Topic editor Public justification (visible to the public if the article is accepted and published):

The reviewers and I appreciate the significant improvements made to the manuscript in this revision. However, a critical concern remains regarding the image data processing workflow. As noted by Reviewer, the current description is still unconvincing and may undermine the reliability of your findings. Please provide a more detailed justification of your methodology to ensure the results are robust and reproducible.

Reply: Thank you very much for the careful evaluation and constructive comment. Following the reviewer's suggestion, we conducted additional analyses and substantially expanded the methodological justification regarding the multi-year compositing strategy, including additional comparisons, validation analyses, and uncertainty discussion. Detailed responses and corresponding revisions are provided below. We hope these additional analyses and clarifications adequately address the remaining concerns regarding the robustness of the methodology.

Anonymous Referee #2 (Report #1)

The main issues have been resolved, but given the 69.8% Producer Accuracy for 1995 in Table S1, please note in the manuscript that the total rice area in the early years may have been underestimated.

(All revisions and responses are highlighted in blue font in the response letter.)

Reply: We sincerely appreciate the Reviewer for this valuable suggestion. We agree that the relatively low Producer Accuracy for 1995 (69.8% in Table S1) indicates that the rice planting areas in the early years may have been underestimated due to limited valid observations and data scarcity. Following the Reviewer's recommendation, we have added the following statement to the revised manuscript to transparently acknowledge this limitation:

Lines 251-255: *"Based on remote sensing retrievals, the rice planting area across South and mainland Southeast Asian countries has increased by approximately 22.5 million hectares since the 1990s, with the largest increases observed in India and Bangladesh. However, we note that the total rice area in the early years may have been underestimated due to limited valid observations and data constraints."*

This clarification explicitly addresses the uncertainty associated with the early-period estimates without altering the core historical trends presented in our dataset.

Anonymous Referee #1 (Report #2)

It is recommended that the cartographic uncertainties introduced by the five-year compositing approach be analyzed in detail.

1. Your response to Comment 2 has not sufficiently convinced me. Based on my prior experience in crop mapping, although a large proportion of cropland remains under stable cultivation, fields with alternating crop types are common. My main concern lies in your mapping pipeline: the use of a five-year composite image introduces a non-negligible systematic bias. This approach not only fails to capture short-term multiple cropping practices but is also inadequate for detecting multi-year changes in cropping patterns. However, the evidence provided in your response does not adequately address this concern. While I understand that, due to observational gaps, single-year Landsat imagery may not fully support rice mapping in certain years, the straightforward use of a five-year composite as a proxy for a single year is, in my view, not a responsible approach. Furthermore, the flood signal mentioned in your response is derived from a five-year composite (1993–1997) and therefore cannot serve as a valid reference for a specific year. In addition, unlike your study, which performs fine-grained crop classification, land-cover products such as GLC_FCS30 and CLCDs do not distinguish crop types in detail. As a result, crop rotation among different species does not affect the definition or spatial extent of the “Cropland” category in those datasets. Please also provide appropriate references for the methods or data products mentioned in your response for further consultation. Additionally, please include references for the methods or datasets mentioned in your response for reference. To help address this issue, I would like to suggest a possible approach. In regions such as South and Southeast Asia, where Sentinel and Landsat 8/9 data can be jointly utilized in recent years (e.g., 2020–2025), you could perform annual mapping using yearly composites. The denser observations during these years can alleviate data scarcity issues. You can then analyze interannual variations in rice distribution. If significant differences are observed, this would indicate that the earlier five-year composite approach introduces substantial systematic bias, and alternative strategies (e.g., multi-source data fusion) should be considered. Conversely, if the differences remain within an acceptable range—ideally smaller than the classification error introduced by the algorithm—then the impact of the compositing strategy on the final dataset quality may be considered controllable.

(All revisions and responses are highlighted in blue font in the response letter.)

Reply: We express our sincere gratitude to the Reviewer for this important and constructive comment. We agree that while a multi-year compositing strategy expands data density, it inherently risks smoothing interannual variability or obscuring year-to-year changes in rice distribution and cropping intensity. To address this concern with rigorous evidence, we followed the Reviewer’s suggestion: we deployed our phenology-based workflow on a strictly single-year basis to generate annual rice-intensity maps for the recent data-rich period (2021-2025), utilizing only the Landsat and Sentinel-2 observations available within each discrete calendar year. We systematically cross-compared these annual maps with our five-year composite products to assess potential systematic biases and map stability.

To better analyze the results, we stratified the comparative analysis into two distinct agricultural zones characterized by different cropping systems. The first region includes the mainland Southeast Asian countries and Bangladesh, where rice is the dominant staple and multi-season rice systems prevail. The second region includes India and Pakistan, where rice–wheat rotation and complex agrosystems are widespread, and non-rice croplands occupy a much larger landscape fraction.

1. Southeast Asia and Bangladesh

For mainland Southeast Asia and Bangladesh, the annual maps from 2021-2025 demonstrate a high degree of spatial stability in the core rice-growing boundaries (Fig. R1, note: *all figure and table numbers prefixed with "R" are unique to this* ***response*** *document*). The interannual discrepancies are concentrated in cropping intensity rather than in the spatial boundary of rice cultivation. Local interannual variations are visible in certain rainfed zones (e.g., eastern Thailand), yet these fluctuations remain minor in spatial extent and do not disrupt the overall regional distribution. Compared to the single-year annual maps, the five-year composite introduces no discernible spatial artifacts, nor does it suffer from large-scale omission or commission errors. This demonstrates that the five-year composite preserves the dominant regional rice distribution patterns while effectively reducing the impact of single-year observation gaps.

