Dear reviewers Feb.20, 2023

Manuscript ID essd-2022-392 entitled

"20 m Annual Paddy Rice Map for Mainland Southeast Asia Using Sentinel-1 SAR Data".

We really appreciate the positive feedback of the editor and two referees and own many thanks to their reviews. We appreciate the thorough reviews provided by the editor and two referees again. We agree with these suggestions and have revised the manuscript accordingly. At the same time, in order to improve the quality of the paper, we also further modify the expression of the full text. Below is our response to his/her comments resulting in some clarification. We hope these revisions resolve the problems and uncertainties pointed out by the referee. In the manuscript and this file, the blue parts are revisions suggested by the reviewer 1, green parts for suggestions of reviewer 2. And the red parts are the changed contents that are intended to improve the expressions.

Sincerely,

Hong Zhang

zhanghong@radi.ac.cn

Response to Reviewer 1

Comments to the Author

The manuscript proposes a rice mapping method to construct representative rice growth patterns based on time-series Sentinel-1 SAR data. Apparently, use of Sentinel-1 SAR data for rice mapping is very useful and seems the work is ongoing in the region for some time. Such methodology is useful, especially if it can give the rice area in advance which can help estimate the production helping in making timely trade/consumption plans. Below are few comments that should be helpful to improve the clarity and completeness of the manuscript.

RESPONSE: Thank you very much for your appreciation of our work.

1. What does this statement, .. rice growth patterns in Southeast Asia are too complex…means? Complexity refers to what? Is it not complex in other regions?

RESPONSE: Thank you very much for your comment.

Sorry that the inaccurate word has troubled you. We referred to relevant literatures and changed the term "growth pattern" to "cultivation pattern" or "planning pattern" in the manuscript. We also revised the entire text.

The climate of Southeast Asia is suitable for the growth of rice all year round. There is no strict restriction on the planting time of rice. The planting time of rice in the whole region is not uniform, and the growing stages of rice in different regions are not synchronized. It is difficult to describe the cultivation of rice with a unified phenological information. Therefore, in this paper "complexity" refers to the diversity of rice planting patterns, especially for the entire land mass of Southeast Asian countries, which makes it difficult to establish a representative rice crop model. In this paper we attempt to establish a method for rice area extraction based on SAR data analysis, rather than relying more on ancillary data, such as complex phenological characteristics of various regions, or huge amounts of ground survey information.

Asia is the main rice producing region in the world. Take China, the world's leading rice producer, as an example. Affected by the climate, northern China usually grows one season of rice, while southern China usually grows two seasons of rice. Although the rice planting patterns in the north and south are different, for the same region the time of year when rice is grown is relatively concentrated (with some regulation by the local government), and it is easy to establish a representative rice crop model for rice area mapping.

2. This is nice to have high-precision rice area mapping but why is it needed. Please explain for the benefit of readers in section 1. Also is it only high precision or high resolution too?

RESPONSE: Thank you very much for your suggestion. We added the reason for the need for high-precision rice mapping in section 1.

We proposed an efficient rice area mapping method based on time series SAR features and a deep learning model to perform large-scale rice area mapping in tropical and subtropical regions. It is described in the manuscript that most of the rice area products covering Southeast Asia have a resolution of 500m. The 500 m resolution is still a bit of a gap for finer agricultural applications. And the high-precision rice area map we obtained has a spatial resolution of 20 meters. This resolution can meet the actual application requirements, and the data processing capacity is also moderate. In the future we plan to provide long-term rice area mapping products for this region.

Page 1,line 29

…High-precision rice planting area maps are the basis for monitoring rice growth and forecasting yields, the cornerstone for the government, planners and policymakers to formulate reasonable policies, and the guarantee of global food security (Mosleh et al., 2015; Laborte et al., 2017; Clauss et al., 2018; Jin et al., 2018; Yu et al., 2020; Hoang-Phi et al., 2021) …

3. Were the data downloaded for whole year of 2019 of specific season? If so, the seasonal difference in rice area matters although there may be irrigation in some areas of some countries with 2 to 3 rice crops in irrigated areas and one crop in non-irrigated areas (as mentioned as Rice 1 through 4 in the manuscript). How was this seasonal difference considered in analysis in mapping the rice area? Because rice area per seasons will be different for the same country.

RESPONSE: Thank you very much for your suggestion. All Sentinel-1 data for the whole year of 2019 were downloaded, but not divided by season. Our method extracted three effective temporal statistical features from the 2019 annual data, and then input them into the semantic segmentation model to obtain the 2019 rice area map. The proposed method directly obtains the information of whether the plots are planted with rice or not, without the need to segment the rice planting season, which is the advantage of our method. We will consider the seasonal difference of rice area in the subsequent study of multi-season rice area extraction.

