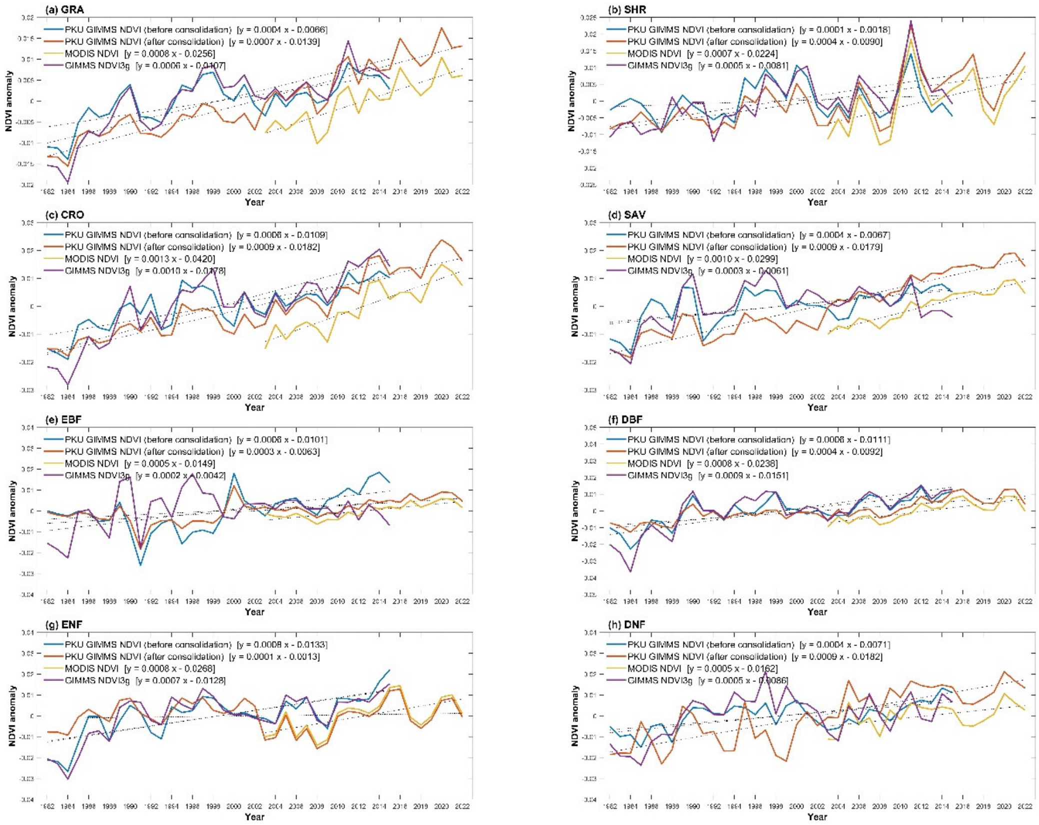

Figure A1. Annual anomalies and trends of PKU GIMMS NDVI (before consolidation), PKU GIMMS NDVI (after consolidation), MODIS NDVI, and GIMMS NDVI3g for different vegetation biome types. The NDVI anomalies were calculated as area-weighted annual averages.

The following changes are made in the revised manuscript:

(a) PKU GIMMS NDVI evaluation in Section 3.4:

"Trends from multiple NDVI products, i.e., GIMMS NDVI3g, MODIS NDVI, and PKU GIMMS NDVI (before and after consolidation), were compared over their overlapping period. The PKU GIMMS NDVI before consolidation was included because it represents the version of our NDVI product that is solely based on AVHRR data, and it can provide a more direct evaluation on the efficacy of the BPNN model and Landsat NDVI samples." (Page 11, Line 291-295)

(b) Vegetation trend analysis in Section 4.3.2:

