Eco. Env. & Cons. 28 (January Suppl. Issue) : 2022; pp. (S517-S522)
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ISSN 0971–765X

http://doi.org/10.53550/EEC.2022.v28i01s.069

Paddy area estimation in Cauvery Delta Region Using Synthetic Aperture Radar

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(Received 18 August, 2021; Accepted 28 September, 2021)

ABSTRACT

Crop inventory through remote sensing provides timely and precise information compared to the conventional method of area estimation. Synthetic Aperture Radar (SAR) overcomes the problems due to cloud cover during the crop growth period. Paddy crops were distinguished based on SAR backscattering coefficient values. This study was carried out in the Cauvery delta region during *samba* season 2020-21. MAPscape-RICE is a fully automated software used to process the SAR data and extracted dB values were subjected to the Multi-Temporal feature extraction method for estimating paddy growing areas. Continuous monitoring for crop parameters and validation exercise was done to assess the accuracy of the classified paddy area. Among the four districts, Thanjavur recorded the highest area under paddy of about 122684 ha and followed by Thiruvarur, Mayiladuthurai and Nagapattinam with an area of 119379 ha, 57015 ha and 46250 ha, respectively. A total paddy area of 345328 ha was estimated in the four districts of the Cauvery delta region using VH polarization with an overall accuracy of 93.4 per cent and 0.87 kappa index.

Keywords: *Paddy, area estimation, Synthetic Aperture Radar (SAR), MAPscape-RICE, software.*

Introduction

Paddy is the predominant food crop grown on a large scale for human consumption purposes and it is a pivotal commodity in the agricultural sector. Its role is irreplaceable in nutrition and food security. Timely, frequent and reliable information on paddy area helps planners, policy makers, resource managers and marketers to manage trade and made the resources available to people (Raman *et al*., 2019).

Remote sensing an advanced technology made it possible for real-time crop monitoring, mapping, crop inventory and yield estimation (Zhang *et al.*, 2019). Crop inventory through remote sensing gives timely and precise information, while the conventional method of area estimation is expensive, time consuming, less reliable and not so precise (Holecz *et al.,* 2013).

The launch of advanced satellites and the free availability of data improves the quality and accuracy of the crop area. Synthetic Aperture Radar (SAR) has been widely used in crop inventory purposes for its capability to penetrate clouds and time independent when compared with optical satellite data (Zhang *et al.,* 2013; Forkuor *et al*., 2014). Cloud cover is an inevitable phenomenon in the tropical

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region and monsoon period, so always better to prefer microwave data for area estimation instead of optical data. The backscattering coefficient is unique for each crop, based on this value different crops have been discriminated from others.

Sentinel-1A data available freely to the users and it was launched by European Space Agency for Earth Observation in 2014. It carries a C-band Synthetic Aperture Radar which provides images in dual-polarization of both VV (Vertical–Vertical) and VH (Vertical–Horizontal) polarization and the data available at twelve days interval irrespective of time and weather (Raman *et al*., 2019). Yang *et al.* (2012) experiment result shown that VH polarization data is optimal for paddy mapping at both early and middle periods of growth stages.

MAPscape-RICE fully automated proprietary software developed by Holecz *et al.* (2013) used to process the SAR data and to retrieve the temporal backscatter values of VH polarization over the paddy crop cover. The rules for rice detection are based on the well-studied temporal signature of rice from SAR backscatter and its relationship with crop stages. This tool is helpful in the mapping of paddy, detection of the start of season, the peak of season and monitoring of crop growth on a seasonal basis (Raviz *et al*., 2015). It has been widely used to estimate the area of major crops like paddy, maize, cotton, mango and banana. (Pazhanivelan *et al*., 2015; Setiyono *et al*., 2019; Sudarmanian *et al*., 2019; Kannan *et al*., 2021; Ramalingam *et al*., 2019; Venkatesan *et al*., 2019; Kaliaperumal *et al*., 2019; Karthikkumar *et al*., 2019). This study is to estimate the area and distribution of paddy in the Cauvery Delta region of Tamil Nadu during *Samba* season 2020-2021.

