Responses to RC #1

Dear Reviewer,

Thank you very much for your helpful comments. The manuscript has been fully revised according to your suggestions. The following is a point-to-point response to your comments, and responses are in **blue.**

General comments.

This very interesting paper use machine learning and deep learning on Sentinel-2 10 m GSD images to obtain a global map of plastic-covered greenhouses (PCGs). Really, it is not the first global PCG maps since Tong et al. (2024) already published other global PCG map derived from PlanetScope images, a commercial satellite with 3 m GSD, but using also in the first steps Sentinel-2. Although both works have a similar objective (i.e., to attain a global PCG map), the strategies used were quite different.

Thanks to the attained global PCG map, Niu et al. (2025) give interesting data about the area of PCG around the world, the major concentrations, spatial distribution, etc.

The manuscript is well written and it is worth being published. However, a few specifics comments should be taken into account.

Response:

Thank you for your encouragement and support on our study. We have revised the manuscript carefully according to your suggestions. The following is a point-to-point response to each suggestion.

Specific comments.

1. Some cites in the manuscript appears with an extra comma. For example, in Page 2, Line 64, the cites "Aguilar et al., (2016) and Yang et al., (2017) independently developed…" should be "Aguilar et al. (2016) and Yang et al. (2017) independently developed…" Similarly, "Zhang et al., (2022a)" in Page 2, Line 66, should be "Zhang et al. (2022a)". Please, correct this issue throughout the manuscript.
2. Page 3, Line 71. The cite (Zhang et al., 2024) should be (Zhang et al., 2024a).
3. Page 3, Line 76. Zhang et al., 2023 should be 2023a or 2023b. Please, review it.

Response:

Thank you for your careful and detailed review. We have thoroughly checked the manuscript and corrected all instances of extra commas in citations to the proper format (e.g., changing "Aguilar et al., (2016)" to "Aguilar et al. (2016)"). Additionally, we have updated specific citations for Zhang et al. to include the correct suffixes, changing "(Zhang et al., 2024)" to "(Zhang et al. 2024a)" on Page 3, Line 71 and clarifying the year suffixes for Zhang et al. 2023 as appropriate (e.g., 2023a or 2023b) to ensure

consistency throughout the manuscript.

4. Page 5, Line 139-140. “Actually, Sentinel-2 is a constellation consisting of two satellites, i.e., Sentinel-2A and Sentinel-2B, which are in the same sun-synchronous orbit while phased at 180° to each other”. In fact, there is a new Sentinel-2C. You should speak a little about it.

Response:

We sincerely thanks for your valuable comment. We have noted the latest development of the Sentinel-2 constellation. As you pointed out, in addition to Sentinel-2A and Sentinel-2B, Sentinel-2C has also been successfully launched on March 3rd, 2024 by ESA to ensure the continuity of Earth observation capability. In the revised manuscript, we have updated the relevant description to reflect the current composition of the Sentinel-2 constellation and have briefly supplemented information about the role of Sentinel-2C. The revised content is as follows:

Sentinel-2 multispectral images were used in this study. As the important part of ESA’s Copernicus Programme, Sentinel-2 aims to provide global Earth Observation data at a fine scale with 10 meters captured by MultiSpectral Instrument (MSI) with a total of 13 bands and a swath width of 290 km. Sentinel-2 is a satellite constellation initially composed of Sentinel-2A and Sentinel-2B, which operate in the same sun-synchronous orbit but are phased 180° apart to ensure a high revisit frequency. In addition, Sentinel-2C, the third satellite in the constellation, was successfully launched in March 2024. It serves as a replacement unit to ensure data continuity and system redundancy throughout the mission duration. Several reg-edge bands that are very sensitive to vegetation have been designed in Sentinel-2, which could capture a more detailed conditions of vegetated regions than other satellites such as Landsat and MODIS.

The above contents have been added in Section 2.2 “Satellite datasets” of the manuscript (**see *Lines 135 ~ 143* for details**).

5. Page 6, Line 163. In Figure 2 (Stage 2) the train/validation ratio is 7:3, and in the manuscript you wrote 8:2. Is it a mistake in the Figure?

6. Page 12, Line 273. In Figure 2 (Stage 2) the train/validation ratio is 7:3, and in the manuscript you wrote 8:2. Please review it.

Response:

Thank you very much for pointing out this inconsistency. We feel sorry for our careless mistake. Actually, there is a mismatch between the figure and the description in the manuscript. We have revised Figure 2 to ensure that the train/validation ratio is consistent with what is reported in the manuscript (8:2). We sincerely appreciate your careful review and helpful comment.

7. Page 7, Line 175. In the caption of Figure 3, you should clarify that the size of the reference samples (512×512) are pixels and not meters.