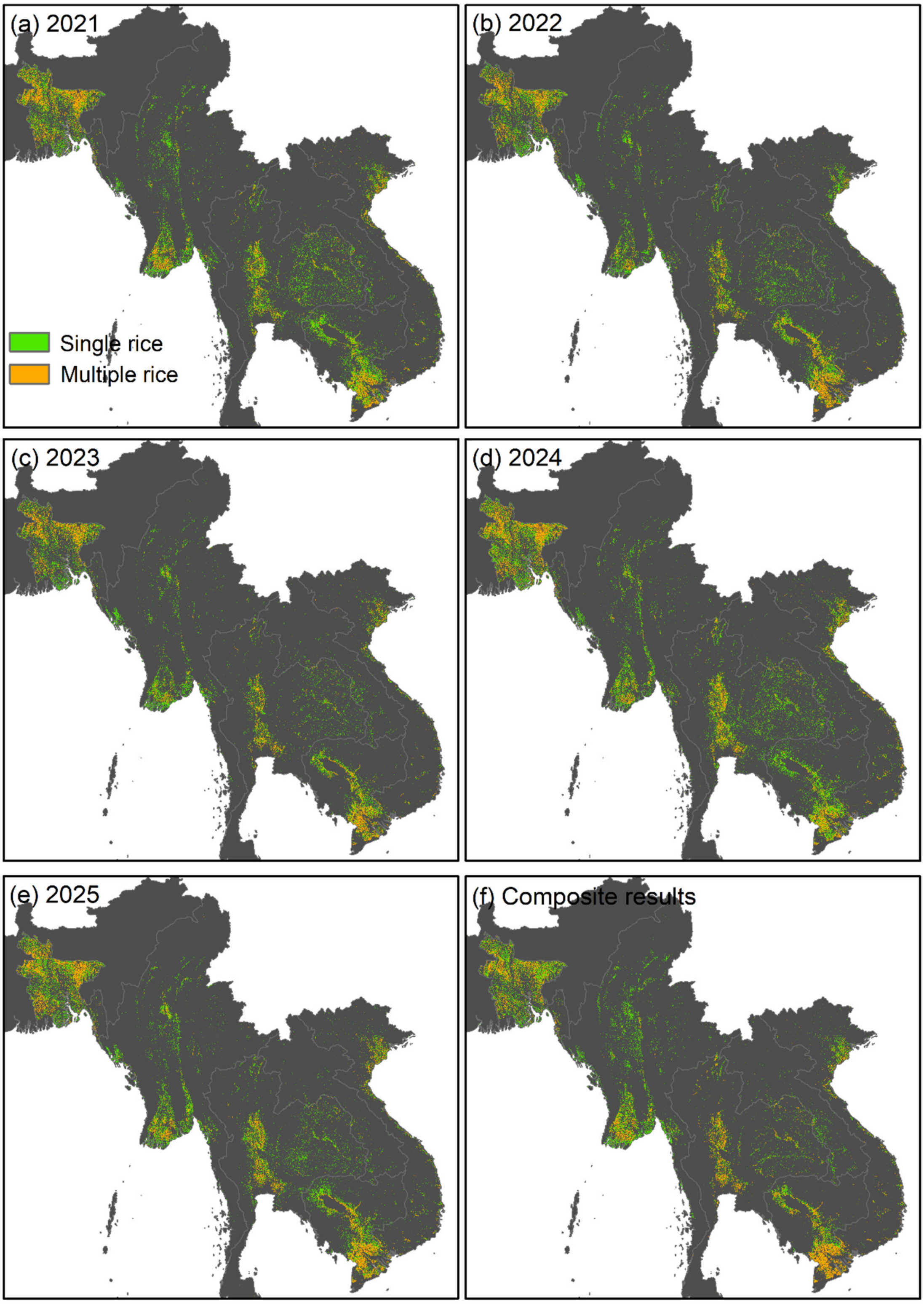

Fig. R1 Comparison of annual and five-year composite rice cropping intensity maps in mainland Southeast Asia and Bangladesh from 2021 to 2025. Panels (a)-(e) display the annual distribution of single- and multiple-season rice derived from single-year observations, while panel (f) presents the five-year composite result using the same algorithm.

In the detailed examples shown in Fig. R2, we focused on Myanmar and Vietnam (Ayeyarwady Delta and Mekong Delta), which represent the most intensive multi-season rice hotspots in our study area. The interannual differences in these regions primarily manifest as intensity fluctuations rather than spatial expansion or crop-type substitution. The interannual differences are driven heavily by variations in cloud-free observation availability and slight phenological timing offsets. Specifically, triple-season rice systems in these regions often overlap across calendar years; the initial planting cycle frequently initiates in October or November of the preceding year and concludes in the next. Consequently, single-year mapping results suffer from omission errors if valid observations are scarce during those transitional months. The composite product tends to preserve the maximum observed cropping intensity across years in these areas, indicating that the flood-related signals were not substantially smoothed out by the five-year compositing strategy.

