Original Research Article

AREA ASSESSMENT FOR RICE CROP IN THIRUVARUR DISTRICT ASSIMILATING SENTINEL 1A SATELLITE DATA

Abstract

This study proposes an effective method to map rice area using the Sentinel-1A SAR (Synthetic Aperture Radar) time series data over the Thiruvarur district during *samba* 2021. Fully automated MAPscape-Rice software was used to pre-process the SAR data and extraction of multi-temporal features. The rice-growing area was estimated based on the extracted multi-temporal features and statistics were derived at district and block level in Thiruvarur district. The study area registered a total rice area of 127027 ha; among the blocks, the Kottur block recorded the largest area of 16615 ha and the lowest area of 6865 ha was recorded in the Thiruvarur block. The estimated rice area was validated with the observed rice area in the Thiruvarur district using accuracy assessment, which indicates an overall accuracy of 92.0 per cent and 0.84 kappa co-efficient.

Keywords: Rice area, Sentinel 1A, Synthetic Aperture Radar (SAR), Validation, Accuracy assessment

I. Introduction

Rice is Asia's most important food crop, accounting for over 90% of worldwide rice production and consumption. In 2021, India's rice area, production, and productivity accounted for 4.56 million ha, 12.436 million tonnes, and 2717 kg/ha, respectively (Indiastat, 2021). Classic statistical sampling approaches based on measurements at sample fields have been widely used for rice area and yield estimation (Murthy *et al.,* 1996). However, this approach provides only a simple but expensive estimate and is best utilised in smaller regions. Crop models based on meteorological data are used to estimate rice yield in larger areas (Mahmood, 1998; Subash and Ram Mohan, 2012), while the precision and accuracy of model inputs raise several concerns. Rice monitoring using remote sensing technology is timely and cost-efficient (Tennakoon *et al.,* 1992; Chang *et al.,* 2005; Wang *et al*., 2005). Instead of time-consuming and expensive conventional field surveys, standardised methodologies can be used to analyse spatial and temporal environmental changes that affect crop growth and health (Fang *et al.*,1998; Moulin *et al.*, 1998). For crop area and yield estimation, the timely information is more valuable.

Remote sensing technology provides the methodologies required to monitor, map, and observe rice-growing ecosystems across large distances and at regular intervals to interpret rice-growing areas from various viewpoints (Kuenzer and Knauer, 2013). This is quite useful for quick and accurate estimation of rice area. The country's economy, government and private organizations, small stockholders, farmers, insurance firms, and policymakers employ the estimation of area and yield. The optical sensors collect data only during the daytime and subjected to ambient and weather conditions, with data being influenced by cloud cover. To overcome these constraints, microwave sensors were eventually deployed because the larger wavelength can penetrate the cloud and collect the data day and night, regardless of the weather (Nihar *et al.*, 2019).

Multi-temporal images give more information about the area and crop type. Continuous field monitoring is important for accurate yield prediction and area estimation. The radar backscattering coefficient is an important parameter for rice area estimation (He *et al.*, 2018). The SAR data is freely available on the internet; hence sentinel 1A SAR satellite data maintained by European Space Agency (ESA) was used in the study. It is especially suitable for rice crop area estimation because the high spatial and temporal resolution gives more information about the area (Bazzi *et al.*, 2019).

Holecz *et al.*, (2013) developed MAPscape-RICE software, a fully automated proprietary programme that is used to analyse the SAR data and get the temporal backscatter values of VH Polarization across the rice crop. Rice detection rules are based on the rice crop's well-known temporal signature derived from Synthetic Aperture Radar (SAR) backscatter and its relationship to crop stages. This tool is helpful for rice mapping, detecting the start of the season, peak of the season, and seasonal crop growth tracking (Raviz *et al.*, 2015). In addition, it is commonly used to estimate the area of important crops, including rice, maize, mango, cotton and banana (Pazhanivelan *et al.*, 2015; Sudarmanian *et al.*, 2019; Setiyono *et al.*, 2019; Venkatesan *et al.*, 2019; Kaliaperumal *et al.*, 2019; Tamilmounika *et al.*, 2022). The study's primary goal is to estimate the rice area for the Thiruvarur district of Tamil Nadu during *samba* season.