8. Page 11, Line 237. You should clarify also in the manuscript that the size of the reference samples (512×512) are pixels and not meters.

Response:

Thank you for your valuable suggestion. We have revised the manuscript at Page 7, Line 175 and Page 11, Line 237 to explicitly clarify that the size of the reference samples (512×512) refers to pixels and not meters to avoid any misunderstanding. Specifically, we have updated the relevant expressions to "512 × 512 pixels" throughout the manuscript for consistency and clarity.

9. Page 9, Line 200. In the caption of Figure 4, it is written Multiple-temporal NDVI. Is not more appropriated multi-temporal NDVI?

Response:

Thank you for pointing this out. We agree that "multi-temporal NDVI" is the more appropriate term. We have corrected the caption of Figure 4 accordingly.

10. Page 9, Line 205. "1> Spectral features". Strange login method.

11. Page 10, Line 212. "2> Textural features". Strange login method.

Response:

Thank you for your careful review. We totally agree with you that the notation "1>" and "2>" in these lines are not appropriate and may be confusing. We have revised them to standard numbering (e.g., "(1) Spectral features" and "(2) Textural features") to improve clarity and consistency.

12. Page 13, Line 286. Fu et al. (2021) is not in reference section.

Response:

Thank you for pointing this out. As suggested, we have added the missing reference for Fu et al. (2021) to the reference section to ensure completeness and consistency.

13. Page 15, Line 332-335. There are some numbers without thousands separation (e.g., 9874.51 km2, 2530.56 km2, 8224.90 km2).

Response:

Thank you for your careful inspect. We have revised these numbers in Line 332–335 to include thousands separation (e.g., 9,874.51 km², 2,530.56 km², 8,224.90 km²) to improve readability and consistency.

14. Page 16, Line 344. Figure 8a is not cited in the manuscript, and it should be.

Response:

Thank you for bringing this to our attention. We have revised the manuscript to include the appropriate citation of Figure 8a to ensure that all figures are properly referenced in the manuscript.

15. Page 18, Line 375. Why 20500 points for GH and 20500 for Non-GH. Justify this figure.

Response:

Thank you for this good question. Initially, we selected 20,500 test samples each for PCG and Non-PCG equally, with the primary goal of ensuring statistical stability for calculating the overall accuracy (OA) and evaluating the classification performance for the PCG category. However, through further literature review and methodological refinement, we have realized that this balanced sampling approach did not fully consider the effects of class imbalance on accuracy assessment.

To address this issue, we referred to the methodology proposed by Olofsson et al. (2014), and drew on best practices from land use and land cover classification studies such as Wang et al. (2023) and Tian et al. (2025) to re-sample PCG and non-PCG and re-calculate the confusion matrix. In the updated method, we strictly followed the stratified random sampling strategy recommended by Olofsson et al. (2014), in which samples were selected in proportion to the actual mapped area of each class within the study region.

However, since PCG covers less than 1% of the global area, a strictly proportionate sampling approach would yield an insufficient number of PCG samples, making it difficult to effectively assess its classification accuracy. To address this issue, we adopted the approach used in the aforementioned studies and increased the proportion of PCG samples in the test dataset to approximately 10%. Now that the number of PCG is 6,000 while Non-PCG is 40,000. This adjustment could enhance the evaluation capability for this minority class (PCG) and ensures the scientific rigor and representativeness of the final accuracy estimates.

References

Olofsson, P., Foody, G.M., Herold, M., Stehman, S.V., Woodcock, C.E. and Wulder, M.A., 2014. Good practices for estimating area and assessing accuracy of land change. *Remote sensing of Environment*, *148*, pp.42-57.

Tian, F., Wu, B., Zeng, H., Zhang, M., Zhu, W., Yan, N., Lu, Y. and Li, Y., 2025. GMIE: a global maximum irrigation extent and central pivot irrigation system dataset derived via irrigation performance during drought stress and deep learning methods. *Earth System Science Data*, *17*(3), pp.855-880.

Wang, M., Mao, D., Wang, Y., Xiao, X., Xiang, H., Feng, K., Luo, L., Jia, M., Song, K. and Wang, Z., 2023. Wetland mapping in East Asia by two-stage object-based Random Forest and hierarchical

decision tree algorithms on Sentinel-1/2 images. *Remote Sensing of Environment*, *297*, p.113793.

16. Page 19, Line 381. Table 1 shows the confusion matrix where OA, User Accuracy (UA) and Producer Accuracy (PA) are depicted. Really, UA=Recall and PA=Precision, so, Table 2 is not necessary. The only data useful in Table 2 is F1 Score. I think that you should rewrite the methods and results about the accuracy assessment. Furthermore, Why is the classification so biased? For example, UA is 99.99% and PA is 86.30% for Non-GH and, UA is 84.18% and PA is 99.99% for GH.

