26 March 2024

Re: Ms. Ref. No.: essd-2023-283

Dear Editor and Reviewers,

We would like to thank the editor for handling our manuscript and the reviewers for their valuable comments and constructive suggestions, which have further improved the quality of this manuscript. We have the pleasure of enclosing a revised version of the manuscript "Monsoon Asia Rice Calendar (MARC): a gridded rice calendar in monsoon Asia based on Sentinel-1 and Sentinel-2 images" (Manuscript number: essd-2023-283) and a detailed response to the Reviewers' comments below. We hope that the revised manuscript has been strengthened, addressing the concerns raised.

In the responses below, we have addressed each of the Reviewers' comments in detail. The comments from each Reviewer are noted as "R" (e.g., R2) while each comment is noted as "C" (e.g., C1) to better index all comments. The line numbers indicated refer to the revised manuscript (with track changes). All the changes are highlighted in red with grey background in revised manuscript.

Please do not hesitate to contact us if you require any further information.

Sincerely yours,
Xin Zhao and Kazuya Nishina

Response to the anonymous reviewer's comments

Report #1:

Anonymous referee #2:

***R2C1**: Thank you for adressing my comments. The manuscript has been significantly improved and the methods section is much more clear. I have few minor comments:*

We greatly appreciate your valuable and constructive comments, which contributes improving the overall quality of our manuscript. Please see below the point-by-point response, with *your Comments in italic black*, our Responses in blue and Changes to the manuscript in red with grey background.

Lines 22-24 maybe you could remove 'rice' which is used 5 times in this sentence – for example, "the proposed calendar" or "our calendar" etc.

Response: Thank you for your suggestion. We have removed the "rice" in this sentence. The revised contents are as follows:

- When compared with single rice data from the census-based RiceAtlas ~~rice~~ calendar, the proposed ~~rice~~ calendar ~~outperformed~~ exhibited better results than the MODIS-based RICA ~~rice~~ calendar (Lines 22-24).

***R2C2**: Do not use space between number and "%"*

Response: Thank you for your reminder. We have removed the space between the number and % in the revised manuscript as follows:

- Specifically, concern regarding the negative impacts of rice cultivation is increasing because irrigated rice paddy field is an important source of anthropogenic GHG emissions, contributing 8% and 11% of global methane and nitrous oxide emissions, respectively (Saunois et al., 2020; Jiang et al., 2019) (Lines 37-39).
- To accurately estimate GHG emissions related to rice cultivation and to establish appropriate reduction measures, a detailed rice calendar that depicts rice phenology dynamics is urgently needed, especially for monsoon Asia, which accounts for 87% of the area of harvested rice globally and for 90% of global rice production (FAOSTAT, 2022) (Lines 40-43).
- Invalid observations of Sentinel-2 images caused by clouds and cirrus were removed using cloud filtering (>50%) and the cloud-score method (QA60 quality assessment band with 60 m resolution) (Inoue et al., 2020) (Lines 134-136).
- Flooding rice cultivation, common in Asia and accounting for over 12% of the global cropland (FAOSTAT, 2020; Zhang et al., 2021a), presents a distinctive flooding signal that can be used for detection of rice transplanting date (Lines 168-169).
- Green area indicates the 95% confidence interval around the smoothed EVI time series (Lines 212-213).
- The proposed rice calendar extracts 9% of triple rice croppings (Fig. 11a), which are scattered and distributed in South China, Southeast Asia, and India (Fig. 10a) (Lines 386-387).
- This proportion is close to that of the RICA rice calendar (6% in Fig. 11c), but markedly lower than that of the RiceAtlas rice calendar (41% in Fig. 11c) (Lines 387-388).

R2C3*: Lines 46-48 – something is missing in this sentence*

Response: Thank you for pointing out the mistake. We have rephased this sentence as follows:

- The limited number of global rice calendars (e.g., SAGE (Sacks et al., 2010), MIRCA2000 (Portmann et al., 2010), and RiceAtlas (Laborte et al., 2017)) that are currently available~~, which~~ ~~rely~~ relies on compilation of statistical data at national and/or sub-national scales (Lines 46-48).

R2C4*: Line 84-85 there are many different methods used besides thresholds, such as derivatives or inflection points*

Response: We greatly appreciate the reviewer's constructive suggestions. As you suggested, we have included the other methods (e.g., derivatives and inflection points) into following revised sentence:

- Different from most widely used peak greenness detection methods, which depend on thresholds, derivatives, or inflection points for detection (Xin et al., 2020; Yang et al., 2020), the fitted Weibull function omits the noisy peaks, which means it can track the shape of the vegetation index time series (Lines 84-86).

R2C5*: Line 101 - "which covered" -> "which covers". What is the total area?*

Response: We greatly appreciate the reviewer's suggestion. As you suggested, "which covered" has been revised to "which covers" as follows:

- ➢ The analysed area is located in monsoon Asia, which ~~covered~~covers the region of 10° S to 53.5° N, 61° E to 153° E (Line 102).

The total area of monsoon Asia is 2106 millions of ha, which has been added into the revised manuscript as follows:

- ➢ The total area of monsoon Asia is 2106 millions of ha (Lines 102-103).

***R2C6**: Lines 181-182 – please rephrase*

Response: Our apologies for the ambiguous description of the sentence. We have rephrased it as follows:

- ➢ ~~If the peak NDYI could not be obtained from those time windows, peak NDYI was identified using the peak EVI date ($DOY_{EVI_{max}}$) plus the corresponding difference days for each rice cropping, as referenced in Zhao et al., (2013) (Fig. 2 Step 1 Process a).~~ If the peak NDYI could not be obtained from those time windows, peak NDYI was identified using the peak EVI date ($DOY_{EVI_{max}}$) plus the difference days. The difference days for each rice cropping can be found in Zhao et al., (2023) (Fig.2 Step 1 Process a) (Lines 182-186).

***R2C7**: Line 196 - "then" is redundant*

Response: Thanks for your suggestion again. We have removed "then" as follows:

- ➢ After application of the function (Eq. (4)), all available arcs of the smoothed EVI time series were ~~then~~ labelled, including the start (start day of detected EVI arc, $DOY_{EVI\ arc_{first\ day}}$), peak (peak day of detected EVI arc, $DOY_{EVI_{max}}$), and end (end day of detected EVI arc, $DOY_{EVI\ arc_{last\ day}}$) of the arc, and the peak EVI value ($Value_{EVI_{max}}$) (Fig. 2 Step 1 Process b) (Lines 201-203).

R2C8: *You use R2 in the figure 9, but is not mentioned in the text. Could you also add that?*

Response: We greatly appreciate the reviewer's comments and have added the R^2 value in the revised manuscript:

- The transplanting dates of the proposed rice calendar are consistent with those of the RiceAtlas rice calendar, with R^2 of 0.43, Bias of 3.93 days, MAE of 16.38 days, and RMSE of 27.62 days (Fig. 9). Additionally, the harvest dates of the proposed rice calendar are correlated with those of the RiceAtlas rice calendar, with R^2 of 0.44, Bias of -5.76 days, MAE of 17.87 days, and RMSE of 28.32 days (Fig. 9) (Lines 324-327).

Report #2:

Anonymous referee #3:

This study presents a new gridded rice calendar for monsoon Asia spanning from 2019 to 2020, with a resolution of 0.5° × 0.5°, utilizing Sentinel-1 and Sentinel-2 satellite imagery. The novelty of this rice calendar lies in its development of a consistent and optimal methodological framework, enabling the spatially explicit characterization of rice transplanting dates, harvest dates, and the number of rice croppings. This framework comprises two key steps: the detection of rice phenological dates and the number of rice croppings using a feature-based algorithm and the fitted Weibull function, followed by the spatio-temporal integration of the detected dates using von Mises maximum likelihood estimates. The development of the gridded rice calendar for monsoon Asia represents an advancement in agricultural research, offering a valuable resource for researchers and policymakers alike. Generally the work is well done. However, I have some comments before its consideration for publication.

We greatly appreciate your valuable and constructive comments, which contributes improving the overall quality of our manuscript. Please see below the point-by-point response, with *your Comments in italic black*, our Responses in blue and Changes to the manuscript in red with grey background.