Table 1. List of Sentinel-1 SAR data in 2019 used in this study

Country	Satellite	Orbit-Frame	Number of images	Country	Satellite	Orbit-Frame	Number of images	Country	Satellite	Orbit-Frame	Number of images
Experimental Data											
Myanmar	S1A	41-44	31	Thailand	S1B	62-1	29	Vietnam	S1A	55-31	31
		41-50	31			62-2	29			55-37	31
		41-55	31			62-3	29			55-42	31
		41-60	31			62-4	29			55-47	31
		41-65	31			62-5	29			55-62	31
		41-70	31		S1A	62-20	27			55-67	31
	S1A	70-1217	31			62-21	27			55-72	31
		70-1222	31			62-22	26	Laos	S1A	26-44	31
		70-1227	31			62-23	24			26-49	31
		70-1232	31			62-24	25			26-54	31
		70-1237	31		S1B	91-1	32			26-59	31
		70-1242	31			91-2	32			26-64	31
		70-1247	31			91-3	32			26-69	31
		70-1252	31			91-4	32		S1A	99-1240	30
		70-1257	31		S1A	135-16	23			99-1245	30
		70-1262	31			135-17	23			99-1250	30
		70-1267	31			135-18	23			128-44	30
	S1A	143-46	30			135-19	23			128-49	30
		143-51	30		S1B	164-1	32			128-54	30
		143-56	30			164-2	32			128-59	30
		143-61	30			164-3	32			128-64	30
		143-66	30			164-4	32	Cambodia	S1A	26-29	28
		143-71	30			164-5	32		S1B	26-32	30
		143-76	30		S1A	164-20	13			26-38	30
	S1A	172-1248	28		S1A	172-17	31			26-43	30
		172-1253	28			172-18	31		S1A	99-1220	30
		172-1258	28	Vietnam	S1A	26-23	28			99-1225	30
		172-1263	28			26-34	31		S1B	99-31	31
		172-1268	28		S1A	128-29	30		S1A	128-34	30
		172-1273	28			128-69	30			128-39	30
Training Dataset											
Thailand	S1A	99-16	29								

4. Line 207-208, …the high heterogeneity of rice backscattering coefficients in Southeast Asia is caused by the high heterogeneity in climate and topography…what does mean that? Climate is obvious but what is heterogeneity in topography?

RESPONSE: Thank you very much for your comment.

First, climate influences rice cultivation patterns through precipitation and temperature. The spatial distribution corresponding to climate is large scale. Therefore, different topography within the geographical area covered by a climatic zone can also cause differences in temperature and temperature. The same can have an impact on rice cultivation patterns.

Second, our previous studies have shown that rice planted in relatively flat areas has a high degree of planting intensification, and the flooding period of the backscatter time series curve is more obvious. However, rice planted in areas with large topographic relief is easily affected by other non-rice plots due to the small and irregular plot area, and the flood period of the backscatter time series curve is not obvious. The sample production process also added samples from this region to ensure that the samples were representative.

5. Figure 3 is not so nice. It should be improved to be more clear to read.

RESPONSE: Thank you very much for your suggestion. We redraw Figure 3 to enhance its the readability. The other figures and tables have been modified in some way to give a clearer presentation.