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II. Materials and Methods

A. Study Area

Thiruvarur district is located in Tamil Nadu, India which lies between latitude 9.28° N, longitude 79.3° E and with an altitude of 10m MSL (Fig.1) and a total area of 2,377 sq. km. The annual rainfall is 1129 mm the maximum rainfall obtained during the North East season is 665 mm (September to December). Thiruvarur district comes under the Cauvery delta region of Tamil Nadu, with temperatures ranging between 26.39˚C to 35.19˚C. The Southwest winds, which began in April, are at their peak in June and last until September, while the northeast monsoon starts during October and lasts until January, which accounts for over 60% of yearly rainfall. The district is dominated with sandy coastal alluvium, which accounts for 56.78 per cent of the total area. Rice is cultivated in three seasons, namely *Kuruvai (*June – August), *Samba* (August – January) and *Thaladi* (January – March). Rice is the most extensively cultivated crop in this region. During the *samba* season 2021, this research was carried out in the Thiruvarur district which consists of 10 blocks.

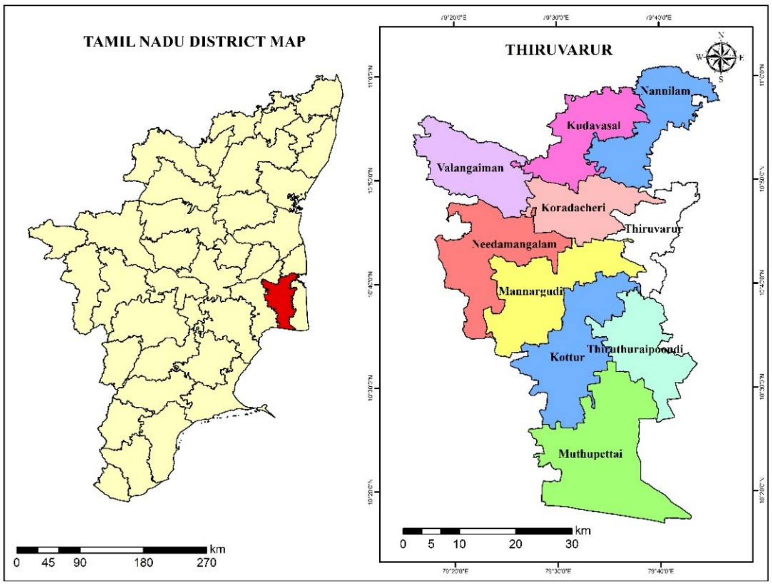

Fig.1. Location of Study area in Tamil Nadu, India

B. Image acquisition

A series of 11 vertical horizontal (VH) polarised Sentinel 1A, C-band ground range (GRD) images (Table 1) were downloaded with interferometric wide swath mode at incidence angles ranging from 31 to 46 degrees and range and azimuth resolutions of 5 and 20 metres, respectively (Torres *et al.,* 2012). The data were acquired between 02 August 2021 to 03 January 2022 at 12 days intervals.

Table.1. Sentinel 1A data acquisition dates during *samba* season 2021

S.No.	Satellite Pass	Date of Satellite Pass
1.	D1	12.08.2021
2.	D2	24.08.2021
3.	D3	05.09.2021
4.	D4	17.09.2021
5.	D5	29.09.2021
6.	D6	11.10.2021
7.	D7	23.10.2021
8.	D8	04.11.2021
9.	D9	16.11.2021
10.	D10	28.11.2021
11.	D11	10.12.2021
12.	D12	22.12.2021
13.	D13	03.01.2022

C. Pre-processing of SAR data

Strip mosaicking, co-registration, time-series speckle filtering, terrain geocoding, radiometric calibration, normalization, anisotropic non-linear diffusion (ANLD) filtering, and atmospheric attenuation removal are basic pre-processing steps for SAR data (Nelson *et al.*, 2014). These steps are performed using the fully automated processing chain module-based MAPscape-RICE software developed by Holecz *et al.,* (2013). This module transforms temporal images into terrain-geocoded backscattering coefficient (σ°).

D. Rule based rice classification

The multi-temporal features viz., maximum, minimum, mean, and range of σ° were computed using the temporal signature of the monitoring sites where from the (i) minimum and (ii) maximum of those mean σ° values across fields; (iii) the maximum of the minimum σ° values across fields; the (iv) minimum and (vi) maximum of the range of σ° values across fields; and the (v) minimum and (vi) maximum of the range of σ° values across fields were calculated (Holecz *et al.*, 2013). The process of rice area estimation is depicted in Fig.2. The number of days between a start-of-season detection and the next highest σ° value in the temporal signature is limited by $T_{minlength}$. Since X-band σ° saturates before rice flowering, this value can be set to 40–70 days. $T_{maxlength}$ limits the time between two σ° minima in the series, and 120 days was an appropriate cutoff for an intense triple-rice system (three crops in one year). t_2 - t_1 is the maximum time of agronomic flooding at the start of the season, which was adjusted to a high value of 40 to 50 to capture the longest land preparation stages.

