



Supplement of

Monsoon Asia Rice Calendar (MARC): a gridded rice calendar in monsoon Asia based on Sentinel-1 and Sentinel-2 images

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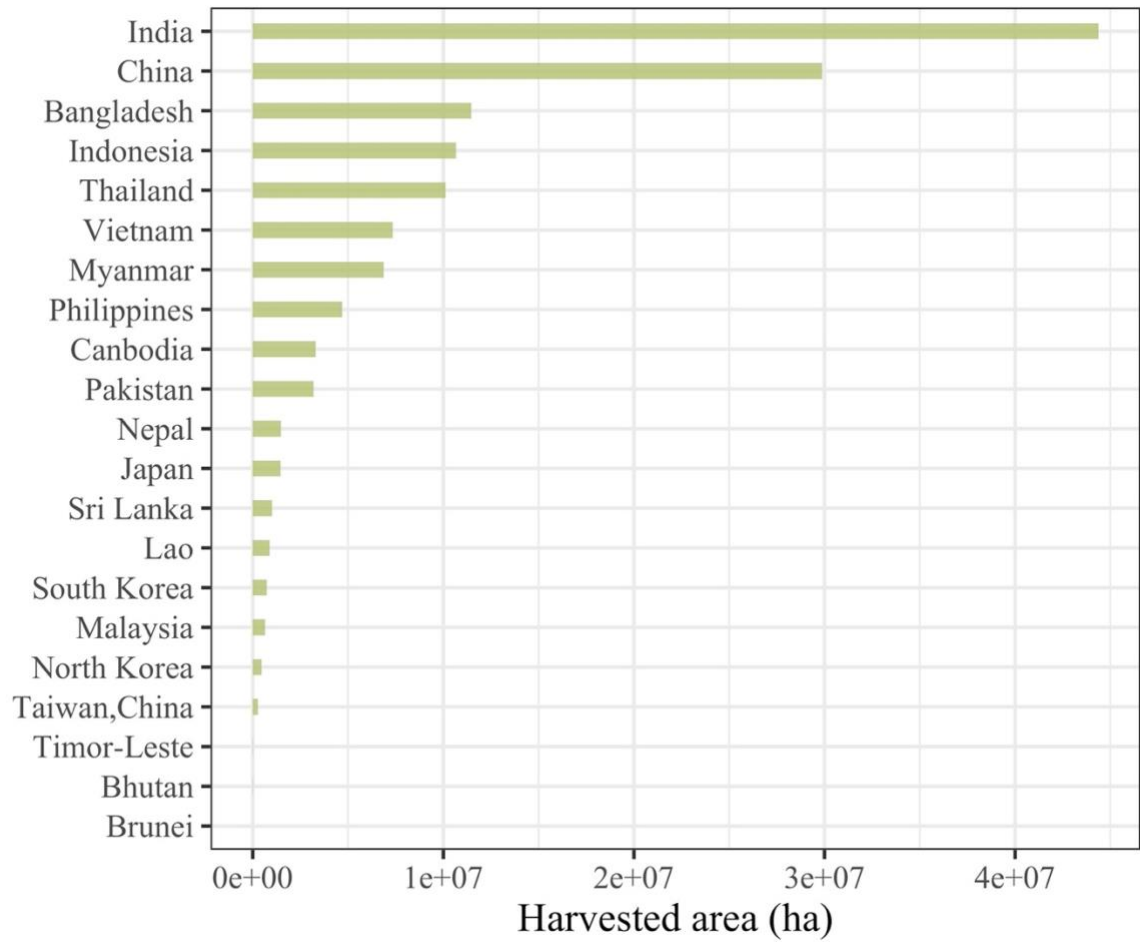


Figure S1. Harvested area of rice paddy fields for countries in monsoon Asia in 2019 and 2020. The data in this figure was derived from FAOSTAT (<https://www.fao.org/faostat/en/#data>) with last update on December 23, 2022 and access on 1 January 2023.