Materials and Methods

Study area

Cauvery delta region comprises of Thanjavur, Thiruvarur, Nagapattinam, Mayiladuthurai, Tiruchirapalli, Ariyalur, Cuddalore and Pudukkottai districts. Paddy is the most extensively cultivated crop in this region. This study was carried

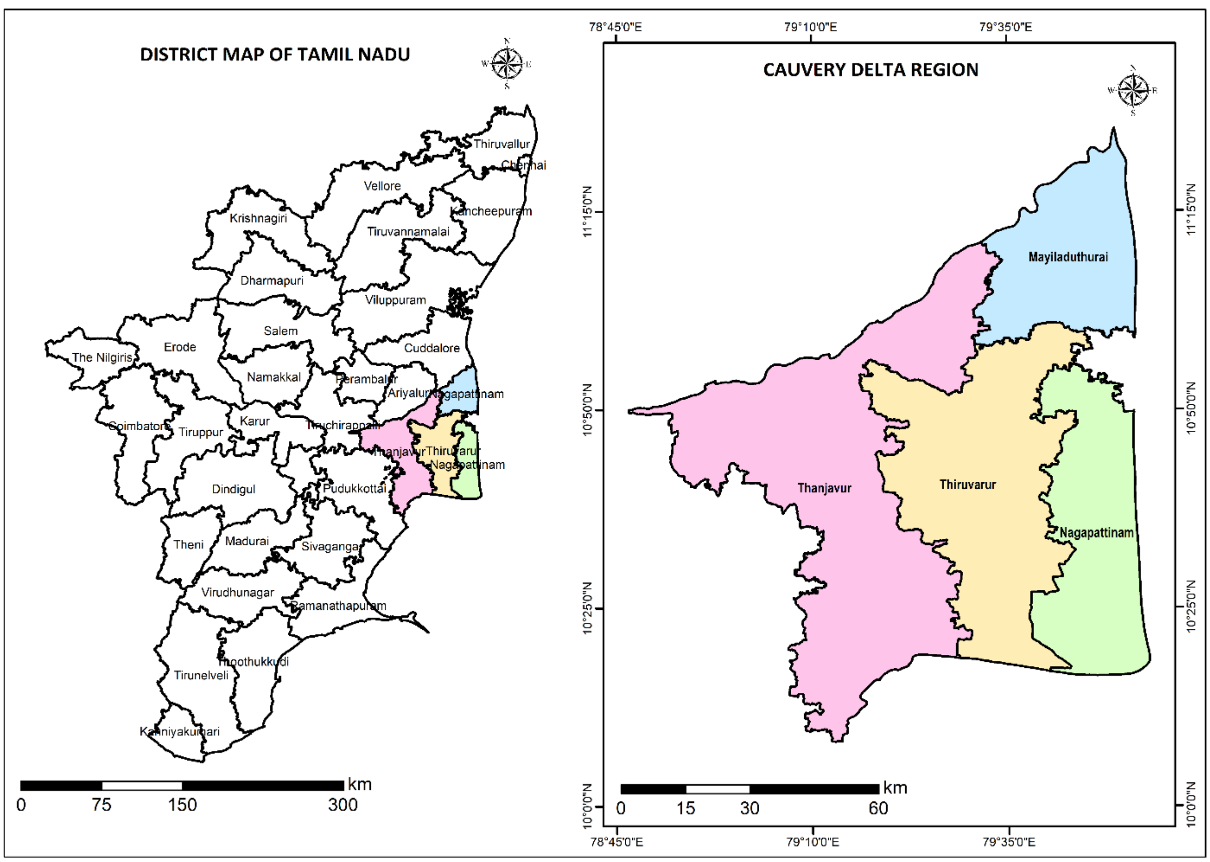

Fig. 1. Study area map

out in Thanjavur, Thiruvarur, Nagapattinam and Mayiladuthurai districts (Fig. 1) during *samba* season 2020-21. In Tamil Nadu, northeast monsoon plays a vital role in paddy area and productivity over this region during *samba* season. Total geographical area of these districts has been around 14.47 lakh ha.

