Mapping Rice-crop Intensity of Southern China Using the Harmonic Analysis Coupled With Time-series Sentinel-1 VH Backscatter and ERA5-Land Temperature Datasets

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Abstract

Rice-crop intensity (Fig.1) is the number of rice growth cycles per year. Using optical data is challenging due to frequent cloud, while SAR data can provide an alternative. However, national-scale monitoring faces challenges, including the diversity of rice backscatter patterns, the inefficiency of feature extraction, the unavailability of prior phenology knowledge. In this study, rice-crop intensity of Southern China (Fig.2) in 2020 is mapped using time-series Sentinel-1 VH backscatter and harmonic analysis. An overall accuracy of 81.64% at 10m resolution is achieved. The method is expected to support Asian or global rice-crop intensity mapping further.

Introduction

Optical-based rice-crop intensity mapping usually has a moderate resolution. Rice backscatter patterns vary with different cultivation practices (e.g., rice variety, field management, and climate condition). The commonly used temporal denosing and feature extraction methods are time-consuming and computationally intensive. Rice phenology is asynchronous across different fields. Rice and non-rice crops growing at different times in the same field are indistinguishable without the guidance of previous phenological information. Thus, an effective SAR-Based method mapping rice-crop intensity at national scale is yet to come.

Objective

The objective is to map rice-crop intensity of Southern China in 2020 at 10m resolution.

- Find reliable time series features potentially related to rice growth.
- Develop efficient temporal filtering and feature extraction methods.
- Identify rice growth features without the guidance of prior phenology information.

Method

Sentinel-1 ascending datasets are collected and preprocessed to generate VH backscatter time series.

- Short-term disturbances within the time series are suppressed while the essential trends are extracted based on harmonic decomposition

$$S[t] = s_0 + \sum_{i=1}^{3} A_i \cos[2\pi\omega_i t - \varphi_i]$$

- Time series features are identified through detecting troughs with low backscatter (Fig.3).
- Rice growth cycles manifested in backscatter time series are identified through assessing ERA5-Land temperature in different phenological periods (Fig.4).
- Rice-crop intensity is mapped with a NASADEM terrain mask retaining only low-altitude flat areas and a ESA WorldCover cropland mask (Fig.5).
- Field samples are used for accuracy validation and error analysis (Fig.6).