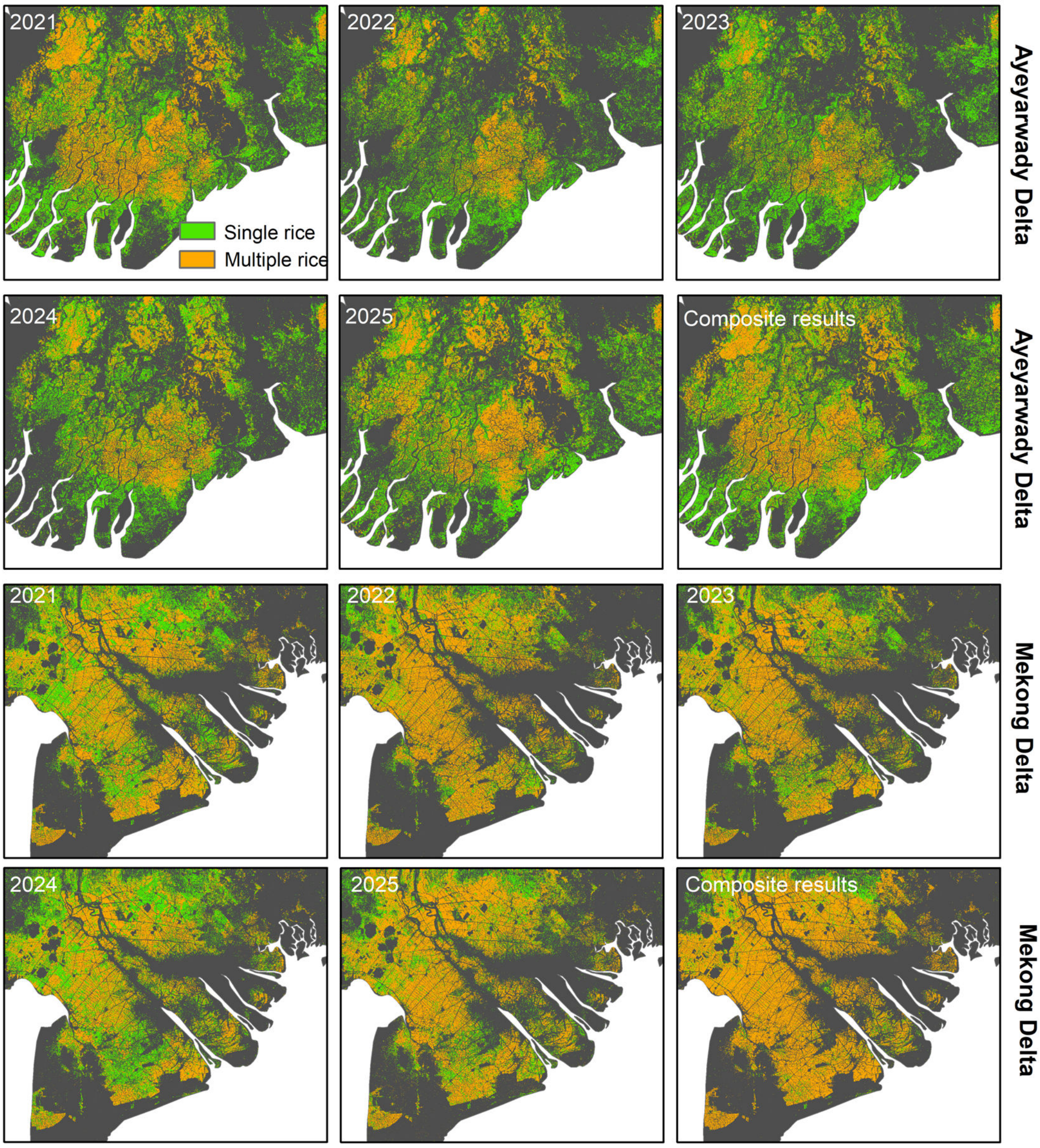

Fig. R2 Detailed local views of annual (2021–2025) and five-year composite rice cropping intensity maps in typical high-intensity, multi-season rice producing areas of Ayeyarwady Delta (top two rows) and Mekong Delta (bottom two rows).

2. South Asia (India and Pakistan)

In the complex agrosystems of India and Pakistan, interannual discrepancies between the annual maps are more pronounced, particularly across northern India where rice–wheat rotation is predominant (Fig. R3). Crucially, our analysis reveals that this spatial inconsistency is largely associated with optical data availability during the critical rice transplanting window, rather than rapid changes in farmer behavior. In this region, heavy monsoon cloud decks, agricultural aerosol haze, and seasonal observation gaps substantially reduce the count of usable images in specific years, rendering single-year optical mapping less stable. Table R1 presents the validation matrices calculated from randomly distributed, visually interpreted ground-truth points across northern India. The five-year composite product does not achieve the highest OA or F1 score in every individual year, which is consistent with the Reviewer's concern that five-year compositing may influence the flooding signal and the detection of interannual crop changes. However, the data reveal an important trade-off: years with relatively low cloud-free scene counts (e.g., 2022) exhibit severe accuracy degradation (OA = 0.788). Furthermore, the accuracies of 2021, 2022, and 2025 single-year outputs are markedly lower than those of the composite product. This quantitative evidence indicates that under data-scarce conditions, the benefit of multi-year compositing in stabilizing the phenological signature significantly outweighs the localized detail lost to temporal smoothing.

Table R1. Accuracy assessment of the annual and composite mapping results.

Year	**OA**	**UA**	**PA**	**F1-Score**
Composite results	0.855	0.942	0.792	0.861
2021	0.830	0.914	0.729	0.811
2022	0.788	0.783	0.797	0.789
2023	0.871	0.877	0.876	0.877
2024	0.879	0.903	0.861	0.882
2025	0.822	0.975	0.610	0.750