Major comments:

***R3C1**: The authors' response to the reviewer's comment regarding the spatial resolution of the proposed rice calendar is not convinced. Why not producing the 10-m phenology data? It would be valuable if the original 10-m phenology information from Sentinel-1 and -2 data can be released and shared in this study.*

Response: We appreciate the reviewer's important comments. We believe that increasing spatial resolution is a future challenge, but in this case we have created this information for use in global biogeochemical and crop models. Regarding the decision to produce a 0.5° resolution calendar instead of a 10-m resolution calendar, we based our decision on the following considerations, as explained in detail below:

(1) There is research gap in the spatial resolution of rice calendars for large areas. Given the currently available global/continental rice calendars, such as RiceAtlas, RICA, and SAGE, which are all based on national/subnational scales, we aimed to produce a large-scale rice calendar with a finer resolution than the existing rice calendars. In other words, the spatial resolution of our proposed rice calendar surpasses that of existing large-scale rice calendars, which can be considered as an advantage of our proposed rice calendar.

(2) The production of 0.5° resolution rice calendar fulfills the requirements for land surface model/terrestrial process-based model simulations. One of the potential and important application of our proposed rice calendar is as an input to land surface model or terrestrial process-based model for estimating greenhouse gas emissions or rice production. Such models are typically simulated at 0.5° resolution, with examples like LPJ-GUESS (Smith et al., 2014), VISIT (Ito, 2019), DLEM (Tian et al., 2009), ORCHIDEE-CROP (Müller et al., 2019), and ISAM (Lin et al., 2021).

(3) The production of 0.5° resolution rice calendar is the result of a trade-off between depicting rice phenology at large scale and computational sources constraints. We agree that 10-m resolution rice calendar would be valuable, however, there are some practical limitations at global (Asian) scale. Processing the Sentinel-1&-2 images at 10-m resolution for monsoon Asia would require immense computational power. In this study, we had to process 127 × 184 = 23,368 grids × 2 years = 46,736 grids at each process, including extracting time series of VH, EVI, and NDYI from Sentinel-1&-2 images, smoothing time series data, and identifying the phenological dates. If we were to prefer 10-m resolution, we would have to process 705,842 × 888,631 = 6.275 × 10^11 grids × 2 years = 12.55 × 10^11 grids, which accounts for approximately 2.683 × 10^7 times more than current study. Also, in practice, the satellite imagery we use faces issues due to cloud coverage, and it is difficult for the algorithm to work well on all grids at detailed scales. Therefore, to produce rice calendars

with detailed spatial resolution, high-frequency data sources such as constellations or geostationary satellites may be required, which is outside the scope of this paper.

Additionally, the primary objective of our study was to develop a continental-scale rice calendar that could provide a synoptic view of rice phenology across monsoon Asia. While 10-m resolution rice phenology data would be beneficial for local-scale applications, it might not be essential for capturing the overall regional patterns and variability in rice phenology. Instead, we had provided the variance in transplanting and harvest dates for each grid, as shown in Fig. 7. Most of phenological dates in each grid vary by less than 50 days, or even 20 days, which could indicate a small variability of phenological dates within each grid.

Optimistically, our proposed rice calendar provides a feasible methodological framework, which enables future researchers to utilize this methodology for high-resolution rice calendar production while minimizing the computational requirements.

References:

Smith, B., Warlind, D., Arneth, A., Hickler, T., Leadley, P., Siltberg, J., Zaehle, S.: Implications of incorporating N cycling and N limitations on primary production in an individual-based dynamic vegetation model, Biogeosciences, 11, 2027–2054, https://doi.org/10.5194/bg-11-2027-2014, 2009.

Ito, A.: Disequilibrium of terrestrial ecosystem CO_2 budget caused by disturbance-induced emissions and non-CO_2 carbon export flows: a global model assessment, Earth Syst. Dynam., 10, 658–709, https://doi.org/10.5194/esd-10-685-2019, 2019.

Tian, H., Chen, G., Liu, M., Zhang, C., Sun, G., Lu, C., Xu, X., Ren, W., Pan, S., Chappelka, A.: Model estimates of net primary productivity, evapotranspiration, and water use efficiency in the terrestrial ecosystems of the southern United States during 1895-2007, For. Ecol. Manag., 259, 1311–1327, https://doi.org/10.1016/j.foreco.2009.10.009, 2009.

Müller, C., Elliott, J., Kelly, D., Arneth, A., Balkovic, J., Ciais, P., Deryng, D., Folberth, C., Hoek, S., Izaurralde, R.C., Jones, C.D., Khabarov, N., Lawrence, P., Liu, W., Olin, S., Pugh, T.A.M., Reddy, A., Rosenzweig, C., Ruane, A.C., Sakurai, G., Schmid, E., Skalsky, R., Wang, X., Wit, A., Yang, H.: The global gridded crop model intercomparison phase 1 simulation dataset, Sci. Data, 6, 50, https://doi.org/10.1038/s41597-019-0023-8, 2019.

Lin, T., Song, Y., Lawrence, P., Kheshgi, H.S., Jain, A.K.: Worldwide maize and soybean yield response to environmental and management factors over the 20th and 21st centuries, J. Geophys. Res. Biogeosci., 6, 50, https://doi.org/10.1029/2021JG006304, 2021.

***R3C2**: The validation of the produced phenology data is still not durable. The Census-based RiceAtlas rice calendar actually cannot be used as "ground truth" data. Can the authors collect some in-situ phenology data for validation? For example, some PhenoCAM-based phenology data can be used for validation of at least harvest timing.*

Response: We sincerely appreciate and agree with your comments. As you pointed out, the census-based RiceAtlas rice calendar is not "ground truth" data, which was also emphasized in our previous paper (Zhao et al., 2023).

In response to this concern, we have taken series processes to conduct the site validation. Firstly, we have collected 39 in-situ records of rice transplanting and harvest dates from the literatures. The years of these selected records are very close to the years used for producing our proposed rice calendar. Additionally, as suggested, we have obtained one rice paddy site in monsoon Asia from the PhenoCam dataset, covering the same experimental years as our study. The available wavelengths from PhenoCam dataset were used to calculate the NDYI time series and detect the harvest date. In total, we have collected 40 records for site validation, covering most areas of monsoon Asia, which can be considered representative. The geographic locations, transplanting dates, and harvest dates of these records are summarized in Table S2 of the Supplementary Text 3. The distribution of these records is shown in Fig. S11. We emphasized in the manuscript, however, that even these site observations cannot be considered ground truth, as the sites may not be representative of the entire area (often being cultivation-managed for research) and these site observations were made in different years from the satellite images.

We have added the description of site validation on Supplementary Text 3 as follows:

- **3. Site validation**

To further validate the proposed rice calendar, site phenological dates close to the experimental period were collected from two sources: 1) 39 sites recorded in the literatures, and 2) observations from one site in the PhenoCam dataset. The transplanting and harvest dates were directly extracted from the literature records for the 39 sites. Since there is only one rice paddy site located in monsoon Asia in the PhenoCam dataset, the Jurong site provides a time series of vegetation phenological observations derived from conventional visible-wavelength automated digital camera imagery. The transplanting and harvest dates for all 40 sites are summarized in Table S2. These 40 sites are representative due to their wide coverage across monsoon Asia (Fig. S11).