Satellite data

Sentinel 1A Level 1 ground range (GRD) product obtained by interferometric wide (IW) swath mode (1) of High Resolution (HR) data of 20m resolution acquired from August 2020 to February 2021 at 12 days interval from the website (https://scihub.copernicus.eu/dhus/.) were used in this study. VH polarization data of Sentinel 1A were used to classify paddy area.

Pre-processing of SAR data

The basic processing of SAR data includes Strip mosaicking, Co-registration, Time-series speckle filtering, Terrain geocoding, Radiometric calibration, normalization, Anisotropic non-linear diffusion (ANLD) filtering, Removal of atmospheric attenuation (Nelson *et al.*, 2014) which processed through fully automated processing chain module based MAPscape-RICE software developed by Holecz *et al*. (2013). This module converts the temporal images into terrain geocoded backscattering co-efficient (σ°).

Parameterized classification

Based on the temporal signature of monitoring fields, the maximum, minimum, mean and range of σ° were calculated. Then, we computed the (i) minima and (ii) maxima of those mean σ° values across fields; the (iii) maxima of the minimum σ° values across fields; the (iv) minima of the maximum ó° value across fields; and the (v) minimum and (vi) maximum of the range of σ° values across fields (Holecz *et al.*, 2013). The parameters $t_{minlength}$, $t_{maxlength}$ and t2 “ t1 are easier to estimate. $T_{minlength}$ restricts the number of days between a start-of-season detection and the subsequent highest σ° value in the temporal signature. Since X-band σ° saturates before rice flowering, this value can be set to 40–70 days. $T_{maxlength}$ restricts the duration between two σ° minima in the series and 120 days is a suitable cut-off that would be representative of an intensive triple-rice system (three crops in one year). $t_2 - t_1$ is the maximum period of agronomic flooding at the start of the season, which is set to be a high value of 40 to 50 to capture the longest land preparation phases (Fig.2).