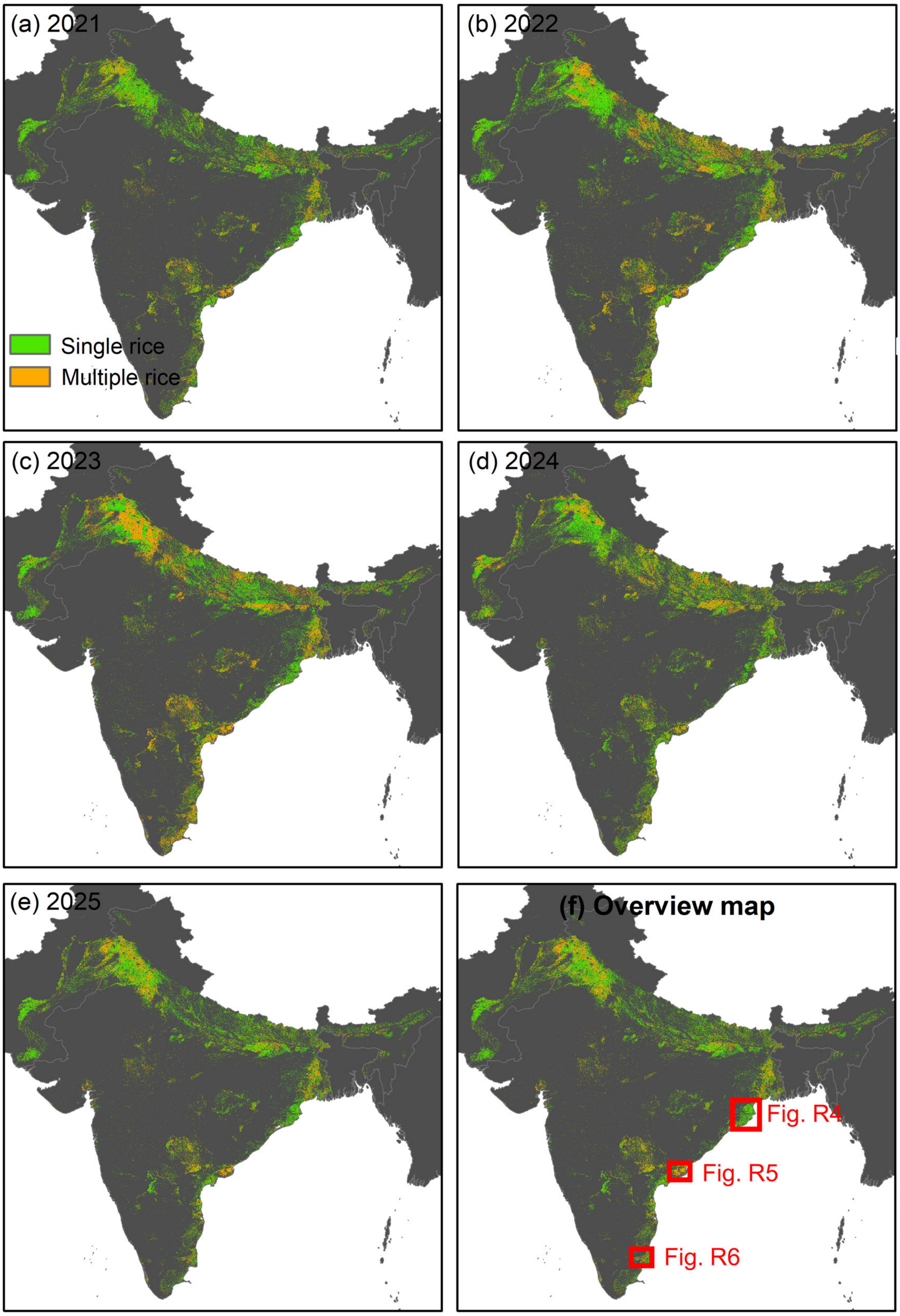

Fig. R3 Annual rice cropping intensity maps for India from 2021 to 2025. The maps illustrate interannual variations across the subcontinent. An overview locator map is included to indicate the specific spatial extents (red bounding boxes) of the local regions detailed in subsequent figures (e.g., Fig. R4, Fig. R5, Fig. R6).

(Note: To facilitate a clearer spatial reference for the reviewer, we have embedded an overview map within this figure (Fig. R3f). The red bounding boxes delineate the exact geographical locations of the zoomed-in, fine-scale analyses presented in the following sections.)

We further examined representative areas in eastern India (Fig. R4), where the largest discrepancy occurs in 2024 as severe striping artifacts due to uncorrectable observation limitations. Conversely, the results in the other years are highly consistent. For southern India (Fig. R5), which features typical double-season rice, the annual maps capture a relatively stable double-cropping pattern, with discrepancies again spiking in 2024 due to cloud-masking artifacts that erroneously omit double-season rice areas in the western sector.

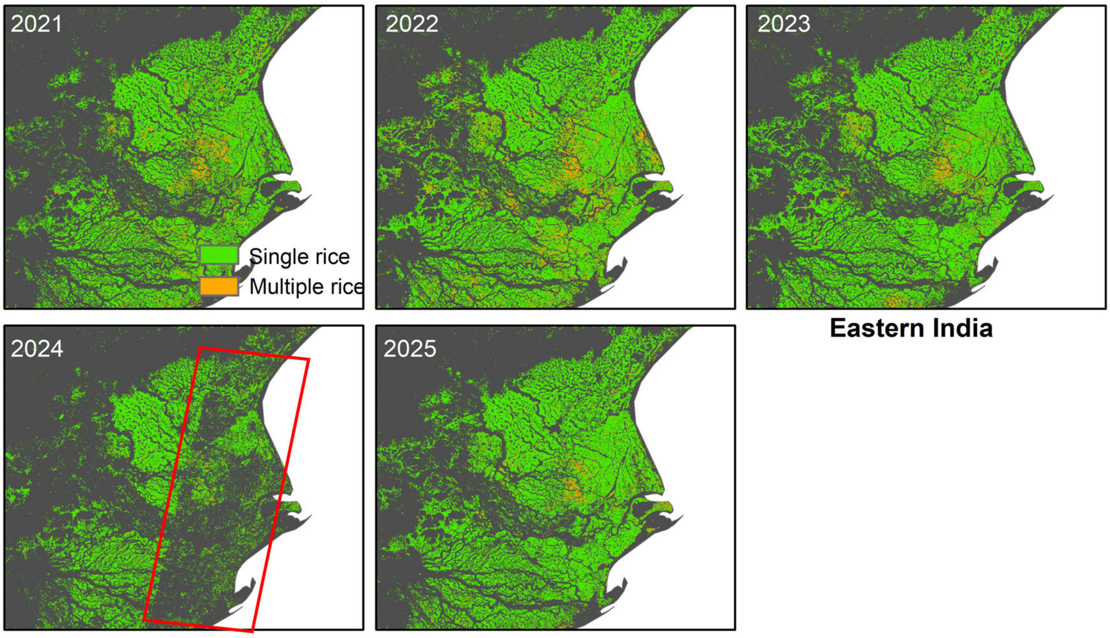

Fig. R4 Detailed annual rice cropping intensity maps (2021-2025) for the major rice-producing regions in eastern India. The exact geographical location of this region is indicated by the red bounding box labeled ‘R4’ in the overview map (Fig. R3). While the spatial distribution is generally consistent across most years, distinct satellite orbit observation gaps are clearly visible in the 2024 mapping result, highlighting how missing optical data can severely degrade single-year mapping accuracy.