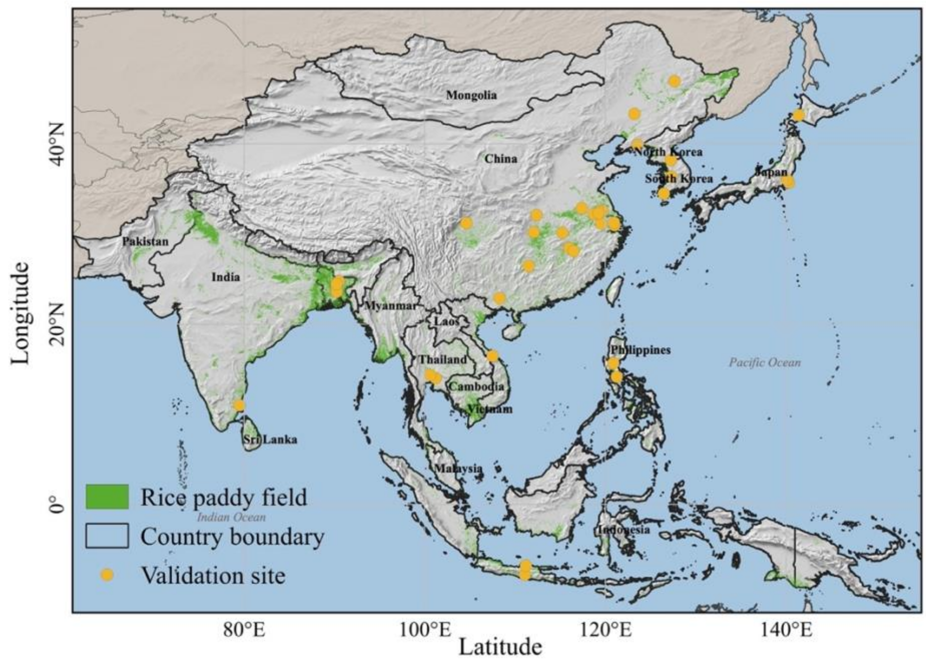

Figure S11. Location of the validation sites in monsoon Asia. Green areas indicate rice paddy fields, and bold black borders indicate the countries in this study area. Yellow circles denote the validation site collected from the literatures and dataset.

Table S2. Transplanting date and harvest date for 40 sites, along with the corresponding phenological dates from rice calendars at each site location

Country	**Latitude**	**Longitude**	**T_ site**	**H_ site**	**T_ MARC**	**H_ MARC**	**T_ RiceAtlas**	**H_ RiceAtlas**	**T_ RICA**	**H_ RICA**	**T_ SAGE**	**H_ SAGE**	**Reference**
Thailand	14.01 ºN	101.22 ºE	182	273	190.34	285.34	135	306	138.73	264.66	185.5	339	Chidthaisong et al., 2018
South Korea	36.37 ºN	127.33 ºE	149	289	164.25	266.18	148	275	145.08	277.41	151	274	Choi et al., 2019
China	30.97 ºN	121.01 ºE	175	297	175.61	269.95	160	304	262.18	19.18	121.5	245.5	Fang et al., 2021
Japan	35.71 ºN	140.34 ºE	158	266	157.68	251.79	117	244	124.19	252.35	167	291	Fawibe et al., 2019
China	32.10 ºN	112.40 ºE	152	274	159.85	253.46	166	294	136.64	257.02	121.5	245.5	Feng et al., 2021
Bangladesh	24.75 ºN	90.50 ºE	20	119	34.10	128.45	5	110	17.83	129.72	-12	127.5	Forhad et al., 2019
China	30.21 ºN	112.09 ºE	157	257	150.93	250.49	166	294	136.64	257.02	121.4	245.5	Fu et al., 2019
South Korea	38.20 ºN	127.25 ºE	121	246	155.95	260.51	140	267	128.19	265.18	151	274	Huang et al., 2018
South Korea	38.20 ºN	127.25 ºE	129	257	155.95	260.51	140	267	128.19	265.18	151	274	Hwang et al., 2020
Philippines	14.16 ºN	121.26 ºE	30	133	-28.93	68.77	−16	105	-8.76	105.02	130	301	Islam et al., 2020
Bangladesh	23.60 ºN	90.25 ºE	25	120	52.86	152.85	10	105	173.01	285.63	-12	127.5	Islam et al., 2020
Bangladesh	24.44 ºN	90.24 ºE	23	118	37.16	134.05	15	120	50.36	154.87	-12	127.5	Islam et al., 2020

South Korea	38.20 ºN	127.25 ºE	135	257	155.95	260.51	140	267	128.19	265.18	151	274	Jeong et al., 2020
South Korea	34.48 ºN	126.48 ºE	152	306	167.17	265.46	-	-	-	-	151	274	Jeong et al., 2020
China	22.88 ºN	108.29 ºE	102	199	86.25	172.03	101	195	88.08	210.59	88	179.5	Li et al., 2020
China	30.14 ºN	115.25 ºE	121	229	161.46	252.94	100	181	136.64	257.02	121.5	245.5	Liang et al., 2019
China	28.44 ºN	116.00 ºE	195	304	186.04	287.20	140	260	109.38	252.92	182.5	306	Liu et al., 2019a
China	28.10 ºN	116.50 ºE	116	203	104.35	195.59	105	201	109.38	252.92	88	179.5	Liu et al., 2019b
China	31.22 ºN	104.62 ºE	149	268	175.62	269.52	135	270	99.7	235.3	121.5	245.5	Liu et al., 2021
Thailand	14.37 ºN	100.61 ºE	305	57	309.77	43.72	390	135	338.71	103.1	37.5	148.5	Maneepitak et al., 2019
Japan	43.18 ºN	141.44 ºE	144	258	175.09	268.64	-	-	-	-	167	291	Naser et al., 2020
China	46.95 ºN	127.67 ºE	139	264	155.51	256.52	135	266	137.53	261.92	121.5	245.5	Nie et al., 2020
Indonesia	-7.79 ºN	111.10 ºE	102	203	69.22	160.35	130	248	-	-	151	243	Nugroho et al., 2018
Japan	36.03 ºN	140.11 ºE	140	271	150.23	257.62	126	251	132.97	256.28	167	291	Okamura et al., 2018
India	11.00 ºN	79.50 ºE	167	264	194.62	310.46	181	301	199.21	315.07	133.5	231.5	Oo et al., 2020
China	26.45 ºN	111.52 ºE	116	199	111.23	198.67	110	200	109.94	240.2	88	179.5	Raheem et al., 2019
Indonesia	-6.78 ºN	111.20 ºE	92	196	93.48	183.12	130	248	-	-	151	243	Setyanto et al., 2018

Philippines	15.67 °N	120.90 °E	168	260	187.61	289.05	189	285	192.15	294.22	130	301.5	Sibayan et al., 2018
China	31.16 °N	119.54 °E	160	313	171.34	267.08	166	280	75.83	186.61	121.5	245.5	Sun et al., 2019a
China	39.88 °N	123.58 °E	149	262	159.20	264.02	140	284	141.37	264.41	121.5	245.5	Sun et al., 2019b
Vietnam	16.47 °N	107.52 °E	20	140	52.27	143.62	30	140	7.2	134.67	18	113.5	Tran et al., 2018
Vietnam	16.47 °N	107.52 °E	162	252	150.62	247.52	155	265	147.96	242.73	227	365	Tran et al., 2018
China	32.86 °N	117.40 °E	180	301	173.67	271.41	161	274	155.72	265.26	121.5	245.5	Wang et al., 2020
China	32.21 °N	118.71 °E	170	299	176.84	271.19	166	280	75.83	186.61	121.5	245.5	Wang et al., 2021
China	43.32 °N	123.23 °E	149	289	155.60	253.35	105	227	131.48	261.93	121.5	245.5	Wu et al., 2019
China	31.25 °N	120.96 °E	181	304	175.61	269.95	166	280	75.83	186.61	121.5	245.5	Yang et al., 2018
China	32.58 °N	119.70 °E	173	307	181.15	277.72	166	280	75.83	186.61	121.5	245.5	Yuan et al., 2021
China	32.50 °N	119.42 °E	164	292	182.86	279.63	166	280	75.83	186.61	121.5	245.5	Zhang et al., 2018
China	32.30 °N	119.25 °E	164	294	179.19	277.27	166	280	75.83	186.61	121.5	245.5	Zhang et al., 2019
China (Jurong, PhenoCam site)	119.22 °N	31.81 °E	-	273.6	177.84	274.33	-	280	75.83	186.61	121.5	245.5	Seyednasrollah et al., 2019

Note: T_site and H_site denote the transplanting date and harvest date of sites from literatures and dataset. T_MARC and H_MARC denote the transplanting date and harvest date of the proposed rice calendar at each site location. T_RiceAtlas and H_RiceAtlas denote the transplanting date and harvest date of the RiceAtlas rice calendar at each site location. T_RICA and H_RICA denote the transplanting date and harvest date of the RICA rice calendar at each site location. T_SAGE and H_SAGE denote the transplanting date and harvest date of the SAGE rice calendar at each site location. '-' denotes phenological dates are not available. Phenological dates less than 0 indicate that the day has been subtracted by 365 days for easy comparison.