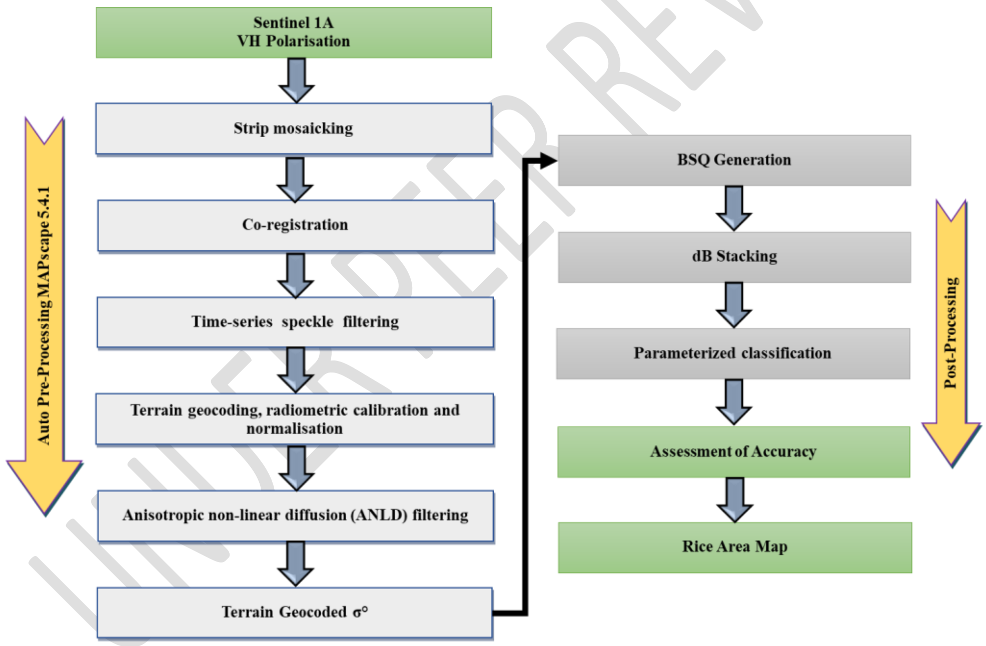

Fig.2. Rule-based rice detection algorithm from multi-temporal Sentinel 1A, C-band σ° using MAPscape-RICE

E. Ground truth collection

During *Samba* 2021 season, 300 ground truth rice points (Each block @ 30 points) were collected at different crop development stages in the Thiruvarur district. These ground truth points were used for training and validation, to improve the accuracy of rice area mapping. Validation sites were provided for land cover types where the SAR signature changes seasonally, such as rice and other annual crops. Locations were chosen such that the land cover was homogenous within the surrounding of 1 ha area, and locations were at least 50 m away from roads, built-up areas and other infrastructures (Raviz *et al.*, 2015).

F. Validation

The accuracy of the predicted rice area was validated using the Error matrix and Kappa statistics. The accuracy was compared to ground truth points. The rice area map is compared to ground truth data analysis to determine accuracy. The validation points were classified into the rice and non-rice points. The accuracy measures, such as overall accuracy, producer's accuracy, user's accuracy and kappa value, are calculated from the error matrix (Congalton, 1991). The percentage of properly identified instances lying along the diagonal calculated the overall accuracy. The kappa coefficient, which measures the classifier's proportional (or percentage) improvement over a purely random assignment to classes, is another way to assess classification accuracy (Richards, 1993).

III. Results and Discussion

The temporal signatures extracted to the rice validation fields were analysed for deriving the multi-temporal features aiding in rice crop detection and classification. The dB values for rice derived from the temporal signature range from -24 to -12 dB (Fig.3).

The parameters extracted from the temporal signature analysis led to the detection and estimation of the rice area in the study district. The total estimated rice area of Thiruvarur district was 127028 lakhs ha (Fig.4). Block wise statistics were performed to understand the distribution pattern of rice area among the blocks of the study area. The highest area was recorded at the Kottur block with 16615 ha, followed by Needamangalm, Mannargudi, Thiruthuraipoondi and Valangaiman, with 15445, 14064, 13862 and 13561 ha, respectively (Table.2). The lowest was recorded in the Thiruvarur block, about 6865 ha, dominated by urbanization.