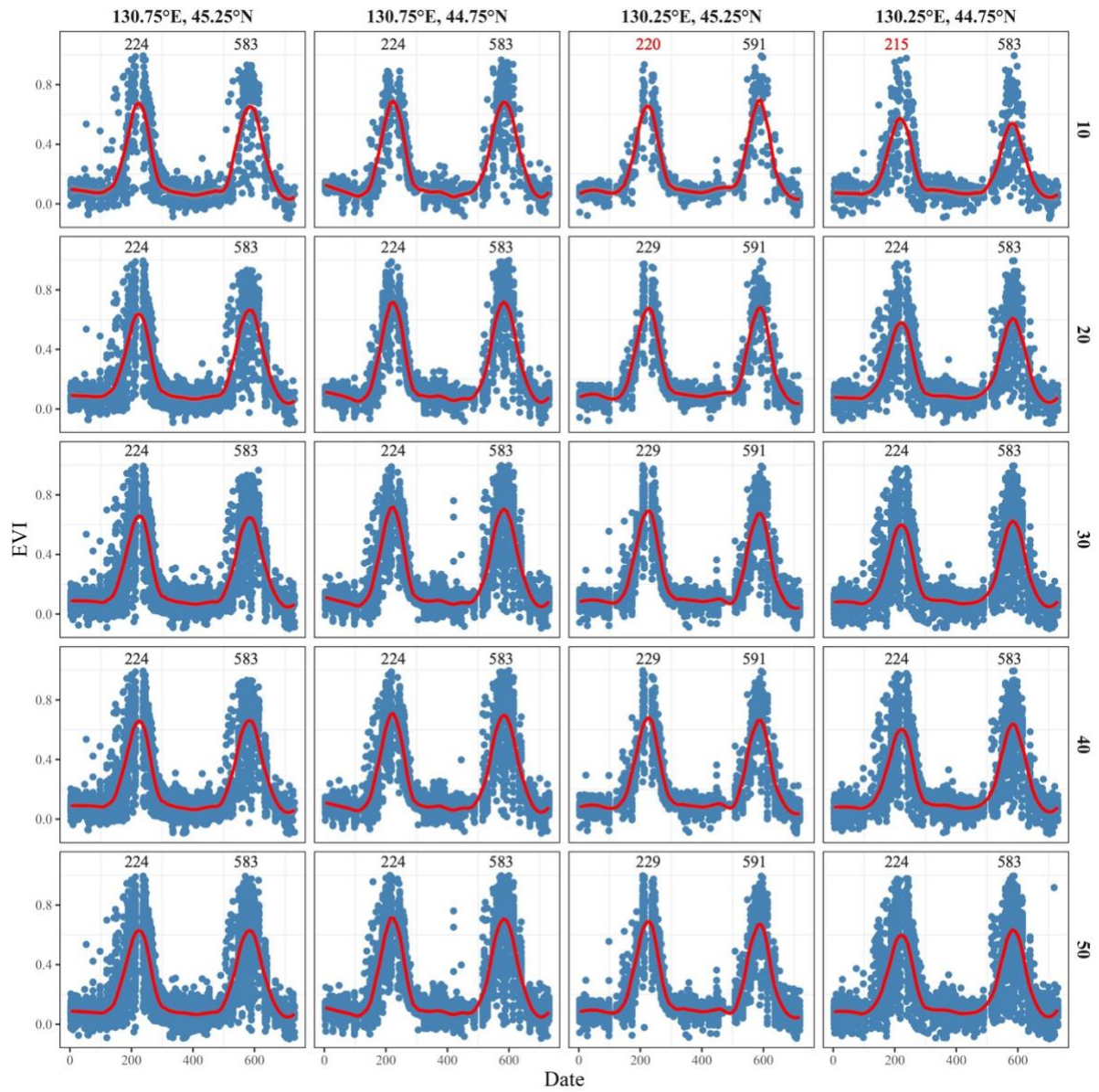


Figure S2. Example of the effect of sampling numbers in rice paddy fields (10, 20, 30, 40, and 50) for extracting phenological dates. X-axis denotes the days from 1 January 2019 to 31 December 2020, and Y-axis denotes the smoothed EVI values. The red line denotes the smoothed EVI values. The number in each panel denotes the extracted peak EVI days.

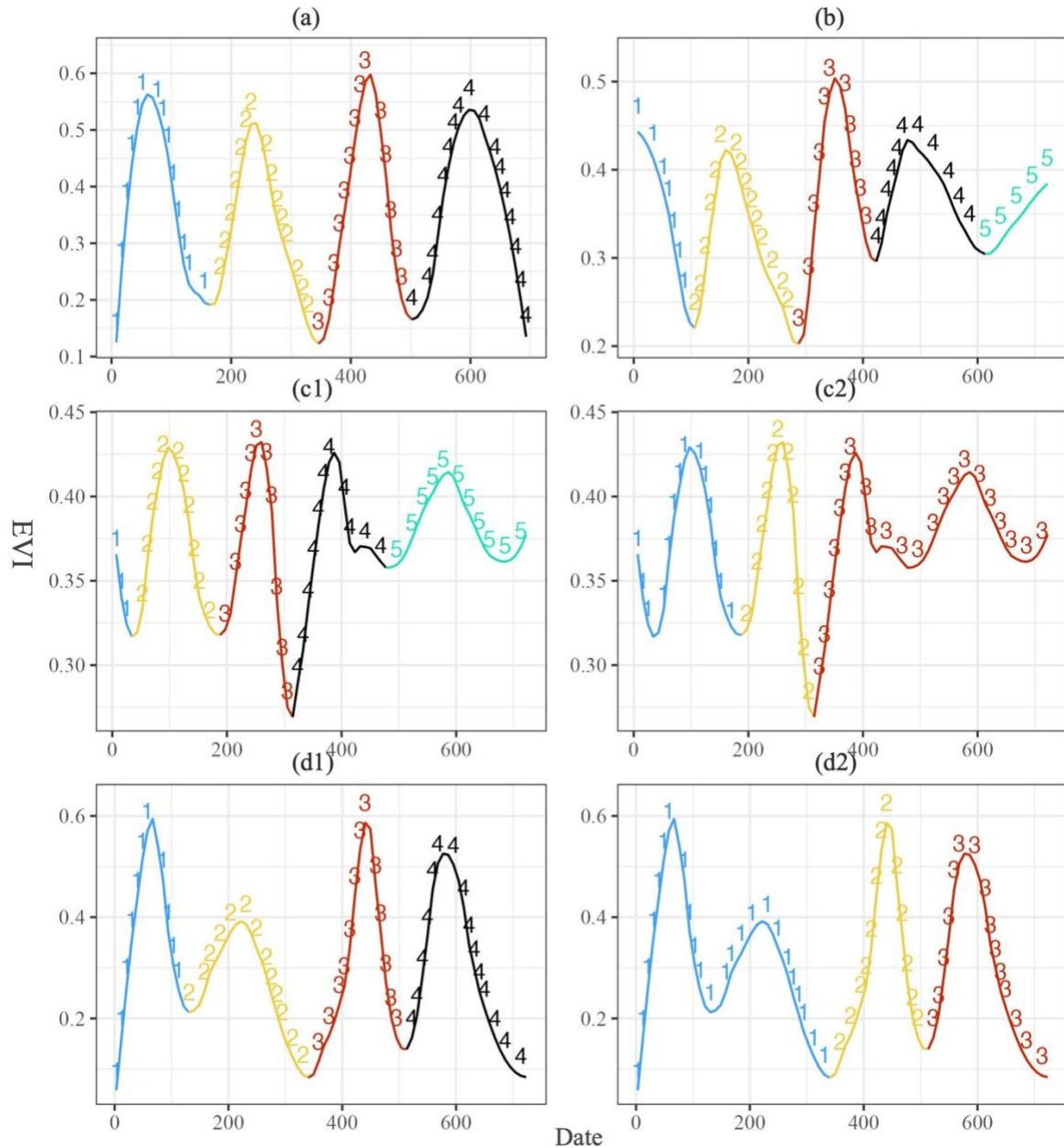


Figure S3. Example of the number of rice cropping season detection using Weibull function implemented via the “carditates” package in R, and comparison of the parameters for detection. X-axis denotes the days from 1 January 2019 to 31 December 2020, and Y-axis denotes the smoothed EVI values. The peakwindow function was used to identify the number of peaks from smoothed EVI time series (e.g., Philippines (16.25°N, 121.75E°)) **(a)**, even though there is an incomplete downward-opening shape (e.g., Philippines (7.25°N, 124.25E°)) **(b)**. Comparison of the *mincut* setting on number of rice cropping season detection (e.g., Philippines (7.25°N, 124.25E°)), the number of rice cropping seasons was 5 when *mincut* equals 0.9 **(c1)**, whereas the number of rice cropping seasons was 3 when *mincut* equals 0.8 **(c2)**. Similarly, comparison of the *minpeak* setting on the number of rice cropping seasons detection (e.g., Philippines (8.25°N, 122.25E°)), the number of rice cropping seasons was 4 when *minpeak* equals 0.6 **(d1)**, whereas the number of rice cropping seasons was 3 when *minpeak* equals 0.7 **(d2)**.