Page 10, line 230

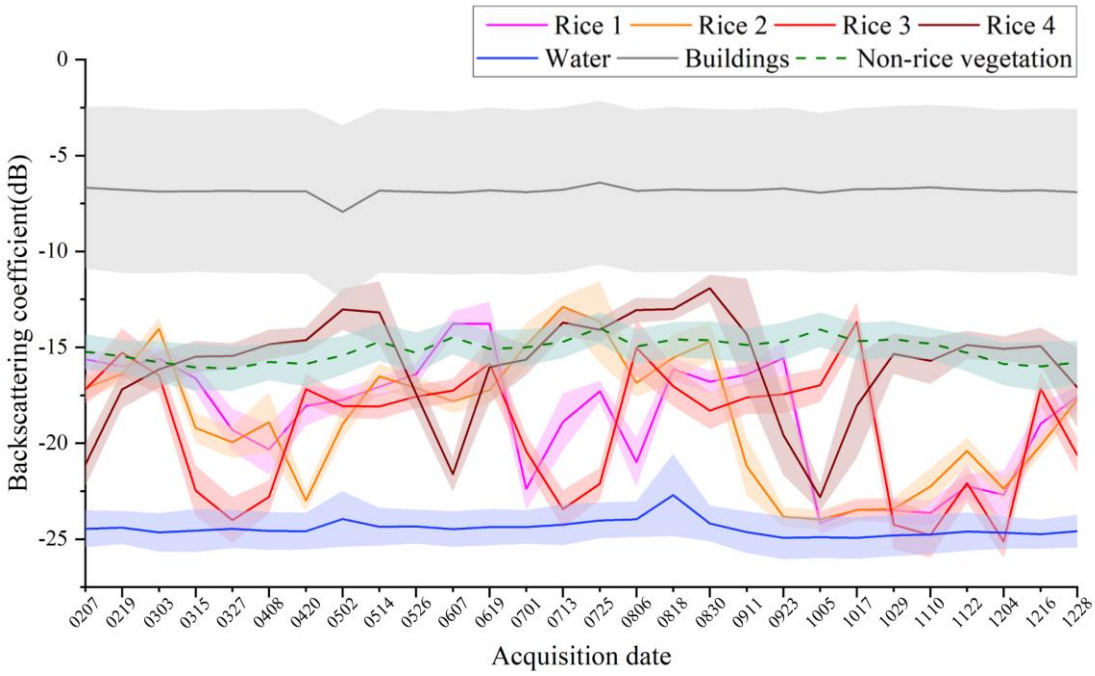

Figure 3. The average VH polarization backscattering coefficient curve of typical landcovers (The shaded areas refer to the standard deviation calculated from the sample points).

6. Line 223, if all flooded, why rice will differ significantly from other crops as other crops will also be flooded and possible similar backscatter, unlike for example sugarcane field which certainly may have different backscatter as they may not submerged. Please clarify the statement – the other crops.

RESPONSE: : Thank you very much for your suggestion. Sorry for the ambiguity caused by inaccurate words. We revised this sentence. The flooding stage is a phase of rice growing stages.

Page 11, line 242

…During the flooding stage, the backscattering characteristics of rice are significantly different from other crops that do not require extensive irrigation, and are close to that of water.….

7. **Figure 4, the term 'Building' does not reflect that square. Appropriate name is settlement. Rice is also vegetation, so vegetation may better be called as non-rice vegetation. What is band combination for optical image?**

RESPONSE: Thank you very much for your suggestion. We modified the names of these two land covers in Figure 4 and the manuscript. We used the optical images of true color composite from Google Earth directly.

Page 11, line 248

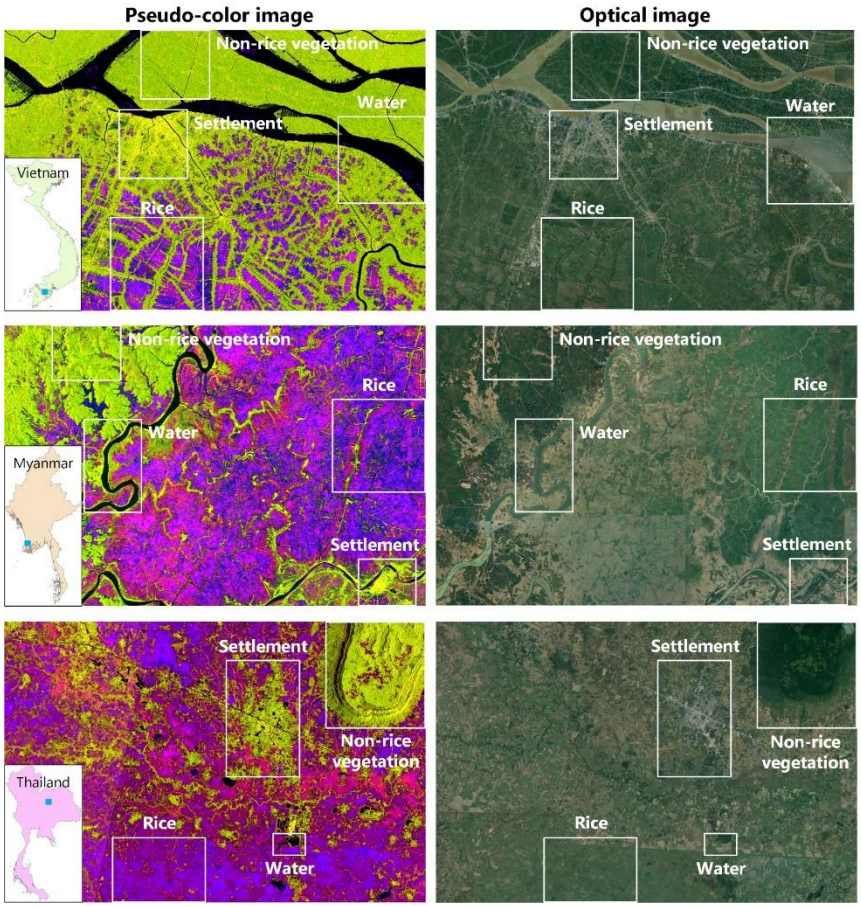

Figure 4. The pseudo-color image synthesized from three SAR feature parameters (R: σ^0_{max}; G: σ^0_{min}; B: σ^0_{var}) and the corresponding optical image from Google Earth ©Google Earth.