The hyperspectral image data has been analyzed in detail in our previous paper (Zhao et al., 2023). Considering the concerns about the length of this manuscript from Reviewer#2, the PhenoCam data processing is described as follows:

- **Processing of PhenoCam data**

Among the 393 sites across diverse ecosystems worldwide in the PhenoCam dataset, the Jurong Observation Station (JROS) is the only rice paddy field site located in monsoon Asia (Seyednasrollah et al., 2019). All available images from PhenoCam from 1 January 2019 to 31 December 2020 were used for detecting harvest dates. To calculate the NDYI vegetation index, green and blue bands were used based on Eq. (2) in the manuscript. The Locally Estimated Scatterplot Smoothing (LOESS) method was adopted to smooth the NDYI time series (Fig. S12). The span value was assigned as 0.2 to depict the NDYI time series pattern. The peak NDYI was detected, and the day on which the peak NDYI occurred was identified as the harvest date. Thus, DOY 273.44 was detected as showing the peak NDYI and identified as the harvest date at Jurong site (Table S2).

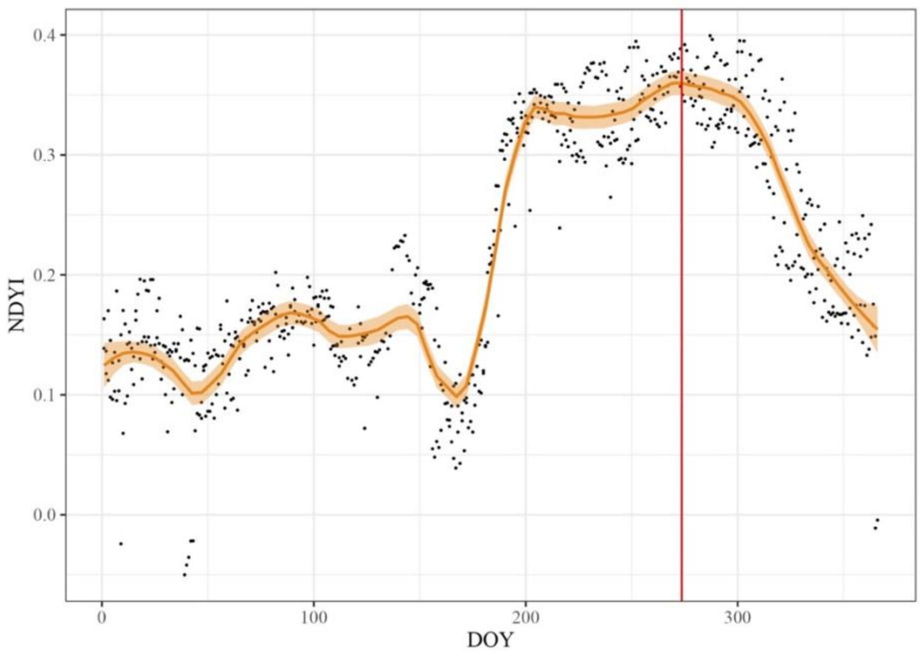

Figure. Smoothed NDYI time series and identification of peak NDYI at Jurong site from PhenoCam dataset. Black points and orange lines indicate the NDYI value at specific dates and the smoothed NDYI time series, respectively. Orange area indicates the 95% confidence interval around the smoothed NDYI time series. Red vertical line indicates the peaks of NDYI.

At the same time, we have extracted the transplanting and harvest dates from the proposed rice calendar based on the locations of these 40 records, as shown in Table S2.

The proposed rice calendar demonstrates high agreement with the site phenological dates (Fig. S12), with R^2 of 0.90 and 0.87, Bias of 7.99 and −9.07 days, MAE of 16.32 and 19.58 days, and RMSE of 19.00 and 22.43 days for transplanting date and harvest date, respectively. This site validation underscores the robustness of proposed rice calendar. The results of site validation have been added in the Supplementary Text 3.1 as follows:

- **3.1 Comparison of transplanting and harvest dates between proposed rice calendar and site records**

  The transplanting and harvest dates from the proposed rice calendar were further compared with those from the site records. The transplanting and harvest dates were firstly extracted from the proposed rice calendar at each site location as shown in Table S2. The transplanting dates of the proposed rice calendar are consistent with those site records, with R^2 of 0.9, Bias of 7.99 days, MAE of 16.32 days, and RMSE of 19.00 days (Fig. S12). Additionally, the harvest dates of the proposed rice calendar are correlated with those of the site records with R^2 of 0.87, Bias of −9.07 days, MAE of 19.58 days, and RMSE of 22.43 days (Fig. S12). This site validation demonstrates the efficacy of the proposed rice calendar.

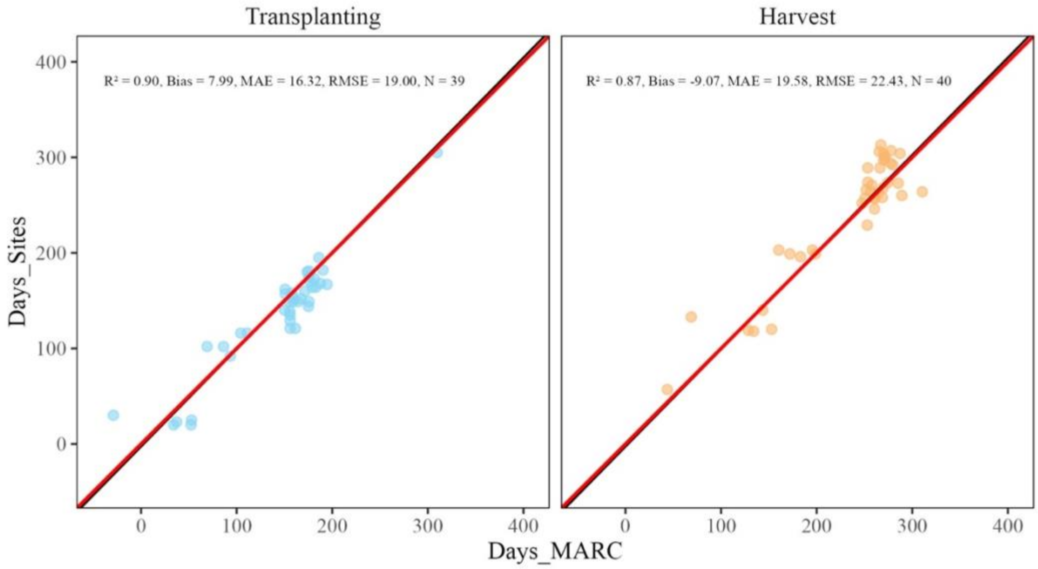

Figure S12. Comparison of transplanting date and harvest date between the proposed rice calendar and site records. Blue and orange points represent the transplanting date and harvest date, respectively. Red and black solid lines represent the 1:1 line and regression, respectively.

Furthermore, to further emphasize the robustness of proposed rice calendar and to evaluate the advantage of the proposed rice calendar, we have compared the site validation results with those of other existing rice calendars, including RiceAtlas, RICA, and SAGE. We have extracted the transplanting and harvest dates from these three rice calendars based on the same locations as the 40 validation records (Table S2). The results, shown in Figure S13, demonstrate that our proposed rice calendar performs better than the other rice calendars, with higher agreement with the in-situ phenological dates in terms of R^2, Bias, MAE, and RMSE (except for the Bias of the RiceAtlas rice calendar). This site validation comparison highlights the advantage and progress of our proposed rice calendar.

