*Short Research Article*

# Mapping rice area in the Cauvery Delta Zone of Tamil Nadu using Sentinel 1A Synthetic Aperture Radar (SAR) data


## Abstract

Since remote sensing based crop inventory provides accurate and timely information as compared to the conventional survey methods of estimating area, Multi-temporal Sentinel 1A Synthetic Aperture Radar data was used for the estimation of rice area during Samba season 2022 in the Cauvery delta zone comprising Thanjavur, Thiruvaru, Mayiladuthurai, and Nagapatnam districts of Tamil Nadu. SAR data was preferred over optical satellite data due to excess cloud cover during cropping the major season in Tamil Nadu. Temporal back-scatter (dB) signature of rice crop was generated from the multi-temporal processed SAR data utilizing the modules of a fully automated MAPscape software aiding the discriminating of the crop from others. The signatures revealed that the dB levels to be the lowest during agronomic floods, reached the highest during maximum tillering stage and started declining thereafter. Multi-temporal feature extraction module of Mapscape was used to estimate rice area and validated for accuracy using ground truth data collected during survey. A total of 3.05 lakh ha of rice area was estimated with an overall accuracy of 90.8 % and 0.82 kappa coefficient. Largest area of 1.12 lakh ha was recorded in Thanjavur followed by Thiruvarur and Mayiladuthurai with 0.95 and 0.51 lakh ha respectively.



**Keywords:** Rice area mapping, Sentinel-1A, Synthetic Aperture Radar, Cauvery Delta Zone.


## 1. Introduction

Rice is the most significant food crop in the world, feeding half of all people. For 20% of their daily calories, more than 3.5 billion people rely on rice.Rice is cultivated throughout the globe, it supports the economy in many nations and accounts for more than 150 million hectares of rice fields or 11% of the world's agriculture.The consumption of rice has rapidly increased due to high population growth and shifting consumer tastes, and the output of rice is predicted to reach 555 million metric tonnes in 2035 (Khush, 2005; Zhang et al., 2013; Son et al., 2014). The globe rice cultivation,from the wet regions to the harsh deserts, in a variety of climatic conditions. In South, South-East, and East Asia, rice takes up an exceptionally large proportion of the overall planted area. India is one of the largest producers and consumers of rice in the world. Rice is the staple food for a significant portion of the Indian population, and it plays a crucial role in the country's agriculture and food security. The total area under rice cultivation in India varies from year to year depending on factors such as weather conditions, government policies, and market demand. However, it is generally around 43-45 million hectares with an annual rice production of around 110-120 million metric tons. Rice cultivation in Tamil Nadu typically varies from 2.5 to 3.0 million hectares contributing around 7 to 9 million metric tons of rice annually to India's overall production. India produced 12.436 million metric tonnes of rice on 4.56 million hectares of rice fields in 2020–2021, with a productivity of 2717 kg/ha. In 2022-2023, Kharif's output target is 112000 tonnes, while Rabi's target is 18500 tonnes.

Based on rainfall, soil characteristics, irrigation potential, and cropping patterns, Tamil Nadu has seven different agro-climatic zones. Tamil Nadu is the country's tenth-biggest and seventh-most populated state (6%). It has a total geographical area of 130.33 Lha, which is 4% of the total land area of the country.The availability of water resources per capita is 750 cubic metres per year, compared to the national average of 2,200 cubic metres. The state has 81.18 lakh operational land holdings, operating 64.88 Lha. Small and marginal holdings account for 92% of overall holdings, with 61% of the total sown area under cultivation. In Tamil Nadu, Rice productivity in the 2020–2021 growing season in Kharfi and Rabi was 3483 and 4436 metric tonnes (Total). Tamil Nadu had a rice coverage of 2024.33/Hectare and 192.94/hectare, respectively. (Indiastat, 2021).

The information about the paddy area and the crop growth conditions were helpful topolicymakers, government, farm managers, and farmers in formulating policies and targeting interventions. Land use map of Cauvery delta zone was prepared using satellite data and it revealed the crop lands were classified in this zone .The distriution of land use,(124927 ha,54.3%),crop(1069 ha,0.46%),crop(17461ha, 7.59%) and and aquaculture(721ha, 0.31%) .within forest.marsh vegetation and deciduous forest area were 251 ha(0.11%) and 6782 ha (2.95%),respectivly .This classification was help to find crop area distrubtion of total area at geographical area which is used by the government agency and use for policy making in farmers community .(Kannan, P., Sankar, M., & Prabhavathi, M. (2010))