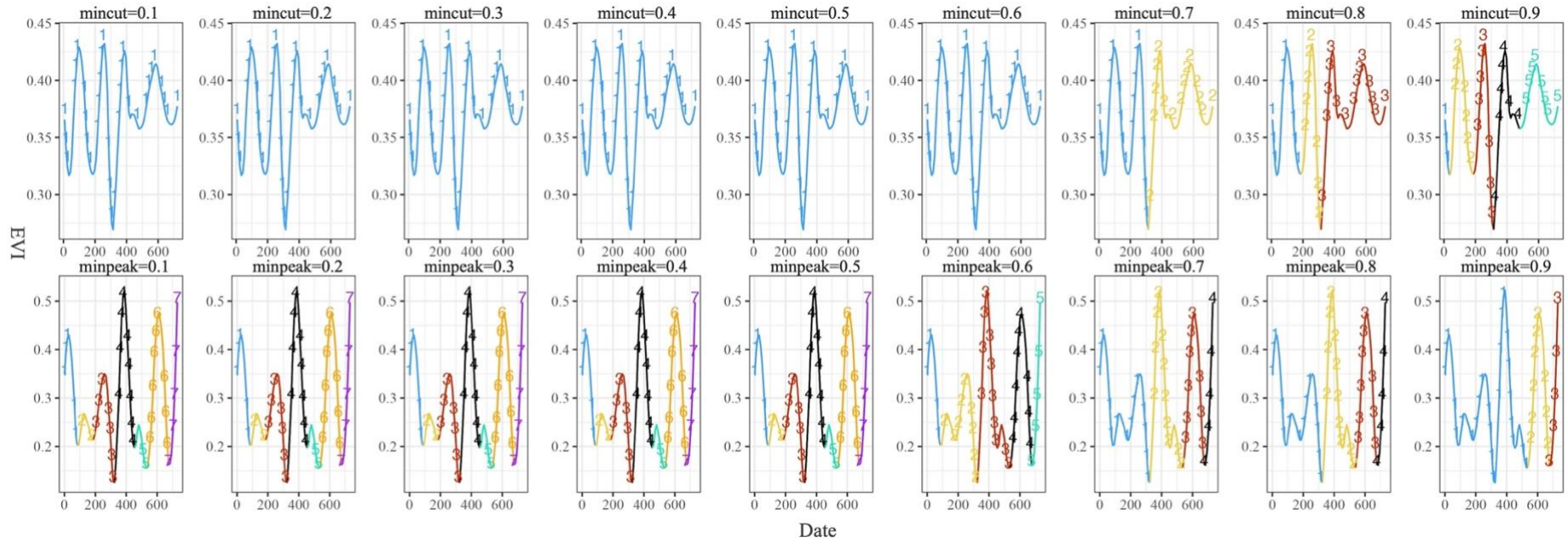


Figure S4. Comparison in *mincut* and *minpeak* values in peakwindow function of “carditate” R package. The *mincut* and *minpeak* values are 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, and 0.9. The two grids are located at 7.25°N, 124.25°E and 15.75°N, 119.75°E in the Philippines.

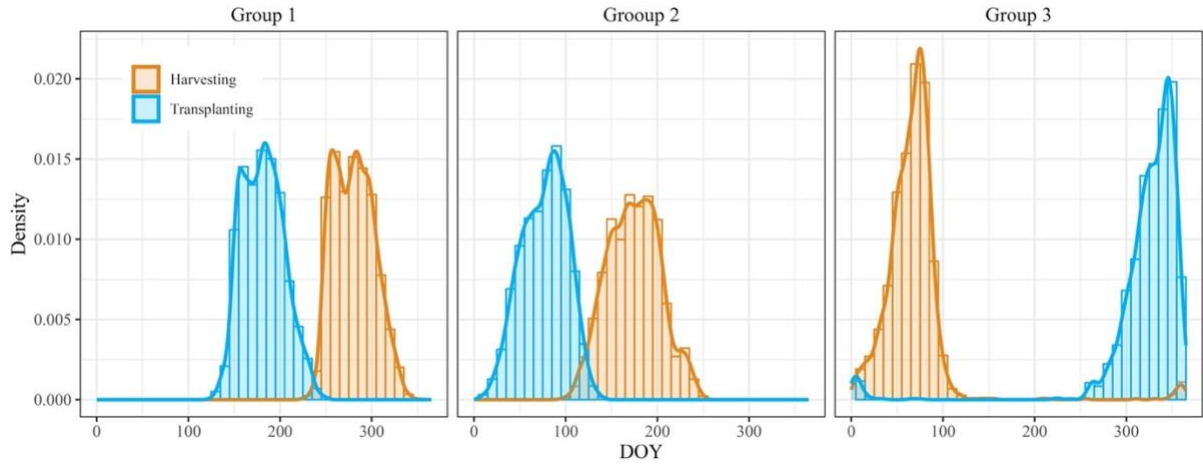


Figure S5. Distribution of transplanting and harvesting dates for three groups. Blue and orange represent the transplanting date and the harvesting date, respectively.