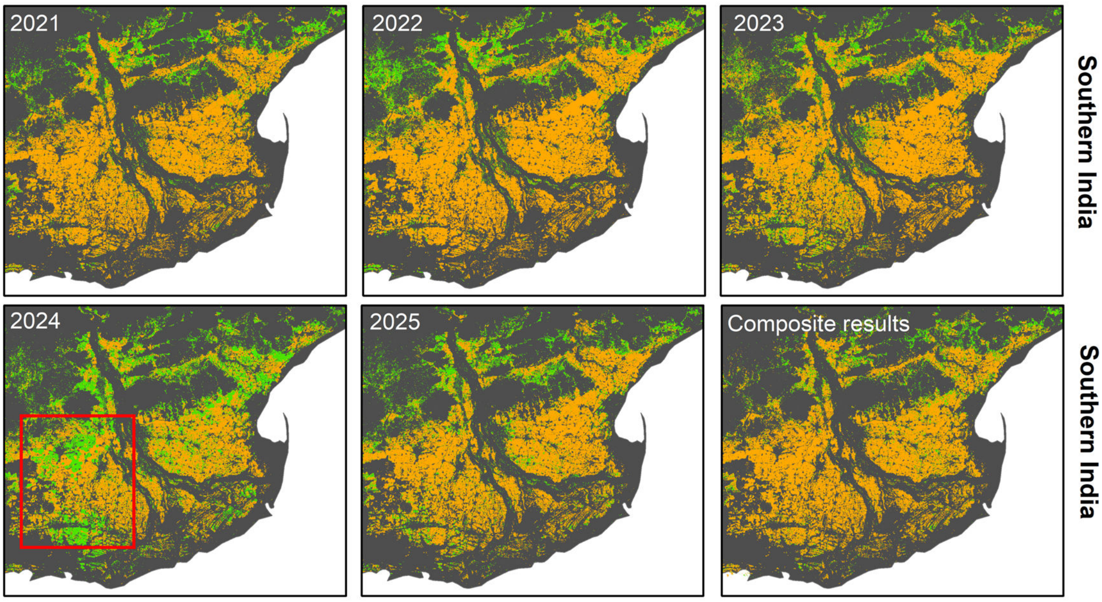

Fig. R5 Local-scale comparison of annual (2021–2025) and five-year composite rice cropping intensity maps in a typical double-season rice region of southern India. The spatial extent of this local region corresponds to the red bounding box labeled ‘R5’ in the overview map (Fig. R3).

Overall, we acknowledge that localized crop rotations and interannual cropping intensity shifts occur across South and Southeast Asia, as illustrated by the nuanced single-year captures in Fig. R6 (e.g., southern India in 2022 and 2023). However, our extensive 2021–2025 annual mapping experiment demonstrates that across these tropical, monsoon-dominated, and highly flood-prone regions, the lack of continuous, cloud-free optical observations remains the primary bottleneck for accurate rice mapping. On a regional scale, the actual interannual variation introduced by crop rotation is smaller than the severe, artificial omission errors triggered by data gaps when forcing a single-year timeline. While generating an annual dataset is undeniably the ideal standard for downstream applications like food security assessment, the lack of long-term Sentinel-1 SAR observations and the extremely low frequency of usable Landsat imagery during the 1990s and 2000s mean that single-year mapping in the early eras yields unstable results heavily compromised by cloud and data gaps. Therefore, our five-year compositing strategy is a deliberate, scientifically justified compromise designed to ensure sufficient data coverage across decades.

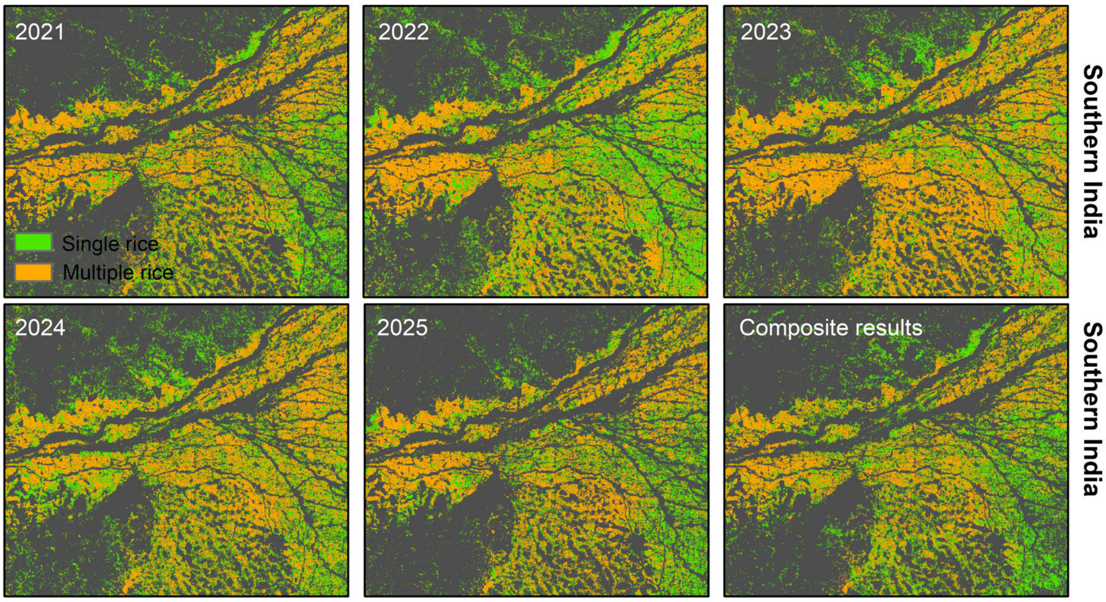

Fig. R6 Fine-scale distribution of single- and multiple-season rice from 2021 to 2025 compared with the composite results in another major double-season rice delta of southern India. The specific location of this delta is highlighted by the red bounding box labeled 'R6' in the overview map (Fig. R3).