8. How was number of (sample)plots of 1913 and 2032 for validation determined, any basis?

RESPONSE: Thank you very much for your comment. The preparation method of rice samples, the distribution and quantity of plots have all referred to previous

studies(Singha et al., 2019; Wei et al., 2022; Lin et al., 2022), ensuring the accuracy and representativeness of plots and the sufficient number of plots. The distribution of the validation sample plots is shown in Figure 1.

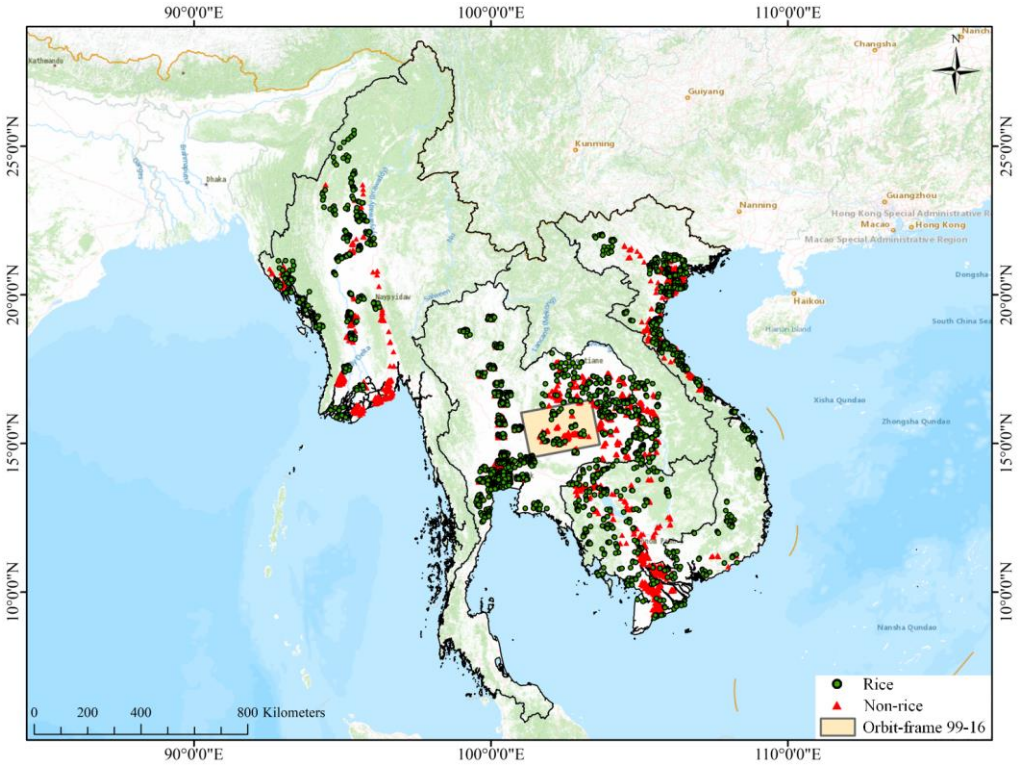

Figure 1. Location of the study area. The Sentinel-1 data with Orbit-frame 99-16 were used for the training samples, and the Rice and Non-rice flags show the distribution of the validation sample set. The base map is from Esri.

9. Country's statistics on area (despite may not align with data collection cycle) are most authentic. Table 5: the extracted rice area is only 44% of the statistics of rice cultivation area. This is rather huge difference. How to explain the feasibility of using the rice mapping method recommended by this study because of that discrepancy? It has now only Vietnam in the table. It is better to show all the countries data in the table.

RESPONSE: Thank you very much for your suggestion.

The statistical data were the total rice harvest areas in different growing seasons each year, but the extracted rice area was the land area where rice was planted. Vietnam's statistical yearbook mentions that there are three seasons of rice, namely, spring rice, autumn rice, and winter rice, while the harvested areas of spring rice and

autumn rice are comparable, and the harvested area of winter rice is smaller. In this way, part of the statistical data of the rice harvest area is repeated and accounts for a large proportion of the area, resulting in a larger rice statistical area than the extracted rice area. Therefore, the extracted rice area of Vietnam is quite different from the statistical data. Although other countries also have multiple rice seasons, the areas of rice in the main season are large, while that in other seasons is small, so the area proportion calculated repeatedly is small.