The issues in consolidation of crop area and production through conventional methods warrant new innovative technologies usage. A cutting-edge approach of remote sensing allows real-time crop monitoring, mapping, crop inventory, and yield estimation (Zhang et al., 2019). Precise crop identification can produce precise figures on crop area spread, planting structure and regional distribution, as well as provide important input traits for crop yield prediction. Hence crop identification and delineation is important for building a national food policy and economic strategy. Remote sensing data allow fast, accurate, detailed, and objective crop labelling, crop tracking, area estimation, and yield estimation. Remote sensing has been used in a wide range of earth observation activities due to the benefits of high time resolution, wide coverage, and low cost, and thus offers a useful tool for crop recognition and planting area tracking on a large scale (Raman *et al* .2019)Hence, the acquisition of data over vast geographic areas, remote sensing offers a cheaper alternative. (De beurs and Townsend, 2008).Crop inventory by remote sensing provides rapid and exact information, while traditional methods of area estimation are costly, time-consuming, less dependable, and less precise (Holecz et al. 2013). Based on biophysical characteristics of crops and/or soils, remote sensing technology has the potential to revolutionise the detection and characterisation of agricultural production. (Liaghat and Balasundram, 2010)

The introduction of modern satellites, as well as the open availability of data, enhances the quality and accuracy of agricultural data. When compared to optical satellite data, synthetic aperture radar (SAR) has been extensively used in crop inventory because of its ability to penetrate clouds and be time-independent (Zhang et al., 2013; Forkuor et al., 2014). Sentinel-1A data is freely accessible to users, and the satellite was launched in 2014 by the European Space Agency for Earth Observation. It is usually utilize microwave data for area estimation rather than optical data since cloud cover is an inescapable phenomenon in the tropical region especially during the monsoon season.This SAR sensor can collect data day or night, regardless of cloud cover, by providing its own light source. Because of how effectively SARs react to these structural variations, these sensors can reliably identify the kind of crop being grown and have shown to be sensitive to a number of crop biophysical characteristics, including leaf area index, biomass, and canopy height.The benefits of combining SAR data from several frequencies (L-, C-, and X-band) for crop categorization were established by( Shang et al. in 2009).Every crop has a distinct backscattering coefficient, which has been used to identify various crops. It has a C-band Synthetic Aperture Radar that delivers data in dual-polarisation of both VV (Vertical-Vertical) and VH (Vertical-Horizontal), with data accessible at twelve-day intervals regardless of time or weather (Raman *et al.*, 2019)**.**

The temporal signature of the rice crop generated by SAR backscatter and its relationship to the crop stages serve as the foundation for rice identification. Several studies has attempted to study the use of SAR data in estimation and monitoring of crop viz., rice, maize, cotton, mango, and banana (Pazhanivelan *et al*., 2015; Setiyono *et al*., 2019; Sudarmanian *et al*., 2019; Ramalingam *et al*., 2019; Venkatesan *et al*., 2019; Kaliaperumal *et al*., 2019; Karthikkumar *et al*., 2019,Kannan, Sugavaneshwaran, et al.,2021,Tamilmounika, R., et al,2022.). With this background, this study attempts to estimate the area and distribution of paddy in the Cauvery Delta region of Tamil Nadu during the Samba season 2022–23.

## 2.Materials and Methods

### 2.1Study area

The Cauvery Delta Zone (CDZ) is situated in Eastern Tamil Nadu surrounded by the Palk Straight in the South, the Bay of Bengal in the East, Perambalur and Ariyalur districts to the West and Cuddalore district to the North. Rice is the primary crop in this area which is grown either in a single season or double season based on the availability of water and other climatic conditions. During Samba season (2022–23), this research was undertaken in the Cauvery Delta region comprising the districts of Thanjavur, Thiruvarur, Nagapattinam, and Mayiladuthurai (Fig.1).