- **3.2 Comparison of transplanting and harvest dates between other rice calendars and site records**

To evaluate the advantage of the proposed rice calendar, the transplanting and harvest dates from other rice calendars were compared with those from the site records. The transplanting and harvest dates from RiceAtlas, RICA, and SAGE rice calendars were extracted at each site location, as shown in Table S2. The transplanting dates of RiceAtlas, RICA, and SAGE rice calendars were correlated with the site records, with R^2 of 0.86, Bias of −2.41 days, MAE of 19.10 days, and RMSE of 26.56 days; R^2 of 0.42, Bias of −20.85 days, MAE of 41.41 days, and RMSE of 57.66 days; R^2 of 0.64, Bias of −11.28 days, MAE of 37.08 days, and RMSE of 45.31 days, respectively (Fig. S13). Similarly, the harvest dates of the RiceAtlas, RICA, and SAGE rice calendars were correlated with site records, with R^2 of 0.80, Bias of 2.96 days, MAE of 22.75 days, and RMSE of 29.51 days; R^2 of 0.11, Bias of −29.29 days, MAE of 56.25 days, and RMSE of 85.61 days; R^2 of 0.44, Bias of −6.88 days, MAE of 43.60 days, and RMSE of 61.10 days, respectively (Fig. S13). The phenological dates of the proposed rice calendar were found to be closer to the site records compared to those of three rice calendars. The good performance in the site validation clearly demonstrates the ability and advantage of the proposed rice calendar in retrieving rice transplanting and harvest dates.

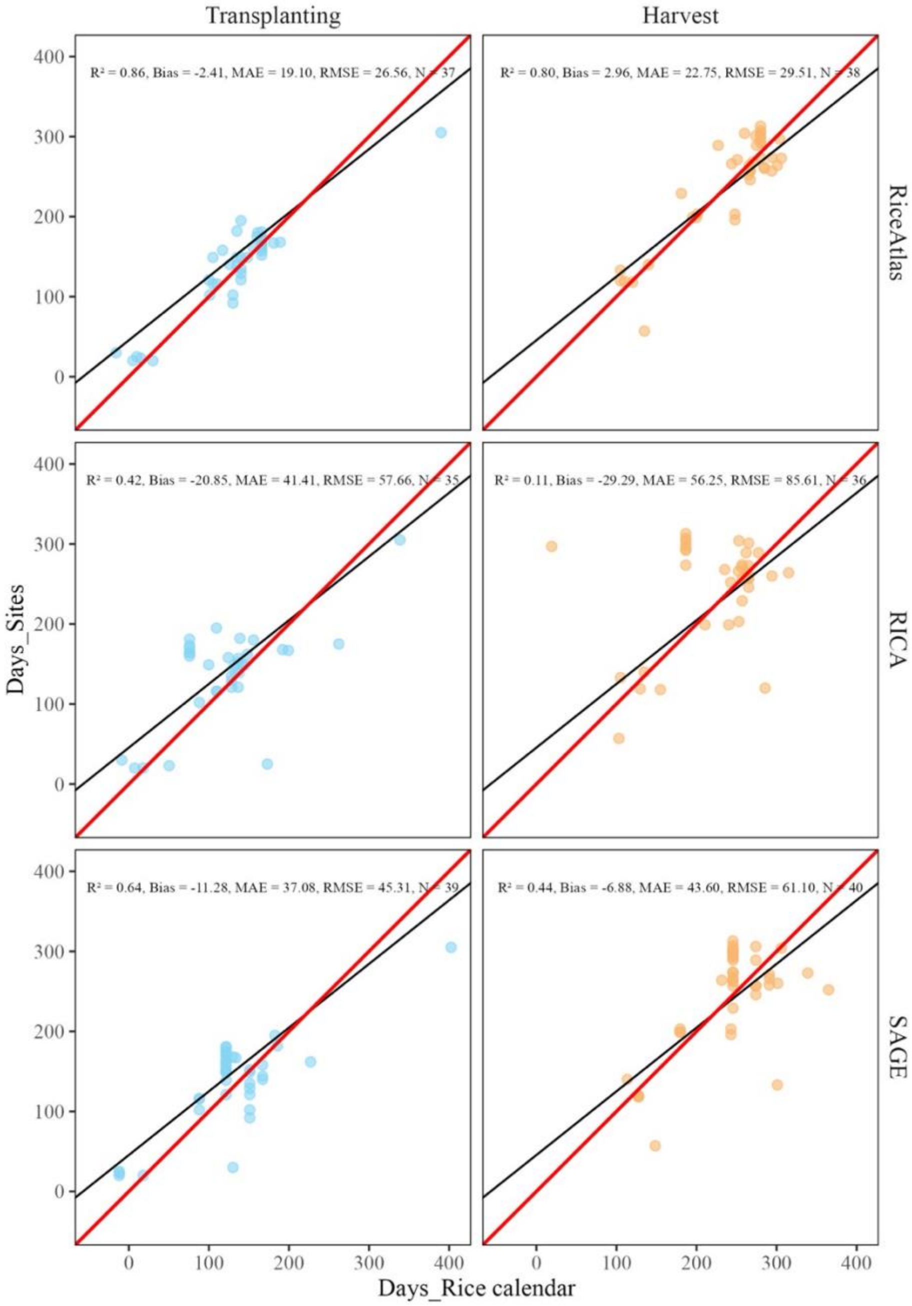

Figure S13. Comparison of transplanting date and harvest date between the rice calendars (RiceAtlas, RICA, and SAGE) and site records. Blue and orange points represent the transplanting date and harvest date, respectively. Red and black solid lines represent the 1:1 line and regression, respectively.

References

Chidthaisong, A., Cha-un, N., Rossopa, B., Buddaboon, C., Kunuthai, C., Sriphirom, P., Towprayoon, S., Tokida, T., Padre, A. T., and Minamikawa, K.: Evaluating the effects of alternate wetting and drying (AWD) on methane and nitrous oxide emissions from a paddy field in Thailand, Soil Sc. Plant Nutr., 64, 31–38, https://doi.org/10.1080/00380768.2017.1399044, 2018.
Choi, E. J., Jeong, H. C., Kim, G. Y., Lee, S. I., Gwon, H. S., Lee, J. S., and Oh, T. K.: Assessment of methane emission with application of rice straw in a paddy field. Korean J. Agric. Sci., 46(4), 857–868. https://doi.org/10.7744/KJOAS.20190069, 2019.
Fang, K., Gao, H., Sha, Z., Dai, W., Yi, X., Chen, H., and Cao, L.: Mitigating global warming potential with increase net ecosystem economic budget by integrated rice-frog farming in eastern China, Agric. Ecosyst. Environ., 308, 107235, https://doi.org/10.1016/j.agee.2020.107235, 2021.
Fawibe, O. O., Honda, K., Taguchi, Y., Park, S., and Isoda, A.: Greenhouse gas emissions from rice field cultivation with drip irrigation and plastic film mulch, Nutr. Cycl. Agroecosyst., 113, 51–62, https://doi.org/10.1007/s10705-018-9961-3, 2019.
Feng, Z. Y., Qin, T., Du, X. Z., Sheng, F., and Li, C. F.: Effects of irrigation regime and rice variety on greenhouse gas emissions and grain yields from paddy fields in central China, Agric. Water Manage., 250, 106830, https://doi.org/10.1016/j.agwat.2021.106830, 2021.
Forhad, A. B. M., Ahatun, R., and Islam, M. Z.: Soil microbial status and methane emission under waste materials application in rice paddy field. International Journal of Environmental Sciences & Natural Resources, 18(1), 555977, https://doi.org/10.19080/IJESNR.2019.18.555977, 2019.
Fu, J., Wu, Y., Wang, Q., Hu, K., Wang, S., Zhou, M., Hayashi, K., Wang, H., Zhan, X., Jian, Y., Cai, C., Song, M., Liu, K., Wang, Y., Zhou, F., and Zhu, J.: Importance of subsurface fluxes of water, nitrogen and phosphorus from rice paddy fields relative to surface runoff, Agric. Water Manage., 213, 627–635, https://doi.org/10.1016/j.agwat.2018.11.005, 2019.
Huang, Y., Ryu, Y., Jiang, C., Kimm, H., Kim, S., Kang, M., and Shim, K.: BESS-Rice: A remote sensing derived and biophysical process-based rice productivity simulation model, Agric. For. Meteorol., 256–257, 253–269, https://doi.org/10.1016/j.agrformet.2018.03.014, 2018.
Hwang, Y., Ryu, Y., Huang, Y., Kim, J., Iwata, H., and Kang, M.: Comprehensive assessments of carbon dynamics in an intermittently-irrigated rice paddy, Agricu. For. Meteorol., 285–286, 107933, https://doi.org/10.1016/j.agrformet.2020.107933, 2020.
Islam, S. F.-u., de Neergaard, A., Sander, B. O., Jensen, L. S., Wassmann, R., and van Groenigen, J. W.: Reducing greenhouse gas emissions and grain arsenic and lead levels without compromising yield in organically produced rice, Agricu. Ecosyst. Environ., 295, 106922, https://doi.org/10.1016/j.agee.2020.106922, 2020.
Jeong, S., Ko, J., Kang, M., Yeom, J., Ng, C. T., Lee, S.H., Lee, Y. G., and Kim, H. Y.: Geographical variations in gross primary production and evapotranspiration of paddy rice in the Korean Peninsula, Sci. Total Environ., 714, 136632, https://doi.org/10.1016/j.scitotenv.2020.136632, 2020.
Li, L., Li, F., and Dong, Y.: Greenhouse Gas Emissions and Global Warming Potential in Double-Cropping Rice Fields as Influenced by Two Water-Saving Irrigation Modes in South China, J. Soil Sci. Plant Nutr., 20, 2617–2630, https://doi.org/10.1007/s42729-020-00328-5, 2020.
Ling, X., Zhang, T., Deng, N., Yuan, S., Yuan, G., He, W., Cui, K., Nie, L., Peng, S., Li, T., and Huang, J.: Modelling rice growth and grain yield in rice ratooning production system, Field Crop. Res., 241, 107574, https://doi.org/10.1016/j.fcr.2019.107574, 2019.