Response:

We totally agree that there was redundant information between Table 1 and Table 2. Following your suggestion, we have removed Table 2 and redesigned Table 1 accordingly.

In addition, the current description regarding the sampling strategy, sample proportion design and the reliability of the test samples in the confusion matrix was insufficient. We have revised this section based on the reconstructed confusion matrix and now provide a detailed explanation of the test sample collection process. The specific modifications are as follows.

To further quantitatively evaluate the reliability of the Global-PCG-10 dataset, we constructed a dedicated test sample set. The spatial distribution of test samples is shown in Figure 10.

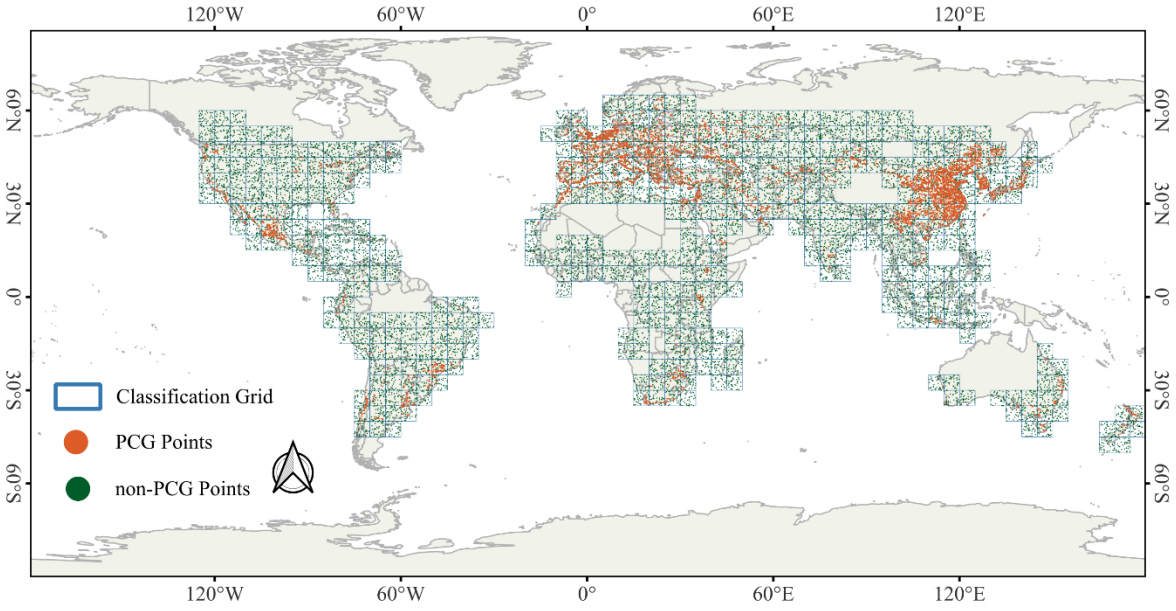

Figure 10. Spatial distribution of global test samples.

The dataset includes two categories, PCG and non-PCG. Based on previous research practices (Olofsson et al., 2013, 2014; Tian et al., 2025; Wang et al., 2023), we followed the stratified random sampling strategy recommended by Olofsson et al. (2014), in which samples were drawn in proportion to the mapped area of each class within the actual mapping region. However, since the global coverage of PCG is less than 1%, strictly proportional sampling would result in too few PCG samples to support a

statistically robust accuracy assessment. To address this issue, and consistent with the approaches adopted in the above studies, we moderately increased the proportion of PCG samples in the test set to approximately 10%. This adjustment could enhance the evaluation capability for this minority class.

As shown in Table 1, the total number of test samples is 46,000, with 6,000 PCG samples and 40,000 non-PCG samples. To ensure the validity, we applied separate sampling strategies for each category. As for PCG, test samples were derived from the global 3-meter PCG dataset in 2019 developed by Tong et al. (2024), and manually verified through Google Earth visual interpretation. Since the Global-PCG-10 dataset is for the year 2020, and considering that PCGs typically have long lifespans and stable structures, the 2019 dataset by Tong provides a reliable reference. Additionally, we performed a second round of verification using historical Google Earth imagery in around 2020 to confirm their existence and status, minimizing sampling bias from prior knowledge. And for non-PCG, due to the large quantity required, manual sampling was impractical. We thus randomly sampled non-PCG from the GLC_FCS30D dataset to ensure independence and randomness. All samples were also verified through visual interpretation of historical Google Earth imagery in around 2020 to ensure label correctness.

Table 1. Confusion matrix.