Figure

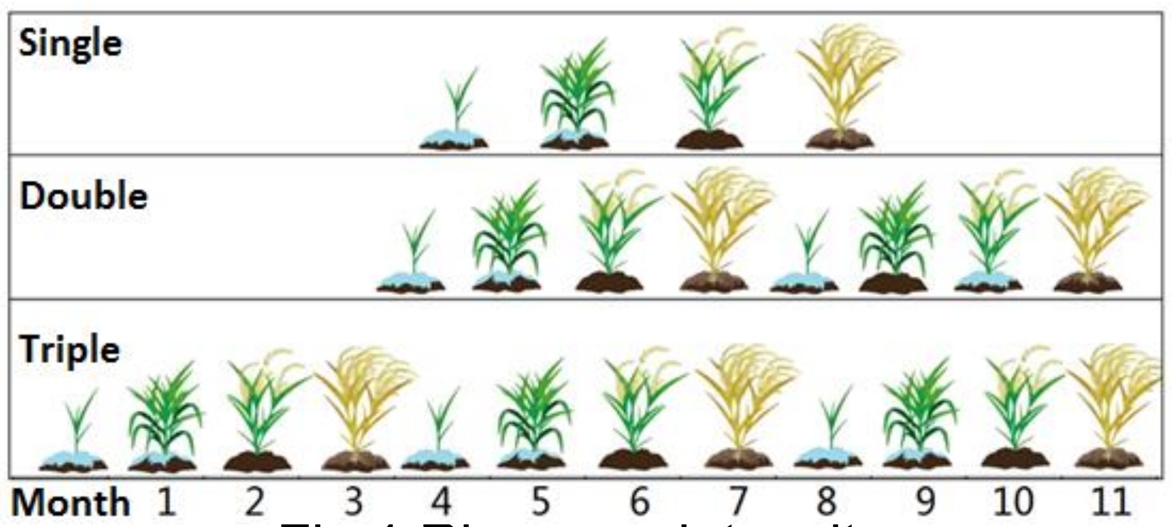

Fig.1 Rice-crop intensity

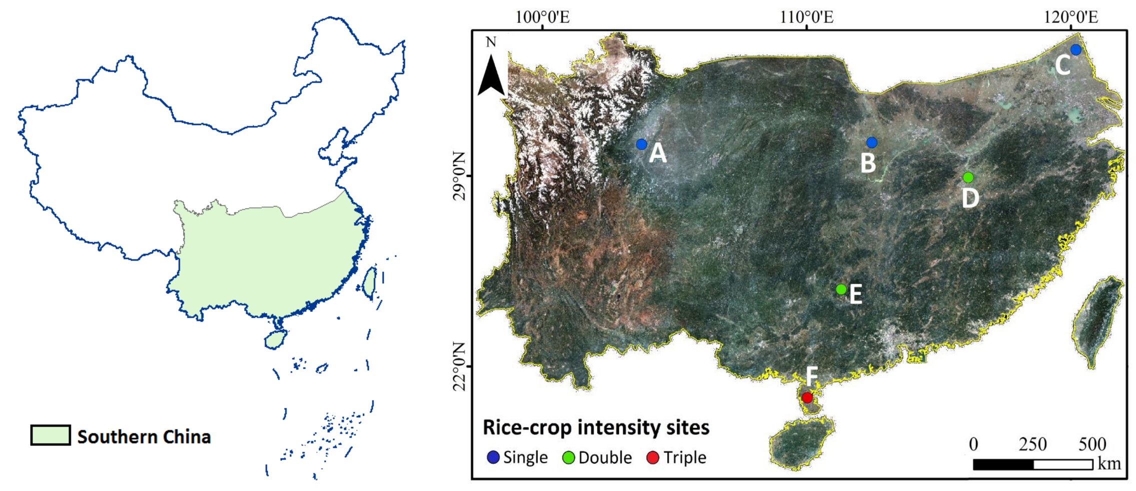

Fig.2 Southern China

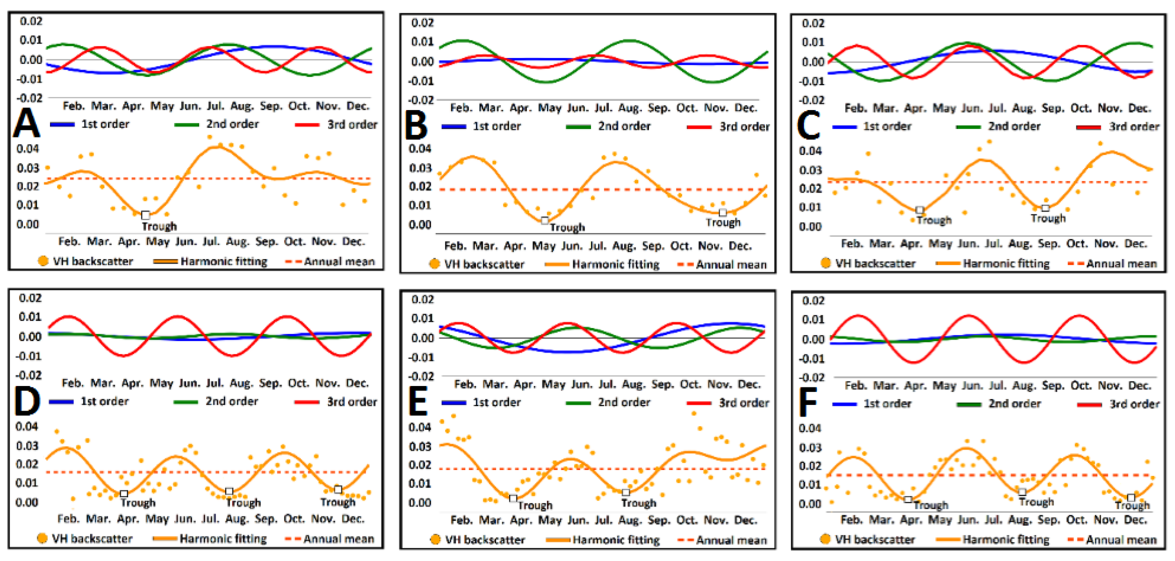
Fig.3 Backscatter trough detection

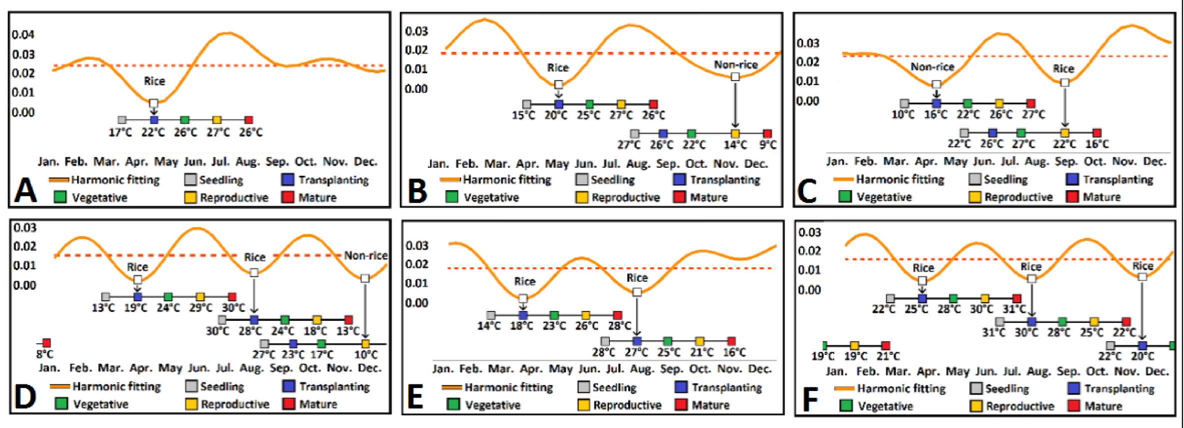
Fig.4 Temperature assessment

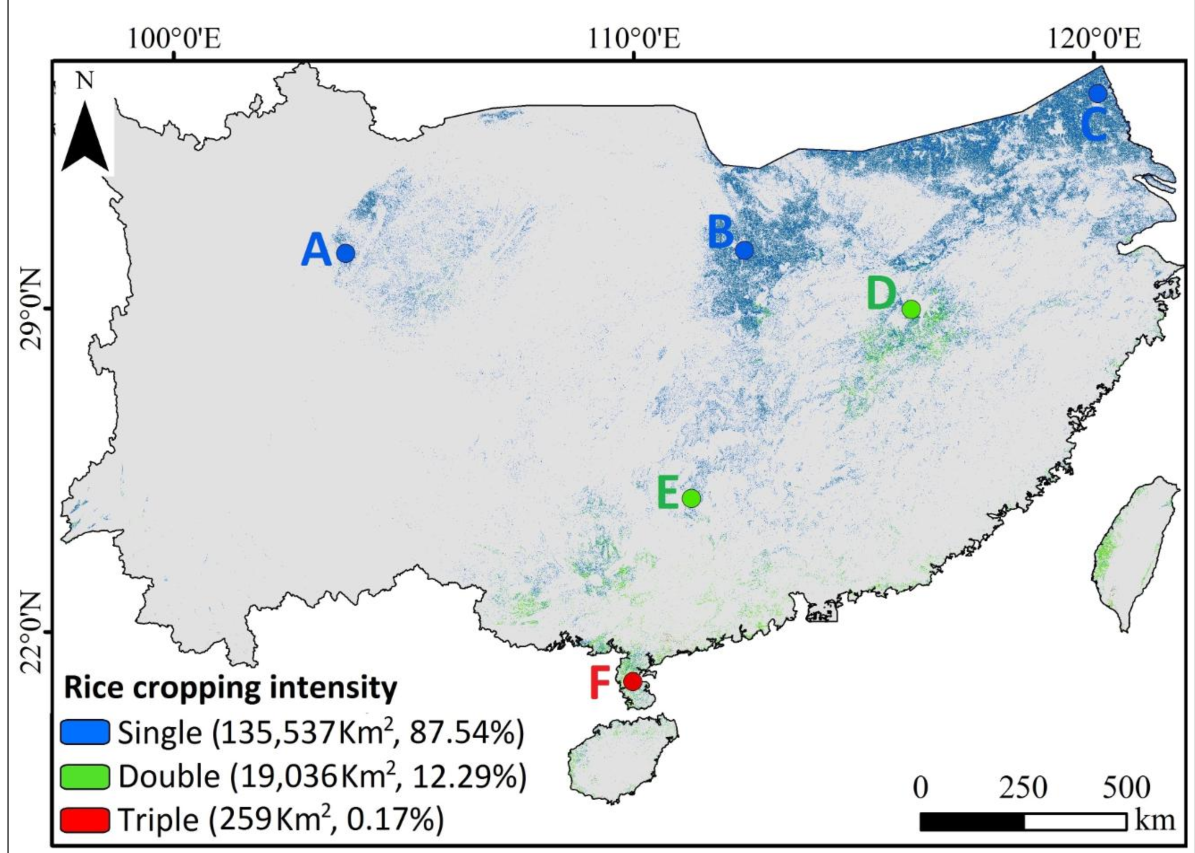

Fig.5 Rice-crop intensity of Southern China

User's Accuracy (UA), Producer's Accuracy (PA), Overall Accuracy (OA)
Single-crop Rice (S), Double-crop Rice (D), Triple-crop Rice (T), Non-Rice (N)

Site	UA-S	UA-D	UA-T	UA-N	PA-S	PA-D	PA-T	PA-N	OA
A	85.37%			78.79%	83.33%			81.25%	82.43%
B	88.10%			78.57%	86.05%			81.48%	84.29%
C	88.37%			75.00%	84.44%			80.77%	83.10%
D	81.82%	78.79%		83.33%	79.41%	81.25%		83.33%	81.25%
E	82.86%	77.78%		79.41%	78.38%	75.00%		87.10%	80.21%
F	76.47%	79.49%	76.00%	84.00%	76.47%	75.61%	82.61%	84.00%	80.25%
All	84.83%	78.79%	79.17%	79.78%	82.49%	77.23%	82.61%	83.04%	81.64%