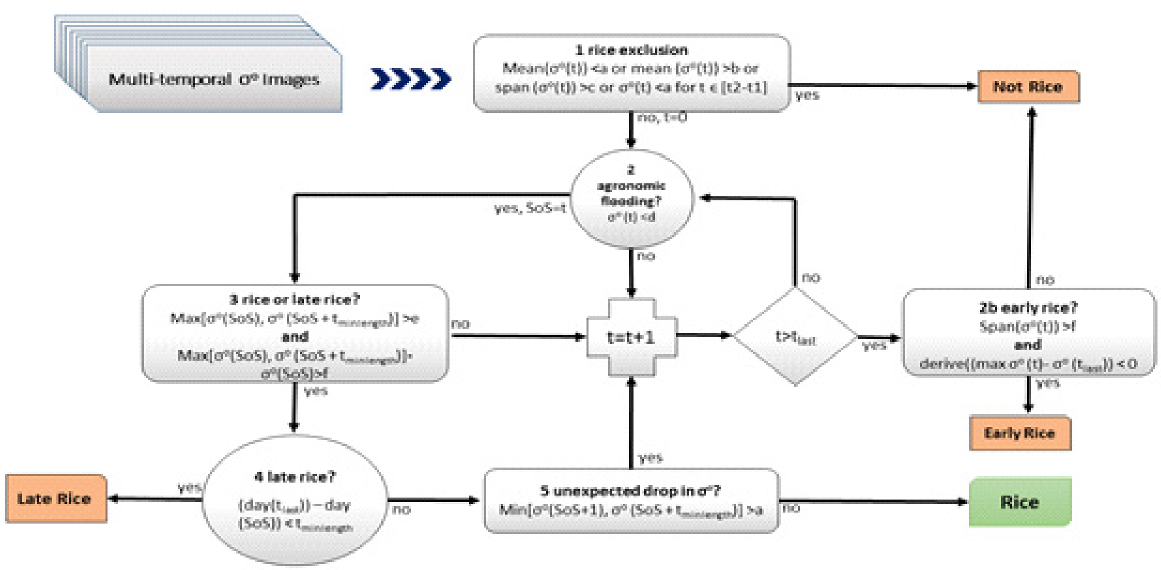

Fig. 2. Rule-based rice detection algorithm for multi-temporal C-band ó° in MAPscape-RIC

a = lowest mean
b = highest mean
c = maximum variation
e = minimum value at maximum peak
f = minimum variation
t = time

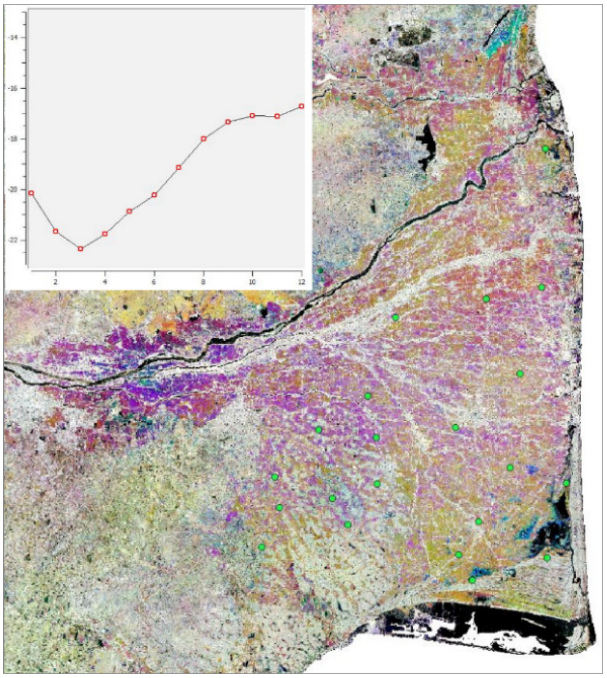

Fig3. BSQ - dB stack generated with Sentinel-1A SAR data

Accuracy assessment

The classification accuracy was evaluated through the Error matrix and Kappa statistics. The accuracy assessment is a comparison of the paddy area map against groundtruth data. Validation points split into two classes namely, paddy and non-paddy points. All land cover classes other than paddy are grouped into non-paddy 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).

Results and Discussion

Multi-temporal SAR imagery stack converted into terrain-geocoded ó° images from August 2020 to February 2021. The SAR satellite data acquired during the cropping season was input to the automated processing chain and analysis was carried out using training pixels collected through ground-truthing to generate temporal back scattering signature (ó°) for rice crop from the study area. The dB curves for paddy in monitoring fields were generated using temporal signatures extracted from VH polarization (Fig. 3). The dB value for paddy ranges between -24 to -12 dB.

Paddy area map generated for the study area covering four Cauvery delta districts *viz.,* Thanjavur, Thiruvarur, Nagapattinam and Mayiladuthurai districts using time series Sentinel 1A SAR imagery (Fig.4).

District level paddy area statistics were calculated for the study area and the summary of district-wise paddy area given in Table 1 In the study area, a total of 345328 ha of paddy area were delineated during *samba* season 2020 from the multi-temporal Sentinel 1A SAR data using a parameterized classification integrating multi-temporal features. Among the districts, Thanjavur recorded the highest area of about 122684 ha followed by Thiruvarur, Mayiladuthurai and Nagapattinam with an area of 119379 ha, 57015 ha and 46250 ha, respectively. Kannan *et al*. (2021) reported area under paddy cultivation in Thanjavur, Thiruvarur and