"The time series of annual NDVI anomalies and trends from different products are shown in Figure 12. All products presented a similar shape of anomalies in their overlapping periods. During 1982−2015, PKU GIMMS NDVI before consolidation had a similar trend with GIMMS NDVI3g (0.4×10^{-3} yr^{-1} vs. 0.5×10^{-3} yr^{-1}). During 2003−2015 when all NDVI products were available, PKU GIMMS NDVI before consolidation (0.8×10^{-3} yr^{-1}), PKU GIMMS NDVI after consolidation (0.9×10^{-3} yr^{-1}), and MODIS NDVI (0.9×10^{-3} yr^{-1}) were similar in vegetation trend (trend values not shown in the Figure), higher than GIMMS NDVI3g (0.5×10^{-3} yr^{-1}). In the EBF area, GIMMS NDVI3g showed a browning trend since 2003 due to the impact of orbital drift and sensor degradation (Figure A1), which was consistent with the research by Wang et al. (2022). In PKU GIMMS NDVI products, the effect of orbital drift and sensor degradation has been alleviated. It showed a greening trend in EBF, consistent with MODIS NDVI (Figure A1)." (Page 22, Line 397-405)

[Comment 4] *Some minor comments: The Landsat NDVI samples were used both to train and validate the PKU GIMMS NDVI dataset. How the Landsat NDVI samples were separated into two groups?*

[Response 4] The Landsat NDVI samples were separated into 80% for model training and 20% for NDVI product evaluation (GIMMS NDVI3g and PKU GIMMS NDVI).

The following changes are made in the revised manuscript:

(a) Introduction to Landsat NDVI sample selection in Section 3.2.1:

"The samples were also divided into 80% for model training and 20% for NDVI product evaluation." (Page 8, Line 217-218)

[Comment 5] *The figure caption for Figure 6 is confusing: comparison of R2 between the GIMMS NDVI4g and PKU GIMMS NDVI products. Is it R2 between the GIMMS NDVI4g and PKU GIMMS NDVI products? Or R2 between the GIMMS NDVI4g and Landsat NDVI, and that between PKU GIMMS NDVI and Landsat NDVI?*

[Response 5] We apologize for the confusion. It is R^2 between the GIMMS NDVI4g and Landsat NDVI, and that between PKU GIMMS NDVI and Landsat NDVI. We have clarified this in the revised manuscript. The way of how R^2 was calculated has also been added.

The following changes are made in the revised manuscript:

(a) Figure 6 caption:

"**Figure 6.** Accuracies of the GIMMS NDVI3g and PKU GIMMS NDVI products measured by R^2 for pre-MODIS (1982–2000) and MODIS (2001–2015) period. The R^2 was calculated between the NDVI products and Landsat NDVI samples. (a) to (d) shows the spatial distributions of R^2 in 2°× 2° grids. Non-vegetated grids and grids with less than 20 validation samples are marked in white. (e) and (f) shows the probability distribution of R^2 differences between the two periods (before 2000 and after 2000) and between the two products (GIMMS NDVI3g and PKU GIMMS NDVI), respectively."

[Comment 6] *Why MOD13C1, not MOD13Q1, MOD13A3 or MOD13C2, is used in this study?*

[Response 6] In this study, the MODIS Vegetation Index product was used to consolidate with PKU GIMMS NDVI after the year 2003. The main differences between MOD13C1 and other MODIS Vegetation Index products are that it is (1) derived from MODIS Terra, (2) 16-day-based, and (3) of 0.05° resolution. MODIS Terra available since 2000 has a longer on-orbit period than MODIS Aqua (available since 2002). The temporal resolution of 16 days and the spatial resolution of 0.05° are close to those of PKU GIMMS NDVI (half-month; 1/12°). As such, MOD13C1 was selected. Note that we could only find year-round global MOD13C1 since 2003 in both USGS Earth Explorer (http://earthexplorer.usgs.gov/) and NASA Earth Data (https://search.earthdata.nasa.gov/search).