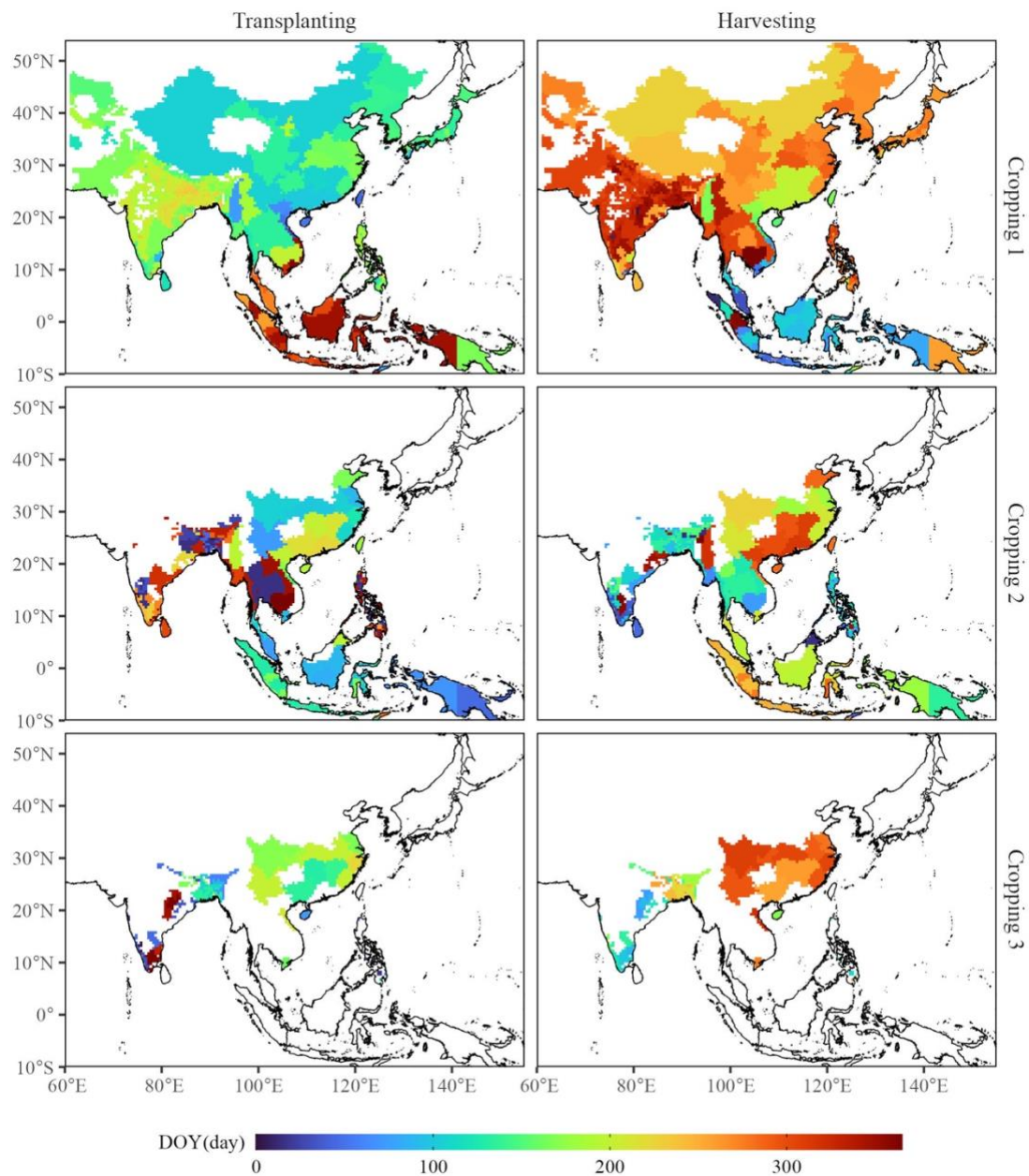


Figure S6. Transplanting and harvesting dates from the RiceAtlas. The gradient from blue to red in the legend denotes the respective transplanting and harvesting dates.

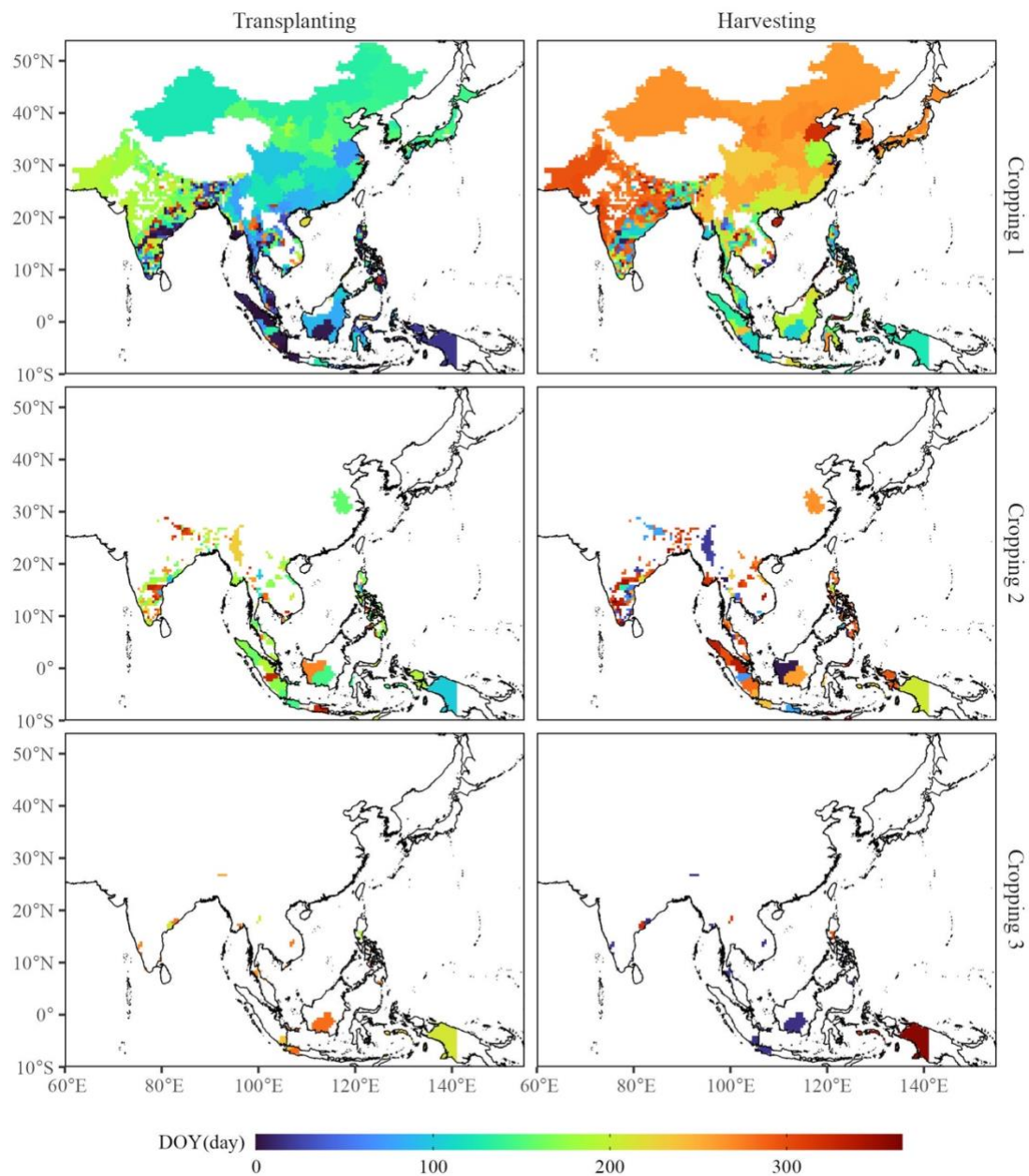


Figure S7. Transplanting and harvesting dates from the RICA. The gradient from blue to red in the legend denotes the respective transplanting and harvesting dates.