Regarding references for this methodology, we direct the Reviewer to a highly relevant study published in *ISPRS Journal of Photogrammetry and Remote Sensing* focused on long-term historical rice mapping under Google Earth Engine (*Carrasco et al., Historical mapping of rice fields in Japan using phenology and temporally aggregated Landsat images in Google Earth Engine*, 2022, 191,1-17, https://doi.org/10.1016/j.isprsjprs.2022.07.018). Faced with identical observation bottlenecks in cloud-prone Asian rice landscapes, the authors employed the same five-year temporal aggregation framework to stabilize early-era Landsat records. As stated in Section 2.4 of their manuscript: *"We divided all available Landsat images (after pre-processing and extracting spectral indices) into collections of* ***five-year periods: 1985–89, 1990–94, 1995–99, 2000–04, 2005–09, 2010–14, and 2015–19.*** *Due to gaps in the data, which were created by cloud cover or the failure of Landsat 7's SLC, the number of available data-filled pixels per year varies spatially. Based on a preliminary analysis,* ***five years was the smallest time interval that provided a sufficient number of images for performing temporal aggregation*** *(i.e., calculating median values)."*

We hope this extensive experimental validation, supported by the 2021-2025 comparative mapping and relevant literature alignment fully addresses the Reviewer's concerns regarding systematic bias of the compositing approach.

2. In your response to Comment 5, the figure numbering is inconsistent with those referenced

in the response letter. I am also unclear about what is meant by the “Figure 5 panel labels” mentioned in the caption of Figure S5—whether this refers to Figure 5 in the response letter, Figure 5 in the revised manuscript, or Figure 6 in the revised manuscript. While occasional formatting errors in figures may be understandable as oversight, such inconsistencies appear repeatedly across the manuscript, response letter, and supplementary materials. This raises concerns regarding the overall rigor and professionalism of the work. I strongly recommend that you carefully review the entire document to eliminate such issues. As a suggestion, you may consider adopting a consistent naming convention to distinguish figures across different components: for example, using “Figure x” in the main manuscript, “Figure Rx” in the response letter, and “Figure Sx” in the supplementary materials. If necessary, the correspondence between figures can be explicitly clarified in the response letter, for instance: “The revised results have been updated in Figure R1 (corresponding to Figure 5 in the revised manuscript).”

Reply: We sincerely apologize for this oversight and deeply appreciate the Reviewer’s constructive guidance regarding document rigor. During our previous revision, one additional figure was inserted into the main manuscript, which caused the original Fig. 5 to be renumbered as Fig. 6. However, the corresponding references in the caption of the original Fig. S5 (now revised as Fig. S3) were not updated accordingly, and the description was not sufficiently clear, leading to confusion.

To rectify this across the entire submission, we have now carefully checked the main manuscript, response letter, and supplementary materials to ensure absolute consistency in all graphical citations, numbers, and descriptive captions.

Following the Reviewer’s recommendation, we have adopted a consistent naming convention to avoid ambiguity:

Fig. X exclusively denotes figures embedded within the main manuscript.

Fig. RX exclusively denotes figures generated for the response letter.

Fig. SX exclusively denotes figures compiled in the Supplementary Materials.

Furthermore, we have revised the caption of Fig. S3 (formerly Fig. S5) to eliminate the ambiguous cross-reference to the main text and to provide a clearer description of the underlying data panels.

All figure numbers and captions related to Comment 5 have been carefully checked and are now consistent across the revised manuscript, response letter, and supplementary materials. The following is the revised version with corrected figure numbers for the original Comment 5.

Comment 5: “The qualitative comparison results presented in **Figures 4, 5, and S2** do not include corresponding remote-sensing images, making it difficult to visually assess the reliability of the mapping outcomes. Moreover, the figures mainly show large-scale regional patterns, while finer spatial details are not adequately displayed. It is recommended to include zoomed-in comparisons with reference imagery to better demonstrate the spatial accuracy and consistency of the rice mapping results."

Reply: We appreciate this important suggestion and agree that the qualitative comparison figures can be substantially improved by incorporating reference imagery and finer spatial details.

In the revised manuscript, we have comprehensively redesigned the comparison figures as follows:

1. **Original Figure 4** mentioned in Comment 5 **(now presented as Fig. R7 in this response letter, corresponding to Fig. 5 in the revised manuscript)** has been updated to include both regional-scale comparisons and field-scale zoom-in views. The rightmost panels now additionally include corresponding Sentinel-1 SAR and Landsat imagery using appropriate false-color composites to provide visual validation of the rice mapping results.