The following changes are made in the revised manuscript:

(a) Introduction to MOD13C1 in section 2.3:

"As the MODIS NDVI product was used to consolidate with PKU GIMMS NDVI, we chose MOD13C1 over other MODIS Vegetation Index products because it was derived from MODIS Terra which has been available since 2000 and it has a close temporal (16 days) and spatial resolution (0.05°) to those of PKU GIMMS NDVI (half-month and 1/12°)." (Page 5, Line 130-132)

[Comment 7] *Figure 11: In the PKU dataset, most tropical regions show greening during 2004-2015, which may be unreasonable.*

[Response 7] This is a good comment. The vegetation trend in tropical regions after

2000 has been an arguable topic. In terms of NDVI, there is a substantial difference between existing GIMMS-based (from AVHRR) and MODIS-based products. Current findings from multiple studies suggested that in tropical regions GIMMS-based NDVI presented a decreasing trend while MODIS-based NDVI presented an increasing trend (Fensholt and Proud, 2012; Tian et al., 2015; Wang et al., 2022). Possible reasons of the trend discrepancy in tropical/humid area could be lack of high-quality data (Fensholt and Proud, 2012), orbital drift effects for GIMMS NDVI (Tian et al., 2015), and NDVI saturation (Wang et al., 2022). In the generation of PKU GIMMS NDVI, we attempted to account for all these factors. For example, we used global long-term massive high-quality Landsat NDVI as reference data to calibrate GIMMS NDVI3g via BPNN models. The BPNN models employed multiple types of explanatory variables to further explain NDVI variations in time, space, and satellite. The effects of NOAA satellite orbital drift and AVHRR sensor degradation have been efficiently eliminated in PKU GIMMS NDVI. After the efforts, PKU GIMMS NDVI (before or after consolidation with MODIS NDVI) demonstrated an increasing trend in tropical regions, as the reviewer has figured out in the Figure 11. Whereas this phenomenon in PKU GIMMS NDVI is different from old versions of GIMMS-based NDVI products, we believe that PKU GIMMS NDVI could be a more reliable reference in studying long-term vegetation trends, especially in tropical regions. This point of view has been discussed in the revised manuscript.

The following changes are made in the revised manuscript:

(a) Introduction to MOD13C1 in section 2.3:

"The improvements in PKU GIMMS NDVI may help to clarify some discrepancies between existing NDVI products, for instance, the vegetation trend in humid tropical regions after 2000. In these regions, current findings from multiple studies suggested that GIMMS-based NDVI presented a decreasing trend while MODIS-based NDVI presented an increasing trend (Fensholt and Proud, 2012; Tian et al., 2015; Wang et al., 2022). Possible reasons could be the uncertainties from NDVI saturation or lack of high-quality data (Fensholt and Proud, 2012; Wang et al., 2022) and orbital drift effects for GIMMS NDVI (Tian et al., 2015). In the generation of PKU GIMMS NDVI, these uncertainties have been well accounted for and we found an increasing NDVI trend in tropical regions after 2000, both before and after data consolidation with MODIS NDVI." (Page 24, Line 427-433)

[Comment 8] *Figure 4: S5 shows no significant improvement compared to S4.*

[Response 8] We agree with the reviewer that S5 shows no significant improvement compared to S4. Indeed, we were also struggling between S4 and S5 when establishing BPNN models. But after analyzing all four error metrics (R^2, RMSE, MAE, and MAPE), we determined that S5 did provide some improvement over S4 in all vegetation biomes despite the improvement was generally subtle. In the end, we chose to use S5 where NDVI, spatial information, time information, NOAA satellite number and years since its launch were included in BPNN models.

[Comment 9] *Figure 8: A color bar is missing.*

[Response 9] Thanks. Color bars have been added to sub-figures in the revised manuscript.