Liu, B., Cui, Y., Luo, Y., Shi, Y., Liu, M., and Liu, F.: Energy partitioning and evapotranspiration over a rotated paddy field in Southern China, Agric. For. Meteorol., 276–277, 107626, https://doi.org/10.1016/j.agrformet.2019.107626, 2019a.

Liu, J., Huang, X., Jiang, H., and Chen, H.: Sustaining yield and mitigating methane emissions from rice production with plastic film mulching technique, Agric. Water Manage., 245, 106667, https://doi.org/10.1016/j.agwat.2020.106667, 2021.

Liu, Y., Tang, H., Muhammad, A., Zhong, C., Li, P., Zhang, P., Yang, B., and Huang, G.: Rice Yield and Greenhouse Gas Emissions Affected by Chinese Milk Vetch and Rice Straw Retention with Reduced Nitrogen Fertilization, Agrono. J., 111, 3028–3038, https://doi.org/10.2134/agronj2019.03.0145, 2019b.

Maneepitak, S., Ullah, H., Datta, A., Shrestha, R. P., Shrestha, S., and Kachenchart, B.: Effects of water and rice straw management practices on water savings and greenhouse gas emissions from a double-rice paddy field in the Central Plain of Thailand, Eur. J. Agron., 107, 18–29, https://doi.org/10.1016/j.eja.2019.04.002, 2019.

Naser, H. M., Nagata, O., Sultana, S., and Hatano, R.: Carbon Sequestration and Contribution of CO_2, CH_4 and N_2O Fluxes to Global Warming Potential from Paddy-Fallow Fields on Mineral Soil Beneath Peat in Central Hokkaido, Japan, Agriculture, https://doi.org/10.3390/agriculture10010006, 2020.

Nie, T., Chen, P., Zhang, Z., Qi, Z., Zhao, J., Jiang, L., and Lin, Y.: Effects of irrigation method and rice straw incorporation on CH_4 emissions of paddy fields in Northeast China, Paddy Water Environ., 18, 111-120, https://doi.org/10.1007/s10333-019-00768-5, 2020.

Nugroho, B. D. A., Toriyama, K., Kobayashi, K., Arif, C., Yokoyama, S., and Mizoguchi, M.: Effect of intermittent irrigation following the system of rice intensification (SRI) on rice yield in a farmer's paddy fields in Indonesia, Paddy Water Environ., 16, 715–723, https://doi.org/10.1007/s10333-018-0663-x, 2018.

Okamura, M., Arai-Sanoh, Y., Yoshida, H., Mukouyama, T., Adachi, S., Yabe, S., Nakagawa, H., Tsutsumi, K., Taniguchi, Y., Kobayashi, N., and Kondo, M.: Characterization of high-yielding rice cultivars with different grain-filling properties to clarify limiting factors for improving grain yield, Field Crop. Res., 219, 139–147, https://doi.org/10.1016/j.fcr.2018.01.035, 2018.

Oo, A. Z., Sudo, S., Fumoto, T., Inubushi, K., Ono, K., Yamamoto, A., Bellingrath-Kimura, S. D., Win, K. T., Umamageswari, C., Bama, K. S., Raju, M., Vanitha, K., Elayakumar, P., Ravi, V., and Ambethgar, V.: Field Validation of the DNDC-Rice Model for Methane and Nitrous Oxide Emissions from Double-Cropping Paddy Rice under Different Irrigation Practices in Tamil Nadu, India, Agriculture, https://doi.org/10.3390/agriculture10080355, 2020.

Raheem, A., Zhang, J., Huang, J., Jiang, Y., Siddik, M. A., Deng, A., Gao, J., and Zhang, W.: Greenhouse gas emissions from a rice-rice-green manure cropping system in South China, Geoderma, 353, 331–339, https://doi.org/10.1016/j.geoderma.2019.07.007, 2019.

Setyanto, P., Pramono, A., Adriany, T. A., Susilawati, H. L., Tokida, T., Padre, A. T., and Minamikawa, K.: Alternate wetting and drying reduces methane emission from a rice paddy in Central Java, Indonesia without yield loss, Soil Sci. Plant Nutr., 64, 23–30, https://doi.org/10.1080/00380768.2017.1409600, 2018.

Seyednasrollah, B., Young, A. M., Hufkens, K., Milliman, T., Friedl, M. A., Frolking, S., Richardson, A. D., Abraha, M., Allen, D. W., Apple, M., Arain, M. A., Baker, J., Baker, J. M., Baldocchi, D., Bernacchi, C. J., Bhattacharjee, J., Blanken, P., Bosch, D. D., Boughton, R., Boughton, E. H., Brown, R. F., Browning, D. M., Brunsell, N., Burns, S. P., Cavagna, M., Chu, H., Clark, P. E., Conrad, B. J., Cremonese, E., Debinski, D., Desai, A. R., Diaz-Delgado, R., Duchesne, L., Dunn, A. L., Eissenstat, D. M., El-

Madany, T., Ellum, D. S. S., Ernest, S. M., Esposito, A., Fenstermaker, L., Flanagan, L. B., Forsythe, B., Gallagher, J., Gianelle, D., Griffis, T., Groffman, P., Gu, L., Guillemot, J., Halpin, M., Hanson, P. J., Hemming, D., Hove, A. A., Humphreys, E. R., Jaimes-Hernandez, A., Jaradat, A. A., Johnson, J., Keel, E., Kelly, V. R., Kirchner, J. W., Kirchner, P. B., Knapp, M., Krassovski, M., Langvall, O., Lanthier, G., Maire, G. l., Magliulo, E., Martin, T. A., McNeil, B., Meyer, G. A., Migliavacca, M., Mohanty, B. P., Moore, C. E., Mudd, R., Munger, J. W., Murrell, Z. E., Nesic, Z., Neufeld, H. S., O'Halloran, T. L., Oechel, W., Oishi, A. C., Oswald, W. W., Perkins, T. D., Reba, M. L., Rundquist, B., Runkle, B. R., Russell, E. S., Sadler, E. J., Saha, A., Saliendra, N. Z., Schmalbeck, L., Schwartz, M. D., Scott, R. L., Smith, E. M., Sonnentag, O., Stoy, P., Strachan, S., Suvocarev, K., Thom, J. E., Thomas, R. Q., Van den berg, A. K., Vargas, R., Verfaillie, J., Vogel, C. S., Walker, J. J., Webb, N., Wetzel, P., Weyers, S., Whipple, A. V., Whitham, T. G., Wohlfahrt, G., Wood, J. D., Wolf, S., Yang, J., Yang, X., Yenni, G., Zhang, Y., Zhang, Q., and Zona, D.: PhenoCam Dataset v2.0: Vegetation Phenology from Digital Camera Imagery, 2000–2018 [data set], ORNL Ridge, https://doi.org/10.3334/ORNLDAAC/1674, 2019.