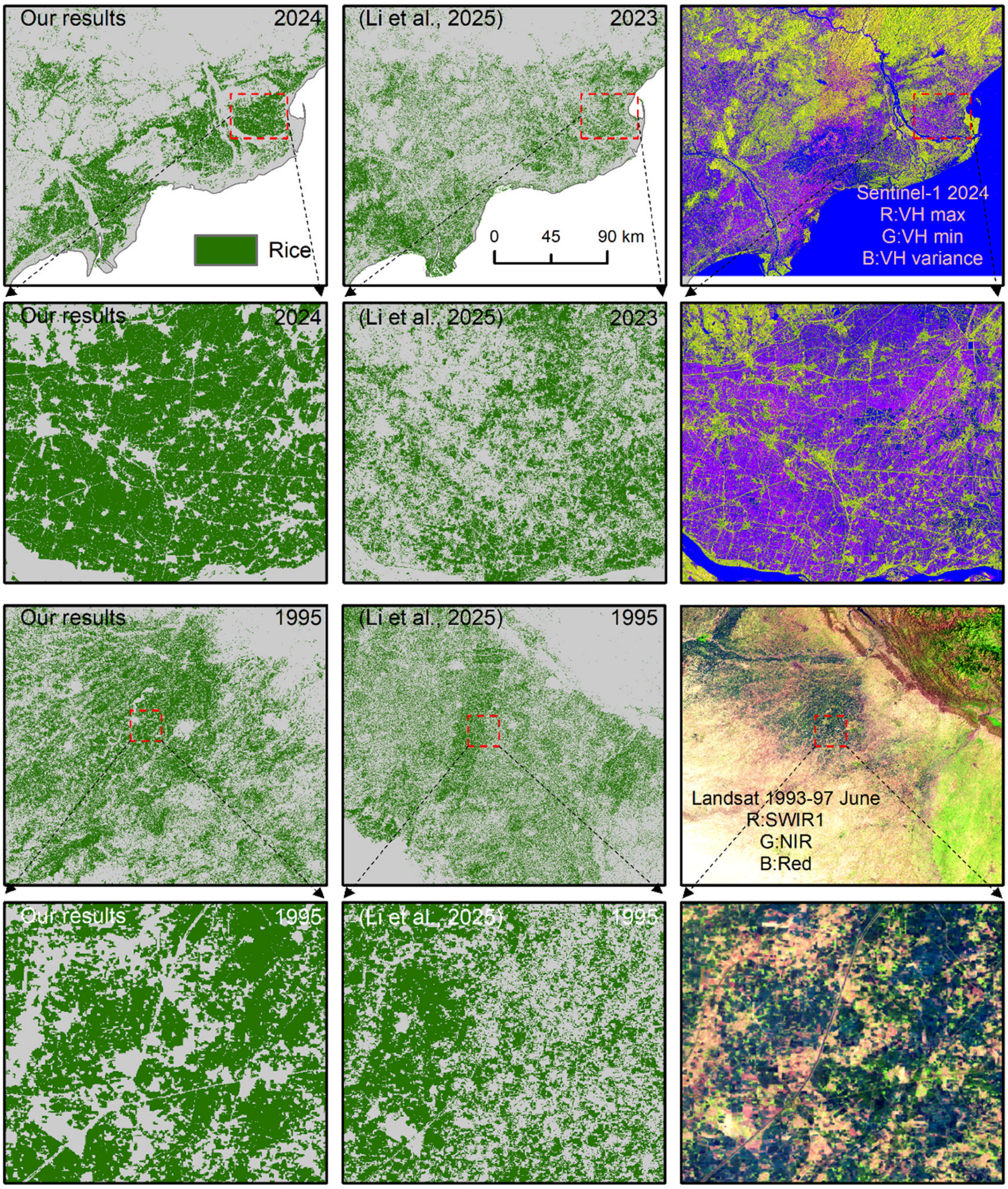

Fig. R7 (corresponding to Fig. 5 in the revised manuscript). Comparison of rice distribution maps: Our Results compared to Li et al. (2025) for South Asia (1995, 2024).

2. **The original Figure 5** presents a comparative analysis of single- and multi-season rice field distribution in Southeast Asia. To avoid excessive visual complexity within the main text, we added a new supplementary figure focusing specifically on field-scale details **(Fig. R8 in this response letter, corresponding to Fig. S3 in the revised supplementary materials)**, following the reviewer's suggestion. This figure demonstrates strong spatial agreement between our results and Open-SEA-Rice-10 at the parcel scale, particularly for multi-season rice systems, while also highlighting omission errors in some single-year optical products (e.g., NESEA-

Rice10) caused by limitations in data availability.

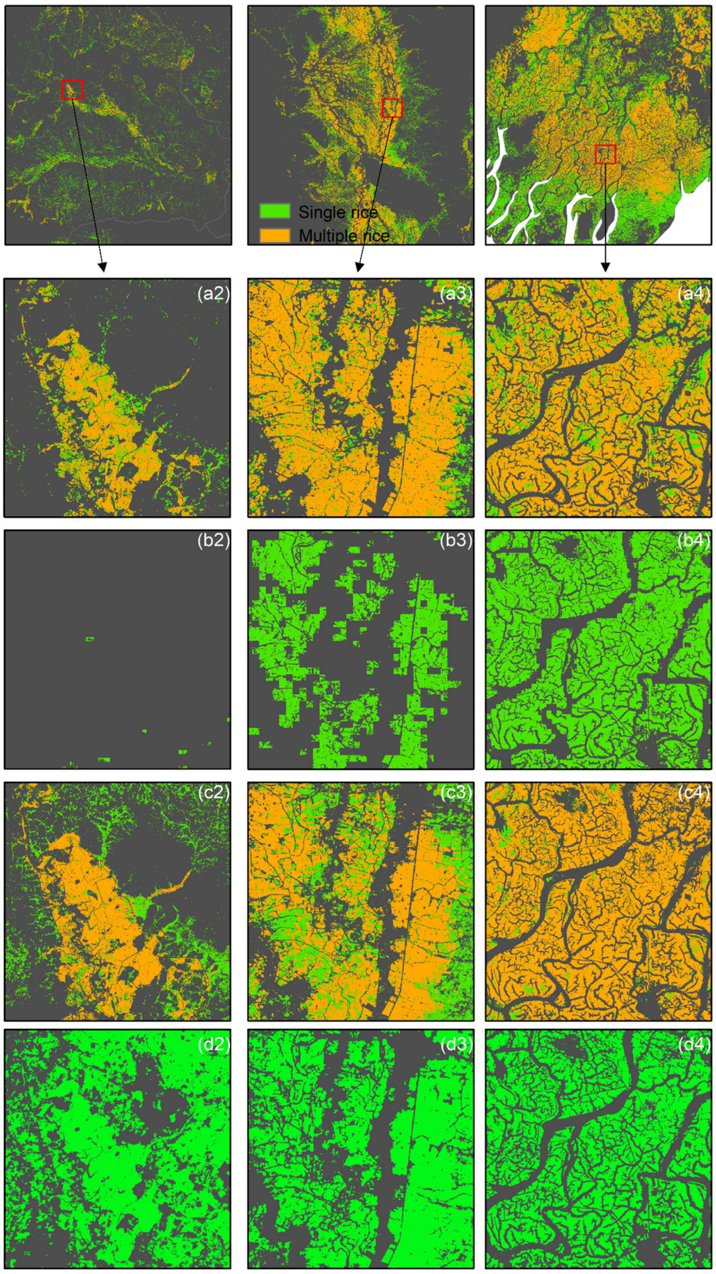

Fig. R8 (corresponding to Fig. S3 in the revised supplementary materials). Field-scale comparison of rice distribution maps. The top row displays the regional overview maps, with red bounding boxes indicating the specific locations selected for magnification.