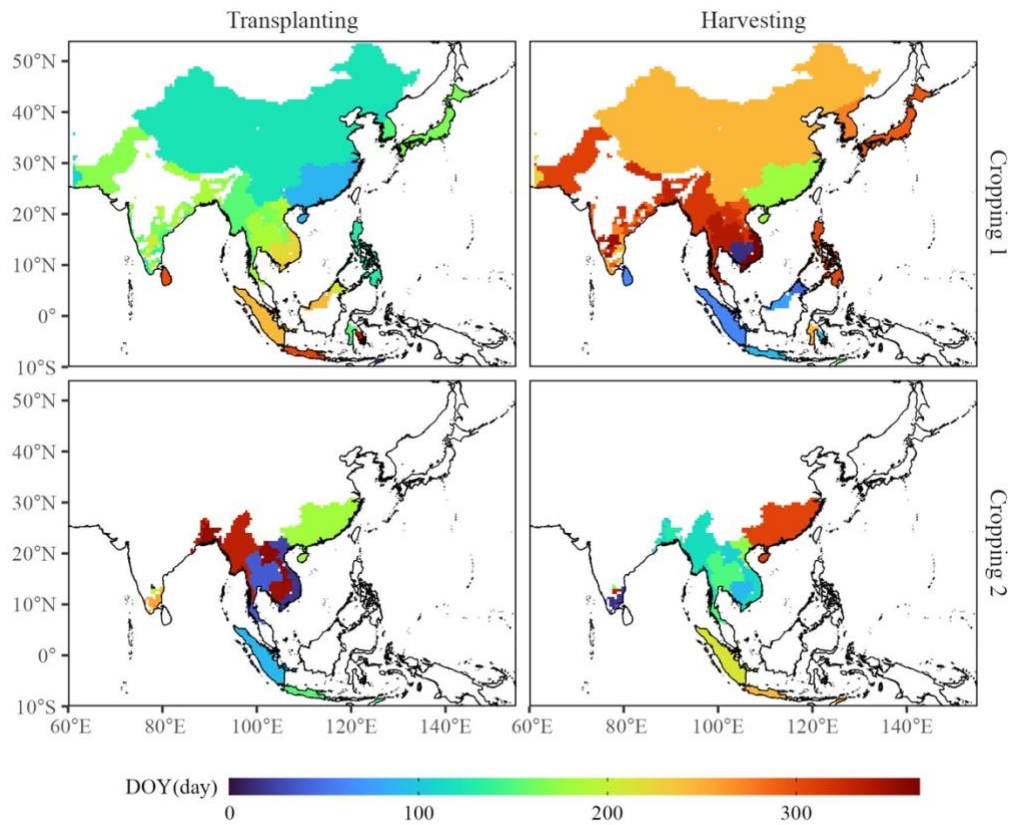


Figure S8. Transplanting and harvesting dates from the SAGE. The gradient from blue to red in the legend denotes the respective transplanting and harvesting dates.

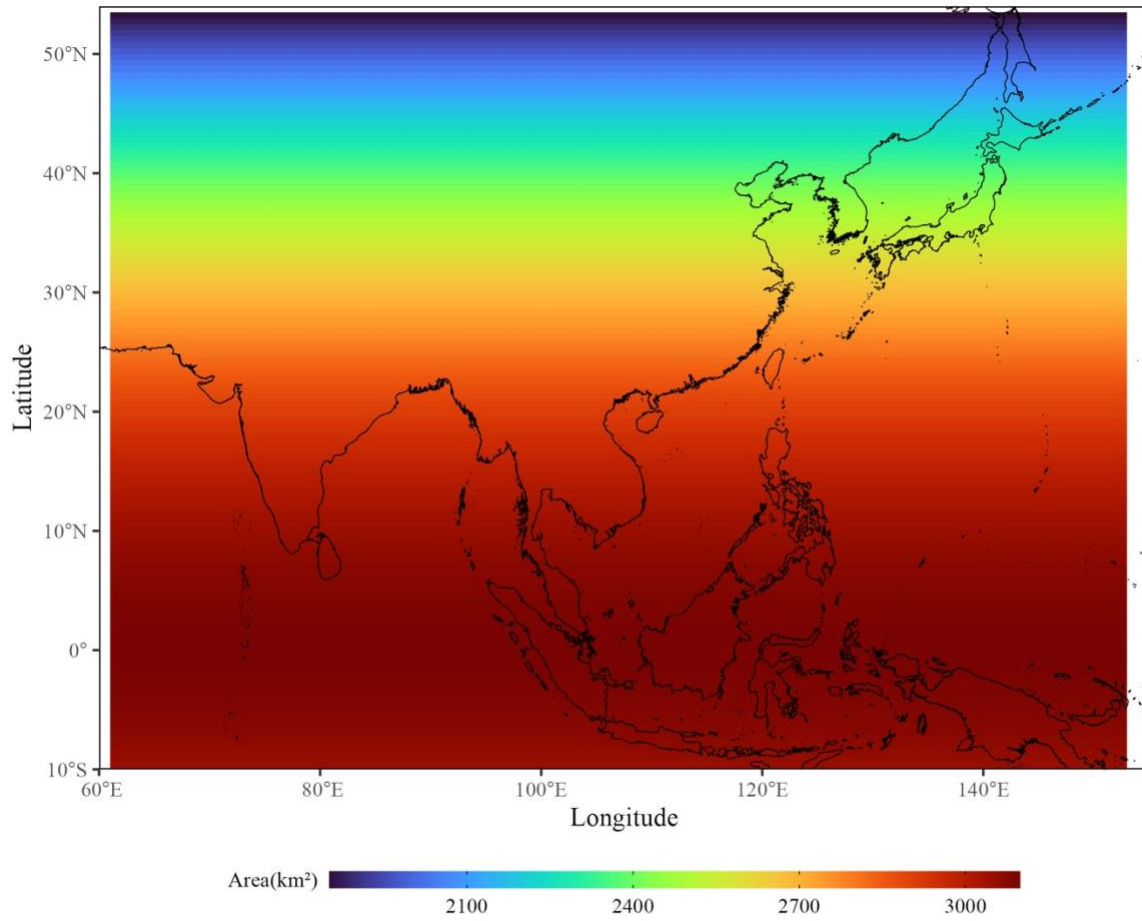


Figure S9. Area of each grid cell (0.5°) on the ellipsoidal earth within the study area (10° S to 53.5° N, 61° E to 153° E).