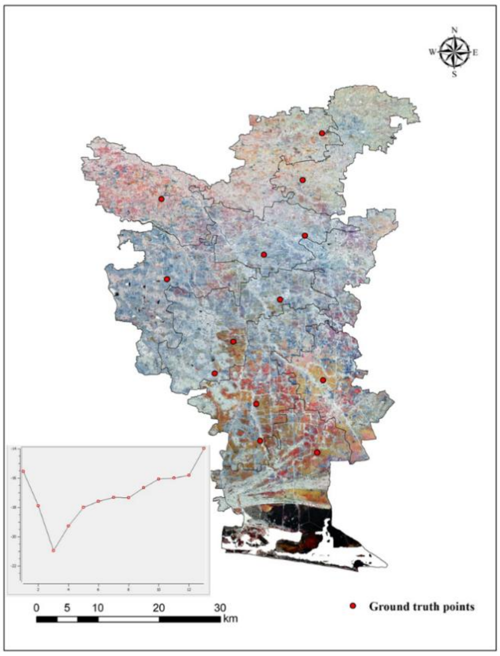

Fig.3. BSQ - dB stack generated with Sentinel-1A SAR data

Comment [WU2]: Increase size of Fig3.

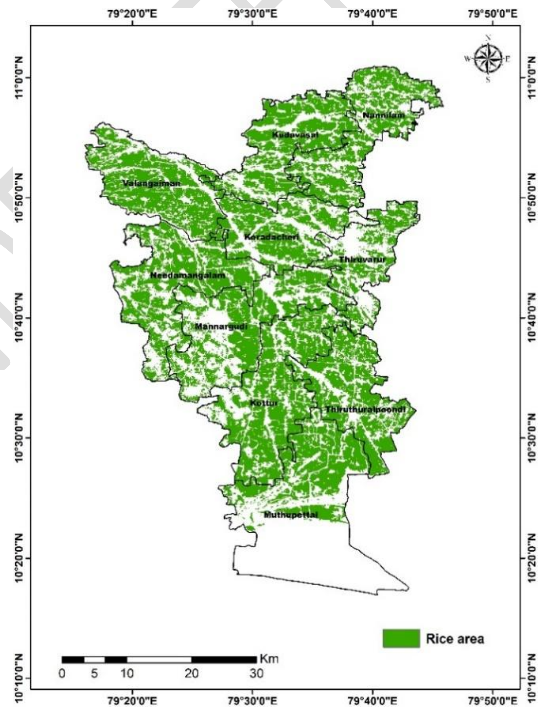

Fig.4. Rice area map during *samba* season 2021 - 2022

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Table.2. Block wise rice area for Thiruvarur district

S.No	Block Name	Area (ha)	Distribution Percentage over Rice area (%)
1	Koradacheri	10213	8.04
2	Kottur	16615	13.08
3	Kudavasal	11931	9.39
4	Mannargudi	14064	11.07
5	Muthupettai	11992	9.44
6	Nannilam	12482	9.83
7	Needamangalam	15445	12.16
8	Thiruthuraipoondi	13862	10.91
9	Thiruvarur	6865	5.40
10	Valangaiman	13561	10.68
Total Area		**127028**	**100.00**

Accuracy Assessment

The ground truth points collected during the survey were used for the accuracy assessment of the rice area estimated during the study. Out of the 300 ground truth points collected, 175 were rice points, and 125 were non rice points. A confusion matrix was generated to validate the rice area estimation and to determine the accuracy of classification (Stroppiana *et al.*, 2019). Among the 175 ground truth rice points collected during *samba* season 2021, 163 points were correctly classified as rice crop. As a result, the overall accuracy of the rice area map was found to be 92.0 per cent, and the kappa co-efficient was 0.84, indicating the methodology's good accuracy (Table.3).

Table.3. Confusion matrix for accuracy assessment of rice classification

	Predicted class from the map			
Actual class from survey	**Class**	**Rice**	**Non-Rice**	**Accuracy (%)**
	Rice	163	12	93.1
	Non-Rice	8	67	89.3
	Reliability	95.3%	84.8%	**92.0**
Average accuracy		91.2%		
Average reliability		90.1%		
Overall accuracy		**92.0%**	**Good Accuracy**	
Kappa index		**0.84**	**Good Accuracy**	

The methodology adopted for the estimation of rice area in Thiruvarur district of Tamil Nadu, India was found to be effective in detection, delineation and estimation which was evident from the high classification accuracy of 92.0 per cent and a kappa coefficient was 0.84. The SAR satellite data is ideal for timely area mapping due to weather and time independence. The results derived will be of much use in policy decisions due to its high accuracy.

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