Fig.6 Validation

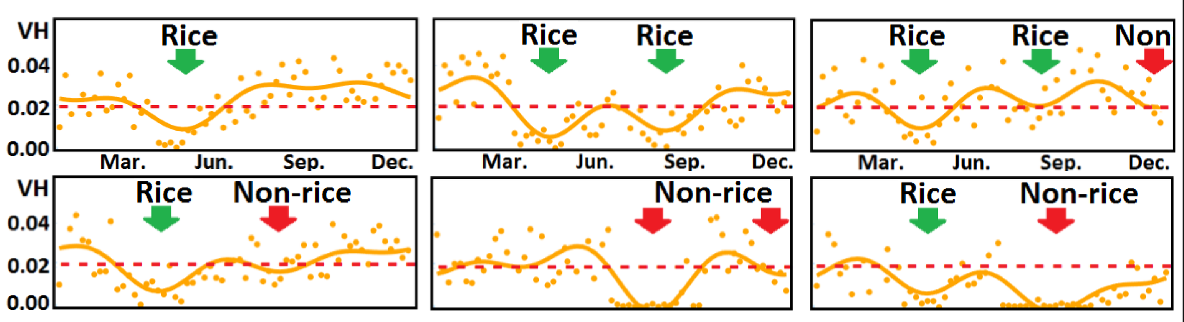
Fig.7 Misclassification cases

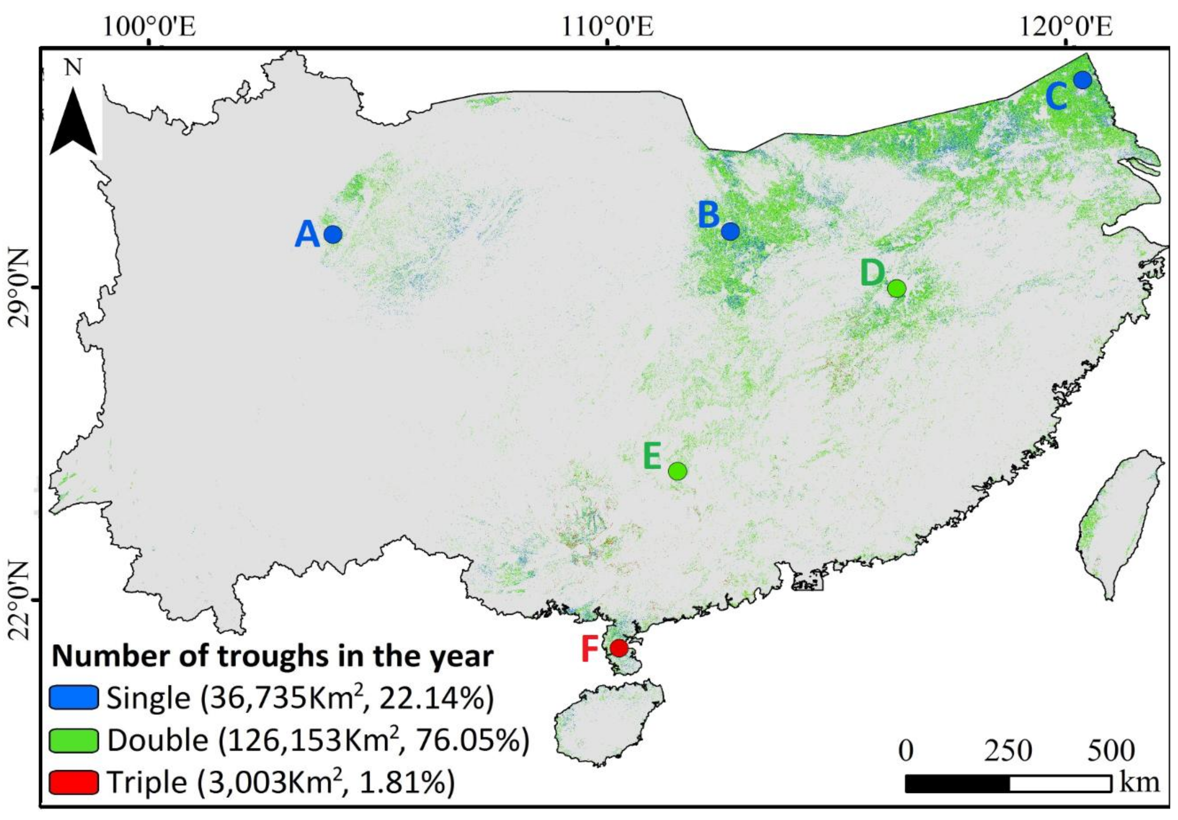

Fig.8. Mapping without assessing temperature

Result

Rice planting area identified in Southern China is 154,832 km2 in 2020. The single rice-crop intensity is the dominant rice-crop scheme (87.54%), distributed mainly in the eastern and western subtropical zone of Southern China. The double rice-crop intensity (12.29%) is distributed in the central and southern subtropical zone, and the triple rice-crop intensity (0.17%) is located in the southernmost tropical zone.

Discussion

Rice fields are sometimes wrongly identified as non-rice cropland when non-rice objects such as graves, transmission or communication towers are present in the fields. In these regions, rice backscatter are influenced by the backscatter from non-rice objects, resulting in high backscatter on the trough days. On the other hand, the non-rice cropland area can be wrongly identified as rice fields when the areas have smooth soil surface or rainwater puddles, resulting in low backscatter. Besides, non-rice cropland adjacent to water areas may be misclassified as rice fields due to backscatter troughs occurring in rainy season (Fig.7).

If temperature information is not used, double-trough fields would dominate Southern China, indicating rice and non-rice crops are not differentiated (Fig.8).

Conclution

We developed a novel scheme implemented on the GEE platform to identify rice-crop intensity at high resolution in large scale based on harmonic analysis of time series Sentinel-1 VH backscatter, coupling with regional temperature analysis. Accuracy assessments at regional scale and comparative analysis at national scale confirm the reliability of our product.

References

1. G. J. Roerink, et al. "Reconstructing cloudfree NDVI composites using Fourier analysis of time series," Int J Remote Sens, 2000.
2. J. Duan and G. Zhou, "Climatic Suitability of Double Rice Planting Regions in China," (in Chinese), Scientia Agricultura Sinica, 2012.