Confusion Matrix	**Reference**: Non-PCG	**Reference**: PCG	*UA (%)*
Predicted: Non-PCG	39,991	893	97.82 ± 0.13
Predicted: PCG	9	5,107	99.82 ± 0.11
PA (%)	99.98 ± 0.01	85.12 ± 0.90	
F1-score (%)	-	91.88 ± 2.71	
OA (%)			98.04 ± 0.12

Note: PA, Producer's Accuracy; UA, User's Accuracy; OA, Overall Accuracy.*

Based on this test dataset, Global-PCG-10 achieved a PA of 85.12% ± 0.90%, a UA of 99.82% ± 0.11%, an F1-score of 91.88% ± 2.71% and an overall accuracy of 98.04% ± 0.12% (Table 1). In the revised confusion matrix, the bias for non-PCG has been effectively reduced. However, PCG still exhibits a gap between precision and recall, characterized by a high precision but a low recall. This may be caused by missed detections of small PCG patches. Unlike PlanetScope, Sentinel-2 has lower spatial resolution with 10 meters, and small PCG often spans only a few mixed pixels, making it difficult to extract meaningful spectral features for accurate PCG classification. The high precision, on the other hand, is likely due to post-processing applied to the initial classification results. Among these steps, the Sieve Filter method played a key role by removing small, erroneous regions through multi-level filtering, thereby improving the quality of PCG predictions and enhancing precision.

The above contents have been added in Section 4.2 "Reliability of Global-PCG-10" of the

manuscript (**see *Lines 423 ~ 455* for details**).

References

Olofsson, P., Foody, G.M., Stehman, S.V. and Woodcock, C.E., 2013. Making better use of accuracy data in land change studies: Estimating accuracy and area and quantifying uncertainty using stratified estimation. *Remote sensing of environment*, *129*, pp.122-131.

Olofsson, P., Foody, G.M., Herold, M., Stehman, S.V., Woodcock, C.E. and Wulder, M.A., 2014. Good practices for estimating area and assessing accuracy of land change. *Remote sensing of Environment*, *148*, pp.42-57.

Tian, F., Wu, B., Zeng, H., Zhang, M., Zhu, W., Yan, N., Lu, Y. and Li, Y., 2025. GMIE: a global maximum irrigation extent and central pivot irrigation system dataset derived via irrigation performance during drought stress and deep learning methods. *Earth System Science Data*, *17*(3), pp.855-880.

Wang, M., Mao, D., Wang, Y., Xiao, X., Xiang, H., Feng, K., Luo, L., Jia, M., Song, K. and Wang, Z., 2023. Wetland mapping in East Asia by two-stage object-based Random Forest and hierarchical decision tree algorithms on Sentinel-1/2 images. *Remote Sensing of Environment*, *297*, p.113793.

17. Page 22, Line 421-422. "… and in May 2024, the University of Copenhagen published a global 3-m PCGs dataset also in 2019". Please, you should cite Tong et al. (2024) here.

18. Page 22, Line 430. You should cite Tong et al. (2024) properly in the caption of Figure 12.

Response:

Thank you for your suggestion. We have now cited Tong et al. (2024) appropriately in the manuscript to reference the global 3-m PCG dataset published by the University of Copenhagen. Additionally, we have added the proper citation in the caption of Figure 12 to ensure full attribution.

19. Page 23, Line 434. "Tong et al., (2024) acquired from 3-m …". Again, this cite appears with an extra comma.

Response:

Thank you for pointing out the punctuation error. We have corrected the citation on Page 23 by removing the extra comma, so it now reads "Tong et al. (2024) acquired from 3-m …" for proper formatting.

20. Page 30, Line 667. "Zhang, X., Liu, L., and Chen, X.: Global annual wetland dataset Data Descriptor at 30 m with a fine classification system from 2000 to 2022, Sci. Data, https://doi.org/10.1038/s41597-024-03143-0, 2024c". This reference do not appear in the manuscript.

Response:

Thank you for your careful review. We have now included the citation for Zhang et al. (2024c) within the manuscript where relevant to ensure consistency between the references and the main manuscript.

Final Comments:

It is very important that the global PCG map and the code are accessible to researchers. I have tested that the code for generating the initial labels of PCGs is publicly available via the following link on Google Earth Engine: https://github.com/MrSuperNiu/Greenhouse_Classification_GEE. It consists of feature extraction, RF classification, etc. Additionally, the code of APC-Net is accessible through the following link: https://github.com/MrSuperNiu/APCNet. The Global-PCG-10 dataset is stored on figshare, and can be downloaded here: https://doi.org/10.6084/m9.figshare.27731148.v2 (Niu et al., 2024).

Response:

Thank you for your careful check on our open-access dataset and code. We are happy to share with the community our global PCG map and hope it helps for other researchers.

Thank you again for your comments. They are valuable and very helpful for revising and improving our paper, as well as the important guiding significance to our studies.

Yours sincerely,

Bowen Niu, Quanlong Feng

on behalf of all the co-authors