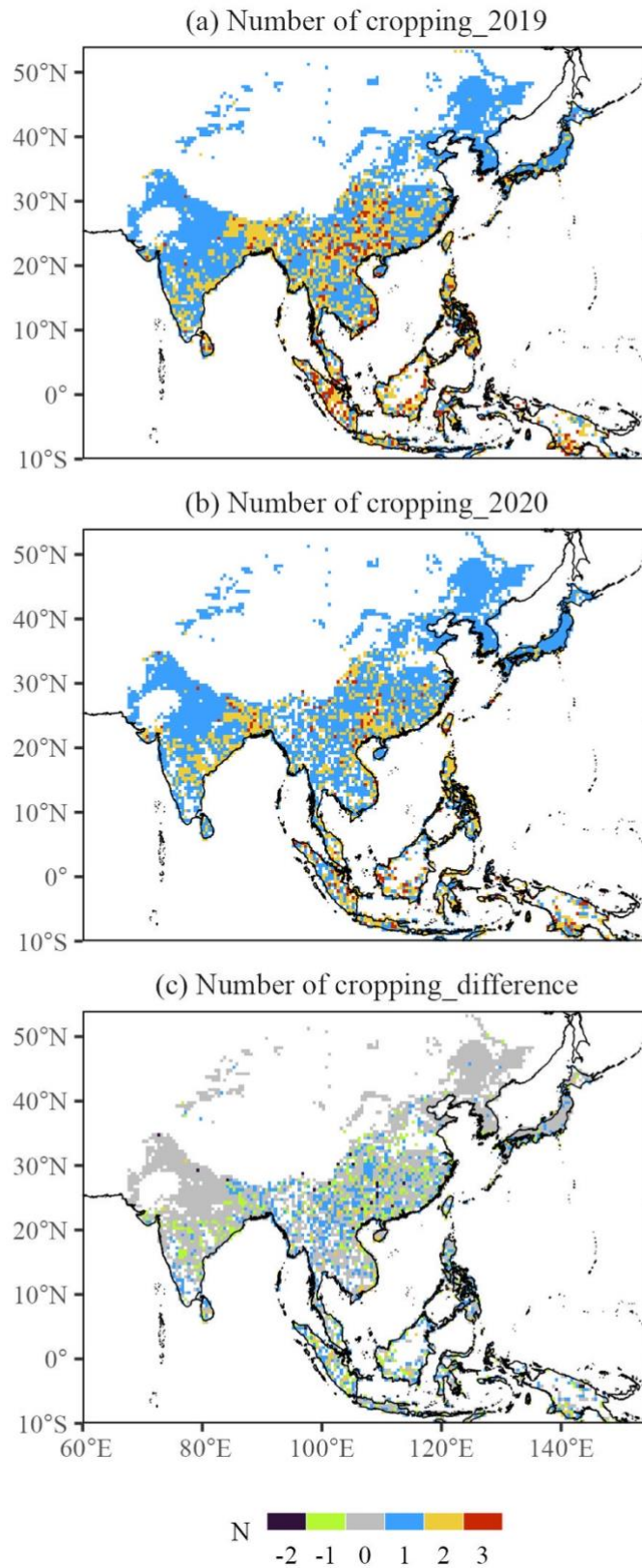


Figure S10. Detected number of rice cropping seasons in 2019 (a) and 2020 (b), and difference in number of rice cropping seasons during the two years (c).

S1. Performance of the proposed rice calendar

The performance of the proposed rice calendar in determining the transplanting and harvesting dates was assessed using the coefficient of determination (R^2), bias error (Bias), Mean Absolute Error (MAE), and Root Mean Square Error (RMSE) which were calculated as follows:

$$R^2 = 1 - \frac{\sum_{i=1}^n (y_i - \bar{y})(s_i - \bar{s})^2}{\sum_{i=1}^n (y_i - \bar{y})^2 - \sum_{i=1}^n (s_i - \bar{s})^2} \quad (1)$$

$$\text{Bias} = \frac{1}{n} \sum_{i=1}^n (y_i - s_i) \quad (2)$$

$$\text{MAE} = \frac{1}{n} \sum_{i=1}^n |y_i - s_i| \quad (3)$$

$$\text{RMSE} = \sqrt{\frac{1}{n} \sum_{i=1}^n (y_i - s_i)^2} \quad (4)$$

where y_i and \bar{y} are the phenological dates from the proposed rice calendar for sample grid (i) and the corresponding mean value, respectively, s_i and \bar{s} are the phenological dates from the reference rice calendar for sample grid (i) and the corresponding mean value, respectively, and n represents the number of sampled phenological dates.

S2. Optimal time window for transplanting and harvesting dates detection

To identify the optimal time window for detection of the transplanting and harvesting dates, the time window for detection of the minimum VH was set from 120 days before the date of peak EVI to 45 days before the date of peak EVI ($DOY_{EVI_{max}}$), or from the first day of EVI arc ($DOY_{EVI_{arc_{first\ day}}}$) to 45 days before the date of peak EVI. The time window for detection of the peak NDYI was set from 13 days after the peak EVI date to 55 days after the date of peak EVI, or from 13 days after the peak EVI date to the last day of the EVI arc ($DOY_{EVI_{arc_{last\ day}}}$). It can be shown as follow table.

Table S1. Optimal time window for transplanting and harvesting dates detection

Time window	Transplanting date	Harvesting date
1	$[DOY_{EVI_{max}} - 120, DOY_{EVI_{max}} - 45]$	$[DOY_{EVI_{max}} + 13, DOY_{EVI_{max}} + 55]$
2	$[DOY_{EVI_{arc_{first\ day}}}, DOY_{EVI_{max}} - 45]$	$[DOY_{EVI_{max}} + 13, DOY_{EVI_{arc_{last\ day}}}]$

S3. 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 harvesting 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 harvesting 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).