Sibayan, E. B., Samoy-Pascual, K., Grospe, F. S., Casil, M. E. D., Tokida, T., Padre, A. T., and Minamikawa, K.: Effects of alternate wetting and drying technique on greenhouse gas emissions from irrigated rice paddy in Central Luzon, Philippines, Soil Sci. Plant Nutr., 64, 39–46, https://doi.org/10.1080/00380768.2017.1401906, 2018.

Sun, H., Lu, H., and Feng, Y.: Greenhouse gas emissions vary in response to different biochar amendments: an assessment based on two consecutive rice growth cycles, Environ. Sci. Pollut. Res., 26, 749–758, https://doi.org/10.1007/s11356-018-3636-0, 2019a.

Sun, Y., Xia, G., He, Z., Wu, Q., Zheng, J., Li, Y., Wang, Y., Chen, T., and Chi, D.: Zeolite amendment coupled with alternate wetting and drying to reduce nitrogen loss and enhance rice production, Field Crop. Res., 235, 95–103, https://doi.org/10.1016/j.fcr.2019.03.004, 2019b.

Tran, D. H., Hoang, T. N., Tokida, T., Tirol-Padre, A., and Minamikawa, K.: Impacts of alternate wetting and drying on greenhouse gas emission from paddy field in Central Vietnam, Soil Sci. Plant Nutr., 64, 14–22, https://doi.org/10.1080/00380768.2017.1409601, 2018.

Wang, H., Zhang, Y., Zhang, Y., McDaniel, M. D., Sun, L., Su, W., Fan, X., Liu, S., and Xiao, X.: Water-saving irrigation is a 'win-win' management strategy in rice paddies – With both reduced greenhouse gas emissions and enhanced water use efficiency, Agric. Water Manage., 228, 105889, https://doi.org/10.1016/j.agwat.2019.105889, 2020.

Wang, Y., Hu, Z., Shen, L., Liu, C., Islam, A. R. M. T., Wu, Z., Dang, H., and Chen, S.: The process of methanogenesis in paddy fields under different elevated CO_2 concentrations, Sci. Total Environ., 773, 145629, https://doi.org/10.1016/j.scitotenv.2021.145629, 2021.

Wu, K., Gong, P., Zhang, L., Wu, Z., Xie, X., Yang, H., Li, W., Song, Y., and Li, D.: Yield-scaled N_2O and CH_4 emissions as affected by combined application of stabilized nitrogen fertilizer and pig manure in rice fields, Plant Soil Environ., 65, 497–502, https://doi.org/10.17221/286/2019-PSE, 2019.

Yang, S., Jiang, Z., Sun, X., Ding, J., and Xu, J.: Effects of Biochar Amendment on CO_2 Emissions from Paddy Fields under Water-Saving Irrigation, Int. J. Environ. Res. Public Health, https://doi.org/10.3390/ijerph15112580, 2018.

Yuan, M., Cai, C., Wang, X., Li, G., Wu, G., Wang, J., Geng, W., Liu, G., Zhu, J., and Sun, Y.: Warm air temperatures increase photosynthetic acclimation to elevated CO_2 concentrations in rice under field conditions, Field Crop. Res., 262, 108036, https://doi.org/10.1016/j.fcr.2020.108036, 2021.

Zhang, H., Yu, C., Kong, X., Hou, D., Gu, J., Liu, L., Wang, Z., and Yang, J.: Progressive integrative crop managements increase grain yield, nitrogen use efficiency and irrigation water productivity in rice, Field Crop. Res., 215, 1–11, https://doi.org/10.1016/j.fcr.2017.09.034, 2018.

Zhang, H., Liu, H., Hou, D., Zhou, Y., Liu, M., Wang, Z., Liu, L., Gu, J., and Yang, J.: The effect of integrative crop management on root growth and methane emission of paddy rice, Crop J., 7, 444–457, https://doi.org/10.1016/j.cj.2018.12.011, 2019.

Additionally, we have included the results of site validation in the revised manuscript as follows:

- The proposed rice calendar successfully extracts rice transplanting and harvest dates at 0.5° grid-cell across monsoon Asia by utilizing the rice feature-based phenology algorithm (Zhao et al., 2023) on Sentinel-1 and Sentinel-2 images (Fig. 2 Step 1 Algorithm a). The detected transplanting and harvest dates have been validated against 40 site-scale records from the literatures, showing high agreement with R^2 of 0.9 and 0.87, Bias of 7.99 and −9.07 days, MAE of 16.32 and 19.58 days, and RMSE of 19.00 and 22.43 days for transplanting and harvest days, respectively (Supplementary Text 3.1). The robustness of the site validation (Supplementary Text 3.1), combined with reasonable performance compared to other rice calendars (Fig. 9), further demonstrates the efficacy of the transplanting and harvest dates in the proposed rice calendar.

  The main difference between the proposed rice calendar with other rice calendar lies in the algorithm for phenological date extraction. In contrast to census-based methods (such as the RiceAtlas rice calendar) that face the issue of overlapping rice croppings, and remote sensing-based methods (such as the RICA rice calendar) that rely on constant threshold values set for large areas, this algorithm is not limited by rice variety, management, and environmental factors. It extracts the features of flooding around the transplanting date and peak yellowness during harvest from the minimum VH and peak NDYI values, respectively, without setting threshold parameters to characterize rice phenological variation. Unfortunately, due to the absence of ground-truth data, it is not possible to validate the Asian continental scale rice calendar with correct accuracy. Instead, the validation in this study was based on observational records available in the previous literature. In this validation, it is worth noting that the proposed rice calendar showed a relatively high coefficient of determination and low RMSE compared to other rice calendars (Supplementary Text 3.2) (Lines 397-414).

References:

Zhao, X., Nishina, K., Akitsu, T.K., Jiang, L., Masutomi, Y., Nasahara, K.N.: Feature-based algorithm for large-scale rice phenology detection based on satellite images, Agric. For. Meteorol., 329, 109283, https://doi.org/10.1016/j.agrformet.2022.109283, 2023

R3C3*: In Central China, there are could be bias in some regions with triple-cropping intensity. Please double check it.*

Response: Thank you for this valuable comments. We agree with you that the detection of triple cropping in central China could be bias, as most rice cultivation in central China follows a single or double rice cropping system (Liu et al., 2020; Zhang et al., 2020). The bias of triple cropping detection in central China might result from the presence of multiple crops cropping systems, leading to an overestimation of the number of rice croppings. In other words, before or after rice cultivation, other crops might be planted, which could be wrongly considered as one of the rice croppings. We have discussed this uncertainty in the "Uncertainty" section of the manuscript as follows:

"Furthermore, the complexity of multiple crop cropping systems can lead to an overestimation of the number of rice croppings. The growth of other crops exhibits a similar pattern of a mono-peaked EVI time series and flood irrigation before sowing, similar to rice (Ahmad and Iram, 2023). Examples include the middle rice cropping system (rice with wheat, barley, or rapeseed cropping systems) in East and Central China (Chen et al., 2020) and the rice–wheat cropping systems on the Indo-Gangetic Plain (Abrol, 1997; Dhanda et al., 2022)."

To call attention to this bias, we have added the following text after the discussion regarding the uncertainty:

- Furthermore, the complexity of multiple crop cropping systems can lead to an overestimation of the number of rice croppings. ~~rice cropping numbers.~~ The growth of ~~the~~ other crop exhibits a similar pattern of a mono-peaked EVI time series and flood irrigation before sowing, similar to rice (Ahmad and Iram, 2023). Examples include the middle rice cropping system (rice with wheat, barley, or rapeseed cropping systems) in East and Central China (Chen et al., 2020) and rice–wheat cropping systems on the Indo-Gangetic Plain (Abrol, 1997; Dhanda et al., 2022). Thus, detected triple rice in central China (Fig. 10a) will be bias, which requires specific noted when using it. (Lines 474-479).