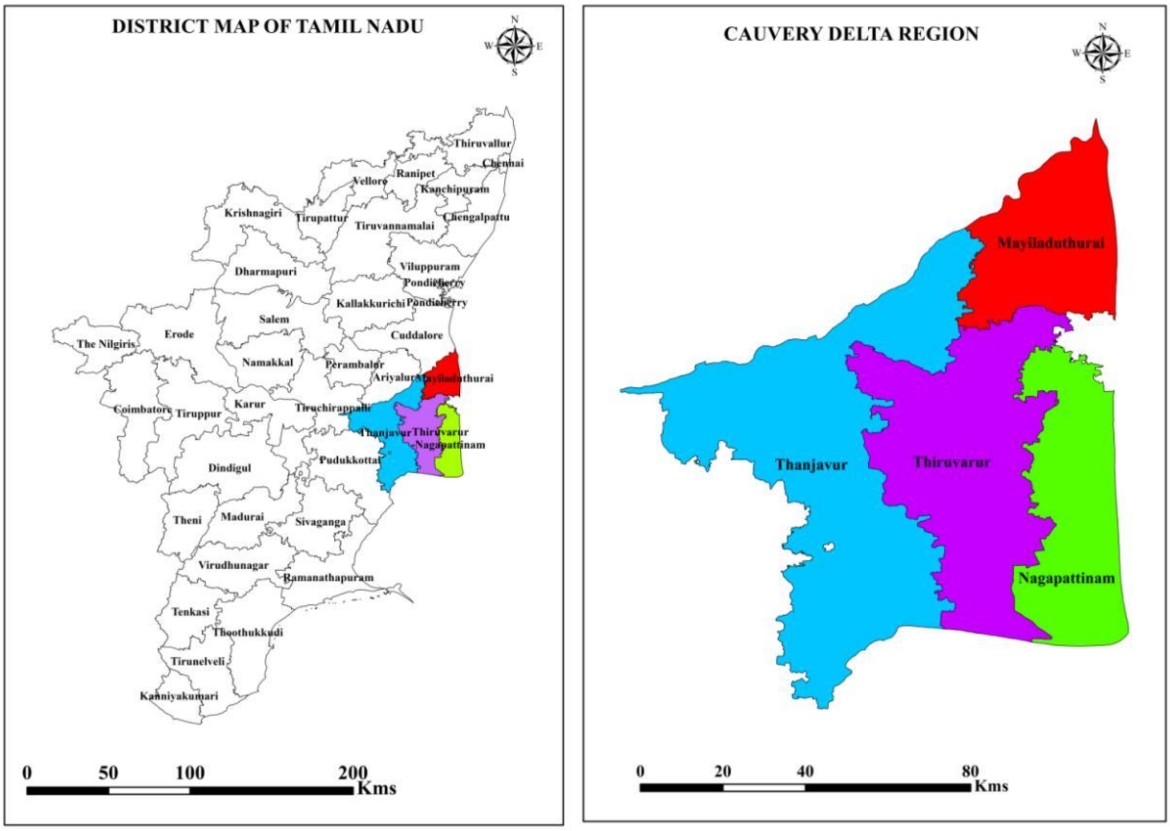


**Fig.1. Study area of Cauvery Delta region**



## 2.2Ground truth data

In the study area, an extensive survey was made and around 300 ground truth points were gathered during Samba, 2022 growing season comprising 200 rice points and 100 non-rice points. During the survey, rice and non-rice points were gathered with information on location, type of land use, age of crop and other ancillary data to aid in precise estimation of crop area. These points were utilized for training and validation of rice area estimates generated from the pre-processed satellite data in Mapscape software.

## 2.3 Satellite data

SAR has the benefit of working at wavelengths that are not impeded by cloud cover or a lack of light, and it can capture data over a location at any time of day or night, in any weather. Sentinel-1A's C band sensor can offer consistent wide-area surveillance. Sentinel 1A Level 1 ground range (GRD) data with a resolution of 20m from August through January, 2022-23 were downloaded from the website (https://sci-hub.copernicus.eu/dhus/) and utilised in this investigation. Sentinel 1A VH polarisation data with 12-day temporal resolution were utilised to estimate the paddy area.

## 2.4 Pre-processing of Sentinel 1A

SAR GRD multi-temporal data were processed using a fully automated chain processing methodology established by Holecz et al. (2013) to provide terrain-geocoded **σ** ° values in the MAPscape-RICE software. Basic SAR data processing comprises radiometric calibration, normalisation, strip mosaicking, co-registration, time-series speckle filtering, terrain geocoding, and anisotropic non-linear diffusion (ANLD) filtering. Atmospheric attenuation is eliminated (Nelson et al., 2014). On processing, this software translates temporal images to backscattering coefficients (**σ**°) based on terrain (Fig.2).