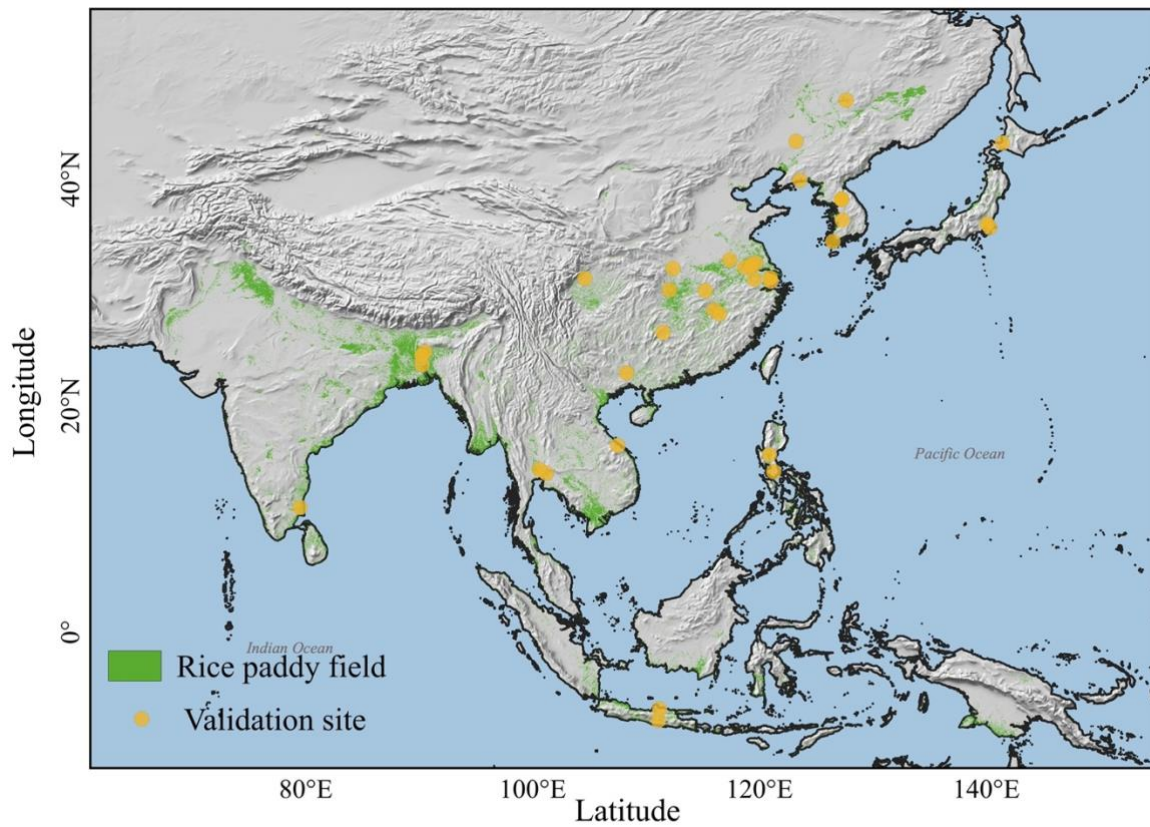


Figure S11. Location of the validation sites in monsoon Asia. Green areas indicate rice paddy fields. Yellow circles denote the validation site collected from the literatures and dataset.

Table S2. Transplanting date and harvesting 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 °N	101.22 °E	182	273	190.34	285.34	135	306	138.73	264.66	185.5	339	Chidthaisong et al., 2018
South Korea	36.37 °N	127.33 °E	149	289	164.25	266.18	148	275	145.08	277.41	151	274	Choi et al., 2019
China	30.97 °N	121.01 °E	175	297	175.61	269.95	160	304	262.18	19.18	121.5	245.5	Fang et al., 2021
Japan	35.71 °N	140.34 °E	158	266	157.68	251.79	117	244	124.19	252.35	167	291	Fawibe et al., 2019
China	32.10 °N	112.40 °E	152	274	159.85	253.46	166	294	136.64	257.02	121.5	245.5	Feng et al., 2021
Bangladesh	24.75 °N	90.50 °E	20	119	34.10	128.45	5	110	17.83	129.72	-12	127.5	Forhad et al., 2019
China	30.21 °N	112.09 °E	157	257	150.93	250.49	166	294	136.64	257.02	121.4	245.5	Fu et al., 2019
South Korea	38.20 °N	127.25 °E	121	246	155.95	260.51	140	267	128.19	265.18	151	274	Huang et al., 2018
South Korea	38.20 °N	127.25 °E	129	257	155.95	260.51	140	267	128.19	265.18	151	274	Hwang et al., 2020
Philippines	14.16 °N	121.26 °E	30	133	-28.93	68.77	-16	105	-8.76	105.02	130	301	Islam et al., 2020
Bangladesh	23.60 °N	90.25 °E	25	120	52.86	152.85	10	105	173.01	285.63	-12	127.5	Islam et al., 2020
Bangladesh	24.44 °N	90.24 °E	23	118	37.16	134.05	15	120	50.36	154.87	-12	127.5	Islam et al., 2020

South Korea	38.20 °N	127.25 °E	135	257	155.95	260.51	140	267	128.19	265.18	151	274	Jeong et al., 2020
South Korea	34.48 °N	126.48 °E	152	306	167.17	265.46	-	-	-	-	151	274	Jeong et al., 2020
China	22.88 °N	108.29 °E	102	199	86.25	172.03	101	195	88.08	210.59	88	179.5	Li et al., 2020
China	30.14 °N	115.25 °E	121	229	161.46	252.94	100	181	136.64	257.02	121.5	245.5	Liang et al., 2019
China	28.44 °N	116.00 °E	195	304	186.04	287.20	140	260	109.38	252.92	182.5	306	Liu et al., 2019a
China	28.10 °N	116.50 °E	116	203	104.35	195.59	105	201	109.38	252.92	88	179.5	Liu et al., 2019b
China	31.22 °N	104.62 °E	149	268	175.62	269.52	135	270	99.7	235.3	121.5	245.5	Liu et al., 2021
Thailand	14.37 °N	100.61 °E	305	57	309.77	43.72	390	135	338.71	103.1	37.5	148.5	Maneevitak et al., 2019
Japan	43.18 °N	141.44 °E	144	258	175.09	268.64	-	-	-	-	167	291	Naser et al., 2020
China	46.95 °N	127.67 °E	139	264	155.51	256.52	135	266	137.53	261.92	121.5	245.5	Nie et al., 2020
Indonesia	-7.79 °N	111.10 °E	102	203	69.22	160.35	130	248	-	-	151	243	Nugroho et al., 2018
Japan	36.03 °N	140.11 °E	140	271	150.23	257.62	126	251	132.97	256.28	167	291	Okamura et al., 2018
India	11.00 °N	79.50 °E	167	264	194.62	310.46	181	301	199.21	315.07	133.5	231.5	Oo et al., 2020
China	26.45 °N	111.52 °E	116	199	111.23	198.67	110	200	109.94	240.2	88	179.5	Raheem et al., 2019
Indonesia	-6.78 °N	111.20 °E	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 harvesting date of sites from literatures and dataset. T_MARC and H_MARC denote the transplanting date and harvesting date of the proposed rice calendar at each site location. T_RiceAtlas and H_RiceAtlas denote the transplanting date and harvesting date of the RiceAtlas rice calendar at each site location. T_RICA and H_RICA denote the transplanting date and harvesting date of the RICA rice calendar at each site location. T_SAGE and H_SAGE denote the transplanting date and harvesting 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

S3.1 Comparison of transplanting and harvesting dates between proposed rice calendar and site records

The transplanting and harvesting dates from the proposed rice calendar were further compared with those from the site records. The transplanting and harvesting 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 0.90, Bias of 7.99 days, MAE of 16.32 days, and RMSE of 19.00 days (Fig. S12). Additionally, the harvesting 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.