References:

Liu, L., Xiao, X., Qin, Y., Wang, J., Xu, X., Hu, Y., and Qiao, Z.: Mapping cropping intensity in China using time series Landsat and Sentinel-2 images and Google Earth Engine, Remote Sens. Environ., 239, 111624, https://doi.org/10.1016/j.rse.2019.111624, 2020.

Zhang, G., Xiao, X., Dong, J., Xin, F., Qin, Y., Doughty, R.B., and Moore, B.: Fingerprint of rice paddies in spatial–temporal dynamics of atmospheric methane concentration in monsoon Asia, Nat. Commun., 11, 554, https://doi.org/10.1038/s41467-019-14155-5, 2020.

R3C4: According to Figure 1b, most of the 0.5° grids have a very low rice proportion, which are dominated by other crops than paddy rices, but the rice cropping intensity map shown in Figure 10 may not consider the potential rice and non-rice mixture issues.

Response: We greatly appreciate the reviewer's helpful comments. The reviewer raises the issue that the rice cropping intensity map shown in Figure 10 may not consider the rice-crop mixing at low rice percentage grid. To be honest, it is not easy to depict the non-rice mixed with rice in the figure of rice cropping intensity. Inspired by your idea, we have recognized that the low rice proportion might have the risk of errors in identifying rice cropping intensity, that is, non-rice will be mistakenly identified as rice cultivation, or wrongly identified as one of rice croppings. Although we have tried to avoid this problem through sampling strategy – rice paddy fields were randomly selected from rice paddy field distribution map to obtain the rice phenology at each 0.5°grid. Obviously, the possibility of classification errors in the rice paddy field distribution map will increase at lower percentage rice grids, consequently resulting in the high possibility of non-rice crops being mixed with rice, as you mentioned. Therefore, to raise attention to this issue, we have incorporated this issue into the "Uncertainty" discussion section. Additionally, we have provided a potential solution for the future, involving the application of a relatively higher resolution rice distribution map. Please see the revision as follows:

- Furthermore, the complexity of multiple crop cropping systems can lead to an overestimation of the number of rice croppings. ~~rice cropping numbers.~~ The growth of ~~the~~ other crop exhibits a similar pattern of a mono-peaked EVI time series and flood irrigation before sowing, similar to rice (Ahmad and Iram, 2023). Examples include the middle rice cropping system (rice with wheat, barley, or rapeseed cropping systems) in East and Central China (Chen et al., 2020) and rice–wheat cropping systems on the Indo-Gangetic Plain (Abrol, 1997; Dhanda et al., 2022). Thus, detected triple rice in central China (Fig. 10a) will be bias, which requires specific noted when using it. Except for the rice-predominant areas, the rice–crop mixing problem can also puzzle the grids with a low rice percentage. While rice phenology extraction was obtained through randomly selected sampling of rice paddy fields from the 500 m resolution rice distribution map (Zhang et al., 2020), grids with a low rice percentage have a higher possibility of errors in wrongly classifying non-rice crops as rice, consequently resulting in a higher possibility of non-rice crops being considered as rice cultivation or one of the rice croppings. The application of a higher resolution rice distribution map is expected to address this issue. (Lines 474-484).

Minor comments:

***R3C5**: Line 77: "Normalized Yellow Index" should be "Normalized Differenced Yellow Index"*

Response: Our apologies. We have revised this as follows in the revised manuscript:

- A feature-based algorithm, proposed for large-scale rice phenology detection (Zhao et al., 2023), excels in utilizing backscattering (VH) and vegetation indices (Enhanced Vegetation Index (EVI) and Normalized Difference Yellow Index (NDYI) derived from Sentinel-1&-2 images to reflect features related to rice cultivation such as flooding, maximum leaf area, and most yellowness around transplanting, heading, and harvest date (Lines 75-78).

***R3C6**: Figure 11 shows very significant differences among the four sources of rice cropping maps, more potential reason on the definition of different products should be carefully considered.*

Response: Thank you for your insightful comment. We agree with you that the more potential reasons among the rice calendars should be carefully considered to explain the observed significant differences in rice paddy field area, as shown in Fig. 11. One potential reason for these area differences could be the different methodologies used for rice calendar production. For instance, the RicaAtlas rice calendar is derived from sub-national statistics compilation, while the RICA and the proposed rice calendar are based on remote sensing techniques. Compared to the census-based method, remote sensing can capture the varying rice phenology at fine heterogeneity within administrative units. These methodological differences might lead to divergent representations of rice cropping areas. Additionally, the algorithm employed in retrieving phenological dates could affect the observed differences. The rule-based algorithm used in the RICA rice calendar relies on the turning point or key nodes of vegetation index, which are constant for large areas. The RiceAtlas rice calendar faces the problem of overlapping between croppings. Instead, feature-based algorithm used for the proposed rice calendar captures the flooding around transplanting date and peak yellowness during harvest. Furthermore, factors such as the spatial resolution and treatment of fragmented rice paddy fields could explain the area differences. For example, the spatial resolution of the RiceAtlas rice calendar is not uniform due to the sub-national statistics covering different spatial extents. All rice paddy fields in some sub-national areas were identified as single/double/triple croppings, and the area was calculated accordingly. Although the RICA rice calendar was produced by the satellite images, it was eventually converted to sub-national spatial scales. Given the coarse spatial resolution, fragmented rice paddy fields cannot be recognized in these three rice calendars either. Moreover, we conducted site validation among all the rice calendars. The site validation results reinforce the advantage of the proposed rice calendar. The phenological dates in the proposed rice calendar were found to be closer to the in-site records compared to those of other three rice calendars. The relatively large bias and variance in these three rice calendars further demonstrate their limitations and uncertainties in calculating the paddy area.

As mentioned in Section 3.3 'Advantages of the proposed rice calendar' and supported by the newly added site validation results, we have revised the manuscript to address these reasons for the significant differences in paddy areas among the rice calendars as follows:

- The advantages of the above-mentioned algorithms (Fig. 2 Step 1, Step 2) largely contribute to the production of a gridded rice calendar. The proposed rice calendar provides spatially explicit rice phenology with continental coverage through remote sensing methods. The major difference between the proposed rice calendar and the RICA rice calendar lies in the use of a feature-based algorithm with VH and NDYI, which allows the proposed rice calendar to theoretically estimate rice phenology more accurately. Zhao et al. (2023) demonstrated that VH can accurately capture the start of paddy water logging, and NDYI is a good indicator of rice maturity stage. The proposed rice calendar presents a highly patchy map of rice phenological information (Figs.6 and 10a). The 0.5° resolution of the proposed rice calendar is finer than that of other rice calendars, including the RiceAtlas, RICA at sub-national scale, and SAGE derived from sub-national data. This improvement greatly reduces the bias error caused by assigning averaged rice phenology to administrative units, as rice phenology can vary considerably with large administrative units (Franch et al., 2022). Furthermore, the proposed rice calendar displays the detailed distribution of rice paddy fields (Figs. 6 and 10a), in contrast to previous rice calendars that covered entire administrative areas, irrespective of the small proportion of rice cultivation (Figs. S6-S8 and 10b-d). Site-scale validation reinforces the above-mentioned advantages, as the phenological dates in the proposed rice calendar are closer to the in-site records (Fig. S13; Fig. S14; Supplementary Text 3). The relatively large bias and variance in other three rice calendars (Fig. S14) demonstrate their limitations and uncertainties in calculating the rice paddy field area as shown in Fig. 11. (Lines 447-461).

R3C7*: Please check whether the data links are active, and hopefully the data and code links can be available later.*

Response: We appreciate the reviewer's suggestions regarding data accessibility. We have checked the data and code links (https://www.nies.go.jp/doi/10.17595/20230728.001-e.html) provided in the manuscript, and they are now active and accessible.