Table 1. District wise *samba* Paddy area estimated using SAR data

Sl. No.	District	*Samba* Paddy Area (ha)
1	Thanjavur	122684
2	Thiruvarur	119379
3	Mayiladuthurai	57015
4	Nagapattinam	46250
	Total	**345328**

Table 2. Confusion matrix for accuracy assessment of SAR based Paddy estimate

Actual class from the survey		Predicted class from the map		
	Class	Paddy	Non-Paddy	Accuracy (%)
	Paddy	136	11	92.5
	Non-Paddy	2	48	96.0
	Reliability	98.6%	81.4%	**93.4**
Average accuracy		94.3%		
Average reliability		90.0%		
Overall accuracy		93.4%		
Kappa index		**0.87**	**Good Accuracy**	

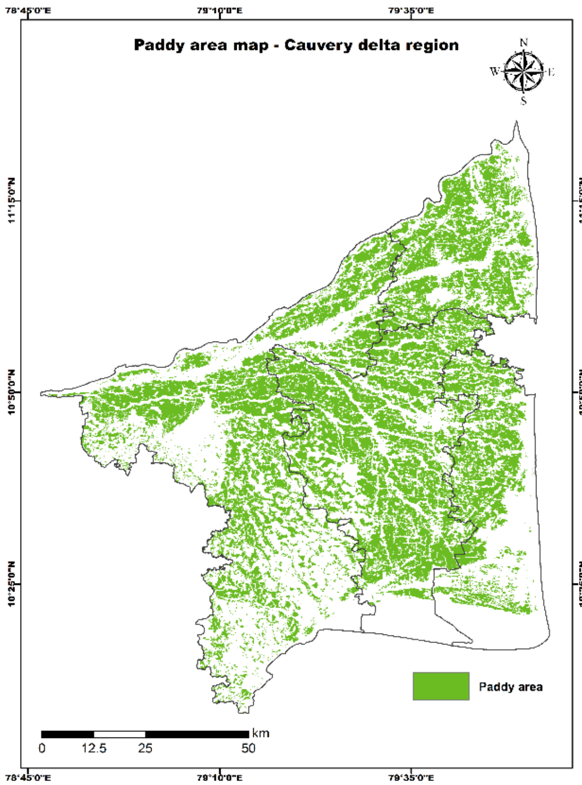

Fig. 4. *Samba* Paddy area 2020-2021

Nagapattinam districts during *kharif* season 2019. Raman *et al*. (2019) documented Thiruvarur *samba* paddy area during 2016.

Totally 197 groundtruth points have been collected randomly during crop growing season in the study area for training and validation processes. The accuracy of the paddy area map was assessed through the confusion matrix using the ground truth points, to classify paddy and non-paddy pixels (Stroppiana *et al*., 2019). Paddy points were classified with an accuracy of 92.5 per cent while non-paddy points were classified with an accuracy of 96.0 per cent (Table 2). Considering the efficiency of the methodology of mapping paddy area with SAR data, the overall accuracy of the paddy area map was 93.4 per cent. The Kappa Coefficient was 0.87 indicating good accuracy levels of the products.

Conclusion

Freely available SAR data were efficiently utilized in delineation and estimation of the paddy area with higher accuracy and reliability. From the study, it is concluded the total area under paddy cultivation in the Cauvery delta region recorded as 345328 ha with overall accuracy of 93.4 per cent and the Kappa Coefficient was 0.87. The information about the paddy area and the crop growth conditions were helpful to policymakers, government, farm managers, and farmers in formulating policies and targeting interventions. Crop area estimates assist the government in providing subsidies during crop failure due to natural catastrophes like floods, droughts, and cyclones.

Acknowledgement

The authors are thankful to the Department of Remote Sensing and GIS for providing the fund through the SUFALAM scheme to carry out the research work in a project mode and like to extend our sincere thanks to Professor and Head and staff members for their valuable comments and constructive suggestions on the manuscript.

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