It is noteworthy that the extracted rice area was closer to the paddy land area in the statistical yearbook of Vietnam and VLUCD (obtained by remote sensing), indicating that the extraction result was reliable and the proposed method is feasible.

According to your suggestions, we have supplemented the contents of Table 5.

Page 17, line 363

Table 5. Statistics, other rice area maps and the extracted rice area for five Southeast Asian countries.

Country	Statistics of rice cultivation area ($\times 10^{\wedge 6}$ ha)	IRRI rice data ($\times 10^{\wedge 6}$ ha)	Statistics of paddy land area ($\times 10^{\wedge 6}$ ha)	VLUCD ($\times 10^{\wedge 6}$ ha)	Extracted rice cultivation area ($\times 10^{\wedge 6}$ ha)
Thailand	10.9442	12.7198	-	-	12.8508
Cambodia	3.2638	3.0740	-	-	2.8215
Myanmar	6.9209	6.4575	-	-	5.5390
Laos	0.8435	0.9856	-	-	0.8458
Vietnam	7.4695	6.1527	4.1205	3.8210	3.3270

10. **The method itself of rice mapping using Sentinel-1 SAR Data is major output of the study. If the proposed method is referring to Figure 2 flowchart, then, it still shows the need of using statistical data and available rice maps. Hence, better discussion with rationale is needed whether proposed method is to replace the existing system as efficient, accurate and even pre-harvest season rice mapping method or just additional task of mapping the rice area. Ideally, the new method is to replace or improve the existing method. It would be nice to indicate with the**

proposed method whether existing statistical data collection on rice is still needed. Also, advise (recommend) how this new method can be made available for the country to use? Afterall the best use of method if adopted will be for the country.

RESPONSE: Thank you very much for your suggestion.

Compared with the existing methods, our proposed method only uses Sentinel-1 SAR data as the data source, without using multi-source data. Sentinel-1 data is free and has a high temporal and spatial resolution. Moreover, the proposed method is simpler and more efficient. The high-precision rice area mapping can be completed using the time series statistical features and the classic semantic segmentation model.

The rice area map we obtained is evaluated from multiple perspectives by validation samples, rice statistical data, and other rice area products. Comparing rice area extraction results with statistical data is a standard accuracy verification method (Han et al., 2021; Wei et al., 2022; Son et al., 2022). In the future, after the improvement of the method and continuous validation, a very reliable rice area extraction system will be obtained, which may not require statistical data.

We will actively and continuously produce rice area data from 2019 onwards. This rice area data will be released through the International Research Center of Big Data for Sustainable Development Goals (CBAS)for free use by the state and the public.

References

Han, J., Zhang, Z., Luo, Y., Cao, J., Zhang, L., Cheng, F., Zhuang, H., Zhang, J., and Tao, F.: NESEA-Rice10: high-resolution annual paddy rice maps for Northeast and Southeast Asia from 2017 to 2019, Earth System Science Data, 13, 5969-5986, 10.5194/essd-13-5969-2021, 2021.

Lin, C., Zhong, L., Song, X.-P., Dong, J., Lobell, D. B., and Jin, Z.: Early-and in-season crop type mapping without current-year ground truth: Generating labels from historical information via a topology-based approach, Remote Sensing of Environment, 274, 112994, https://doi.org/10.1016/j.rse.2022.112994, 2022.

Singha, M., Dong, J., Zhang, G., and Xiao, X.: High resolution paddy rice maps in cloud-prone Bangladesh and Northeast India using Sentinel-1 data, Sci Data, 6, 26,

10.1038/s41597-019-0036-3, 2019.

Son, N.-T., Chen, C.-F., Chen, C.-R., Cheng, Y.-S., Toscano, P., Syu, C.-H., Guo, H.-Y., Chen, S.-L., Liu, T.-S., and Zhang, Y.-T.: Exploiting Sentinel-1 data and machine learning–based random forest for collectively mapping rice fields in Taiwan, Applied Geomatics, 1-15, 10.1007/s12518-022-00440-4, 2022.

Wei, J., Cui, Y., Luo, W., and Luo, Y.: Mapping Paddy Rice Distribution and Cropping Intensity in China from 2014 to 2019 with Landsat Images, Effective Flood Signals, and Google Earth Engine, Remote Sensing, 14, 759, 10.3390/rs14030759, 2022.