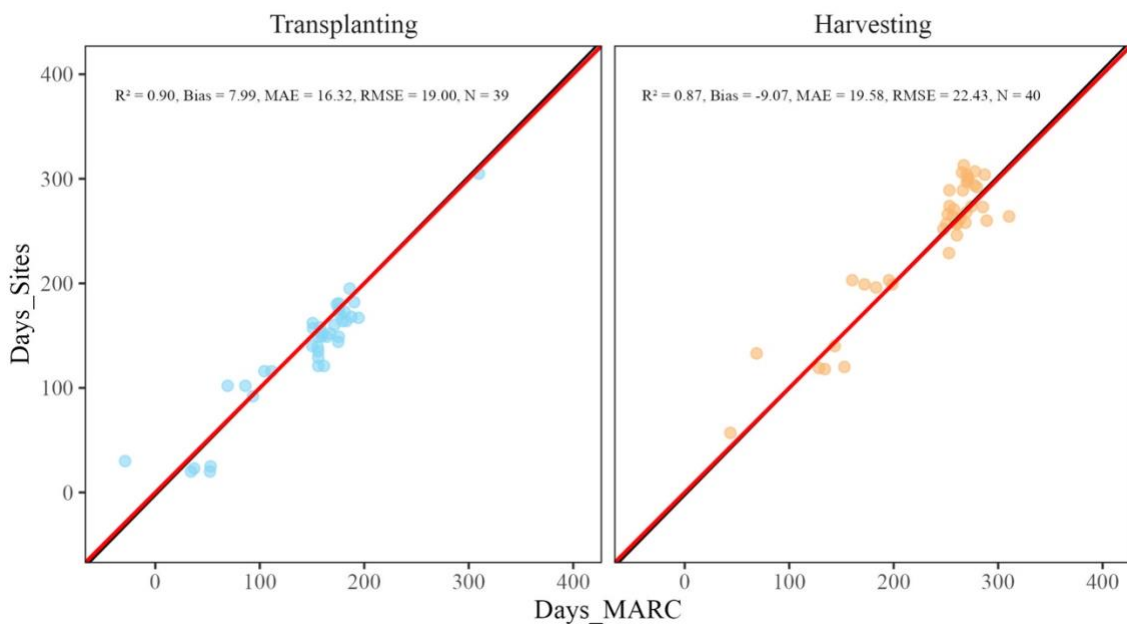


Figure S12. Comparison of transplanting date and harvesting date between the proposed rice calendar and site records. Blue and orange points represent the transplanting date and harvesting date, respectively. Red and black solid lines represent the 1:1 line and regression, respectively.

S3.2 Comparison of transplanting and harvesting dates between other rice calendars and site records

To evaluate the superiority of the proposed rice calendar, the transplanting and harvesting dates from other rice calendars were compared with those from the site records. The transplanting and harvesting 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 harvesting dates of RiceAtlas, RICA, and SAGE rice

calendars were correlated with the 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 harvesting dates.

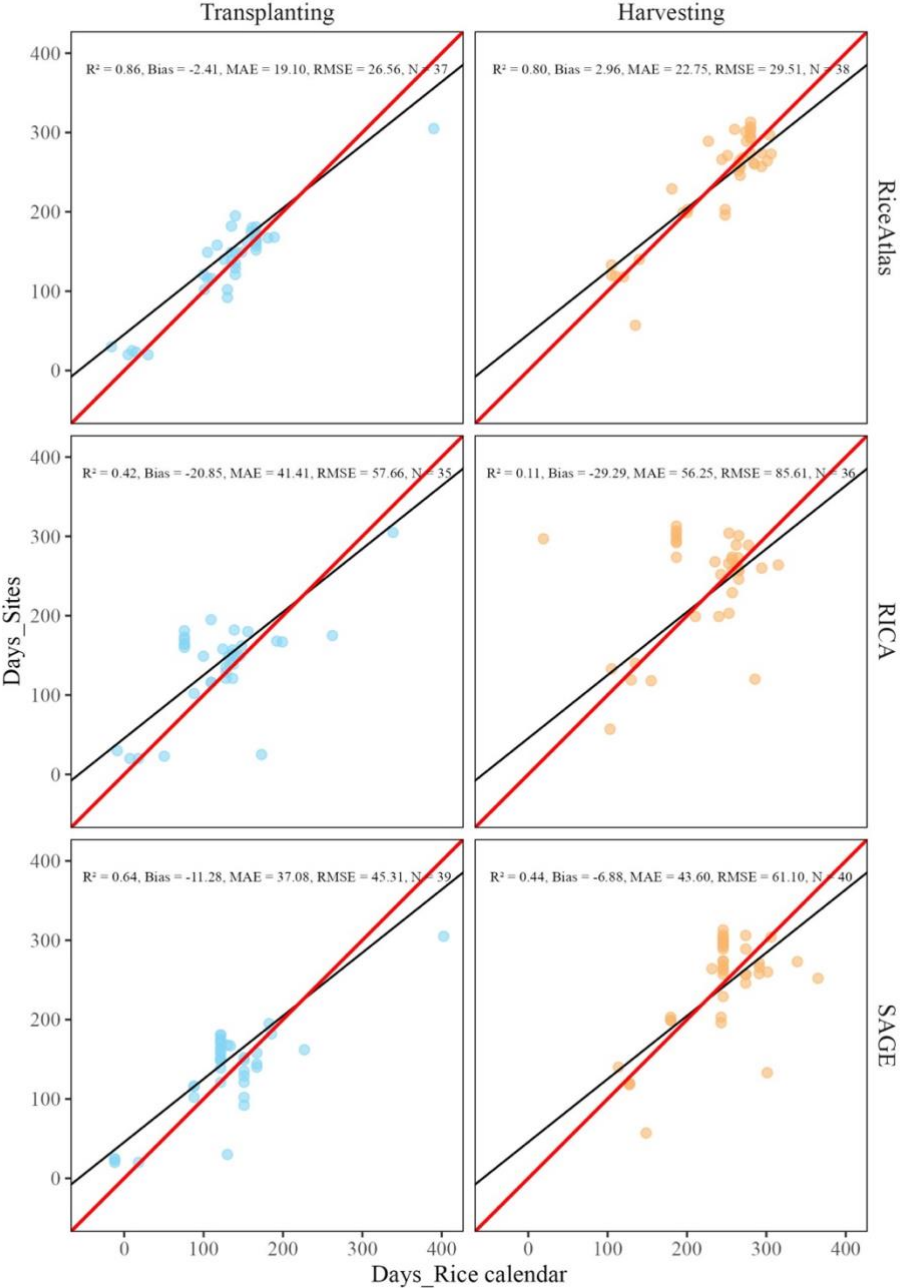


Figure S13. Comparison of transplanting date and harvesting date between the rice calendars (RiceAtlas, RICA, and SAGE) and site records. Blue and orange points represent the transplanting date and harvesting date, respectively. Red and black solid lines represent the 1:1 line and regression, respectively.

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.

Maneejitak, 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 CO₂, CH₄ and N₂O 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 CH₄ 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.

Syednasrollah, B., Young, A. M., Hufkens, K., Milliman, T., Friedl, M. A., Froking, 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., Brunzell, 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. I., 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., Nestic, 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., Wetzell, 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/ORN LDAAC/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 CO₂ 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 N₂O and CH₄ 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 CO₂ 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 CO₂ 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.