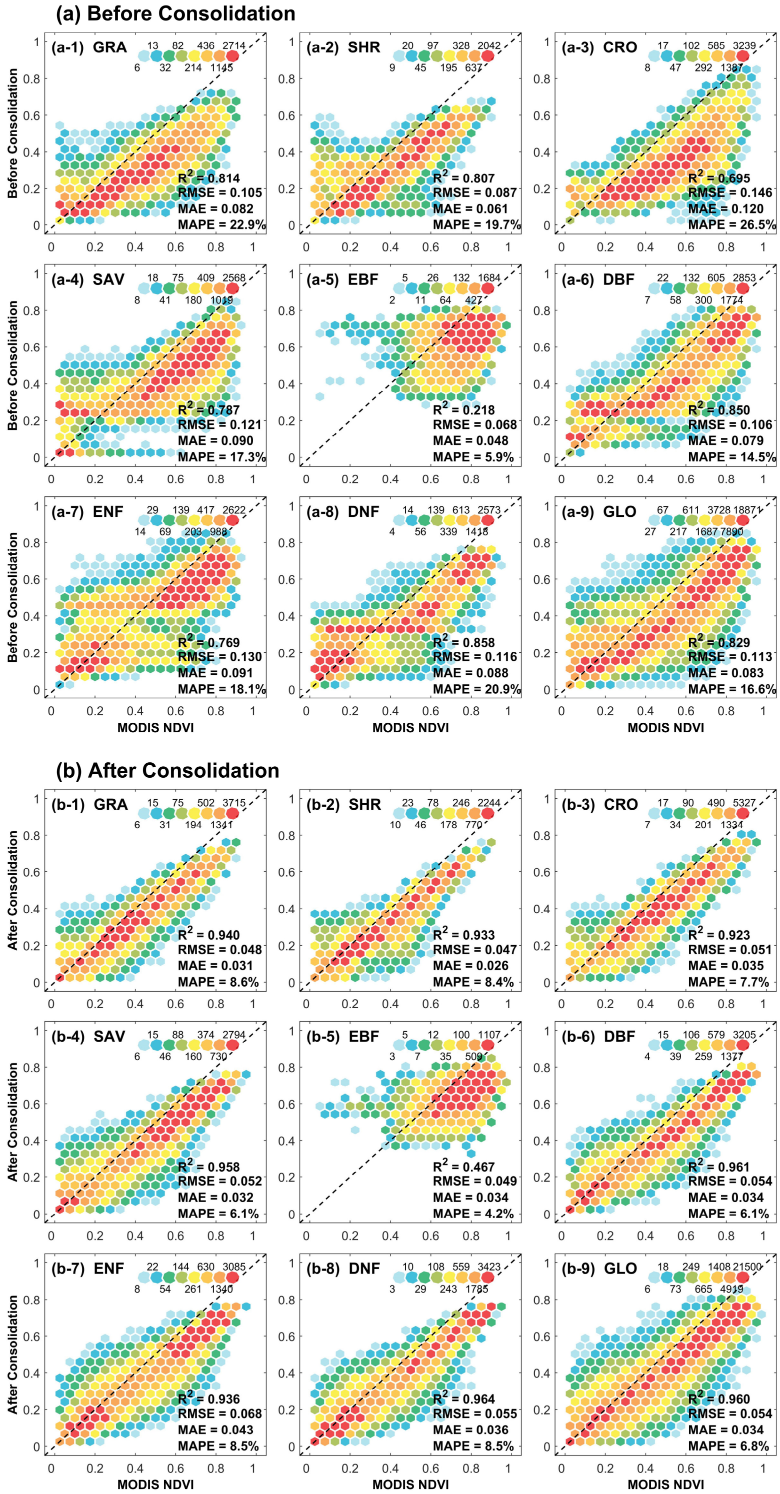

Figure 8. Direct validation of the PKU GIMMS NDVI product (a) before and (b) after consolidation. The validation was performed using 1,000 MODIS NDVI samples at a 1/12° resolution for each vegetation biome type from 2004 to 2015.

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Fensholt, R., and Proud, S.R.: Evaluation of Earth Observation based global long term vegetation trends — Comparing GIMMS and MODIS global NDVI time series, Remote Sens Environ, 119, 131–147, https://doi.org/10.1016/j.rse.2011.12.015, 2012.

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