3. **The original Figure S2 (retaining its position as Fig. S2 in the revised Supplementary Materials and shown as Fig. R9 in this response letter)** has been significantly expanded. In addition to the original country-scale comparison for Vietnam, we included zoomed-in comparisons over the Mekong Delta and the Red River Delta, together with the corresponding Sentinel-1 SAR imagery. These high-resolution comparisons show strong consistency between our mapped rice areas and the radar-derived flooding signals.

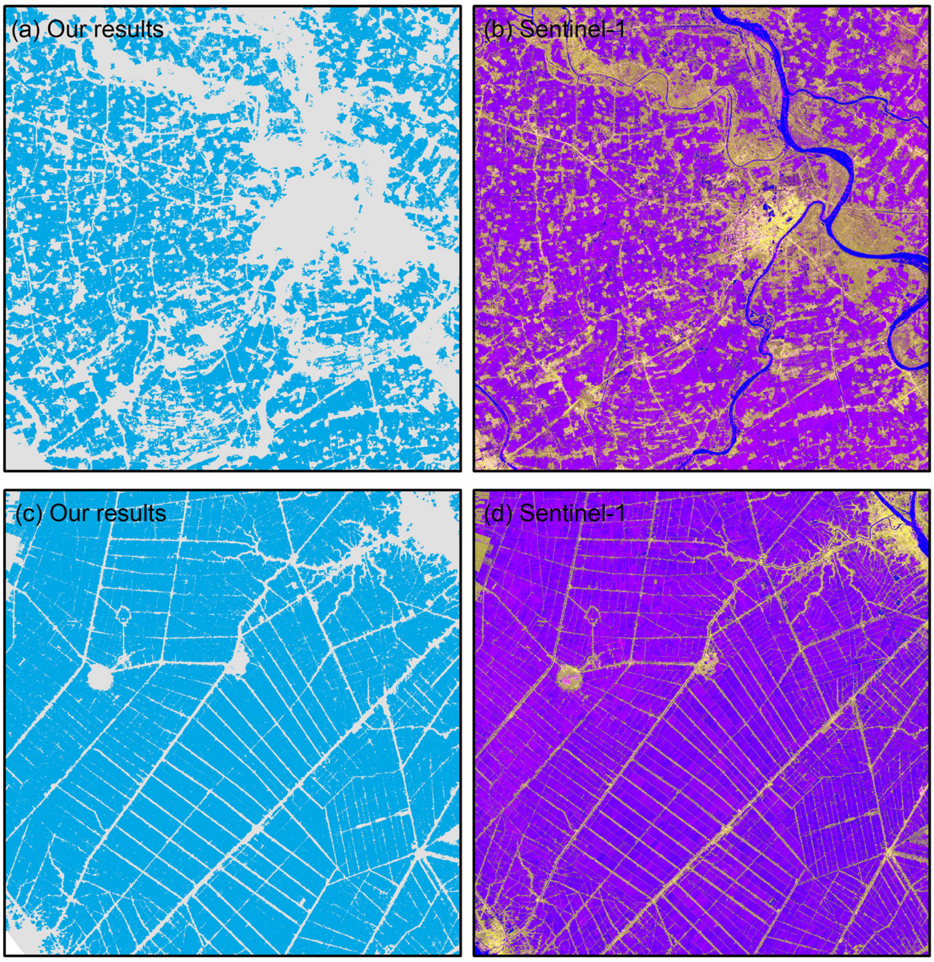

Fig. R9 (corresponding to Fig. S2 in the revised supplementary materials). Spatial comparison of rice distribution maps and reference imagery over selected regions in Vietnam, highlighting consistency between optical- and SAR-based rice detection.

Notification to the authors:

Regarding figure 1: this contains maps/aerials. To clarify whether a copyright statement or a credit must be given in the image itself or in the caption, we differentiate between (a) maps entirely created by you, (b) maps/aerials created by you but based on layers reused from other originators, or (c) maps/aerials simply reused from other originators. An example for (a) is a digital elevation model (DEM) purely based on measurement points collected by you and derived by using a software product. If you use an existing map layer from another originator as a basis for significantly enriching the map with your own content, this would be an example for case (b). Case (c) could be a pure reproduction of Google Maps where your own contribution is rather small (e.g. a city map where you only added a few marks for your study locations). If the map was entirely created by you (case a), there is no need to change the caption or map. Please simply inform us. To the contrary, if your maps/aerials follows cases (b) or (c), please let us know whether the map is distributed under public domain. If yes, please do not include a copyright statement (copyright is waived) but consider adding a credit to the map or caption. However, if your maps/aerials follows cases (b) or (c) and is not distributed under public domain, please include at least a credit or even a copyright statement, if this is required by the map provider, in the map itself or in the caption. For further information please see our website: https://publications.copernicus.org/for_authors/manuscript_preparation.html#mapsaerials

Dear Editor,

Regarding Fig. 1, this map falls under case (b): it was entirely created by the authors but integrates existing spatial layers and datasets retrieved from external originators.

In accordance with the Copernicus manuscript preparation guidelines, we have explicitly updated the figure caption in the revised manuscript to include the appropriate credits and copyright statements for each constituent layer, as specified below:

1. Administrative Boundaries: Sourced from Natural Earth, which is distributed under the public domain (copyright waived).

2. Agricultural Statistics: Reused from the Food and Agriculture Organization (FAO) database.

3. Satellite Imagery Insets: We have included the mandatory copyright and credit statements directly into the figure itself, as required by the imagery provider.

We have also added a standard boundary disclaimer to the caption in the revised manuscript to ensure complete administrative neutrality.

Thank you for bringing this important matter to our attention.

Best regards,

Zizhang Zhao, Geli Zhang, and all coauthors