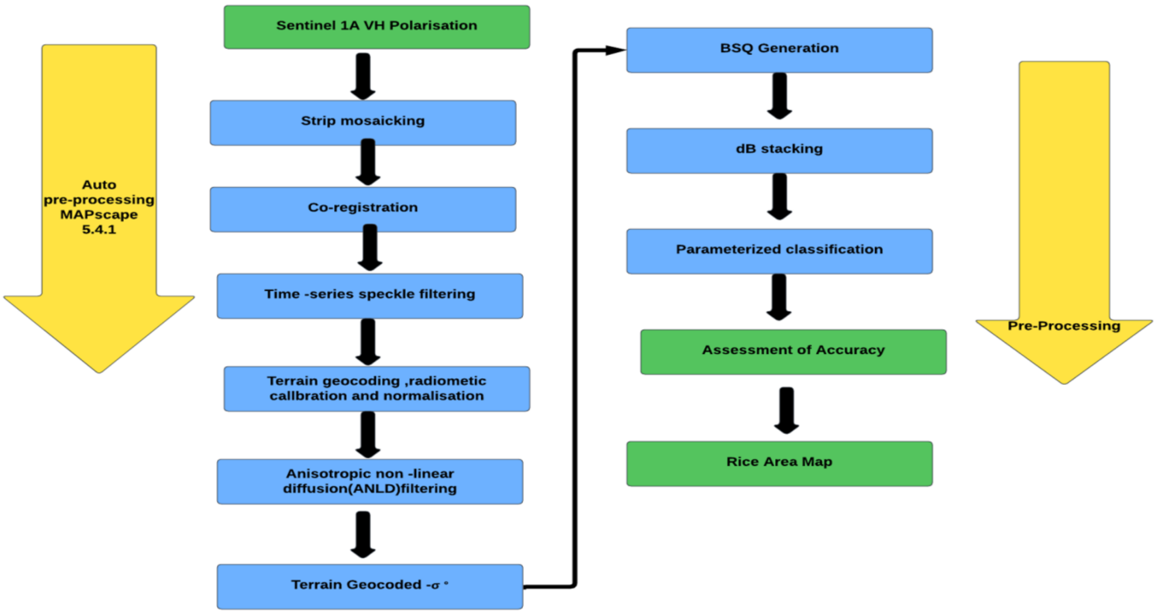


**Fig.2. Rule-based rice detection algorithm from multi-temporal Sentinel 1A**

## 2.5 Classification using parameters

Multi-temporal feature viz., maximum, minimum, mean, and range of degrees were extracted from the temporal characteristics of satellite data for the ground truth points. Then, 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 **σ**° value across fields; and the (v) minimum and (vi) maximum of the range of **σ**° values (Holecz et al., 2013) were computed for the ground truth points. 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 40–50 days. $T_{maxlength}$ restricts the duration between two **σ**° minima in the series and 120 days is a suitable cutoff that would be representative of an intensive triple rice system. t2– t1 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.

## 2.6 Accuracy assessment

The Error matrix and Kappa statistics were used to assess classification accuracy. A comparison of the paddy area map is used to determine accuracy and versus data from the ground. There are two types of validation points: paddy points and non-paddy points. Non-paddy points include all land cover groups other than paddy. The error matrix is used to determine accuracy measurements such overall accuracy, producer accuracy, user accuracy, and kappa value (Congalton, 1991).

**3. Results**

The multi-temporal 12 days interval Sentinel 1A SAR images from August, 2022 and January, 2023 were downloaded, processed and stacked by transforming into terrain-geocoded **σ°** images. The SAR satellite data gathered throughout the cropping season was fed into the automated processing chain, and analysis was performed using training pixels collected via ground-truthing to develop a temporal back scattering signature (**σ°**) for the rice crop in the research region. The temporal characteristics recovered from VH polarisation were used to produce the dB curves for paddy in monitoring fields. Paddy's dB value varies from -24 to -12 dB. Using time series Sentinel 1A SAR images, a paddy area map comprising four Cauvery delta districts, Thanjavur, Thiruvarur, Nagapattinam, and Mayiladuthurai, was estimated. For the study region, district-level paddy area data were computed, and a summary of district-wise paddy area is shown in Table 1. In the research field, during the samba season 2022–23, 305388.58 hectares of rice area was estimated from multi-temporal Sentinel 1A SAR data using a parameterized classifier combining multi-temporal characteristics. Thanjavur had the largest area of roughly 112534.24 hectares, followed by Thiruvarur, Mayiladuthurai, and Nagapattinam, with 95670.62 ha, 51248.20 ha, and 45935.52 ha, respectively.

**Table 1. District wise rice area in Cauvery delta region during samba season 2022-23**

| S.No | District | Rice Area (ha) |
|---|---|---|
| 1. | Mayiladuthurai | 51248.20 |
| 2. | Nagapattinam | 45935.52 |
| 3. | Thiruvarur | 95670.62 |
| 4. | Thanjavur | 112534.24 |
| | **Total** | **305388.58** |

The ground truth points collected during the survey were used to assess the accuracy of the estimated rice area. There were 200 rice points and 100 non-rice points among the 300 ground truth points collected. A confusion matrix was built to validate the rice area computation and to assess classification accuracy. During samba season 2022, 180 of the 200 ground truth rice points obtained were correctly classified as rice crop. As a result, the overall accuracy of the rice area map was 90.8 %, and the kappa co-efficient was 0.82, indicating that the technique was accurate (Table 2).

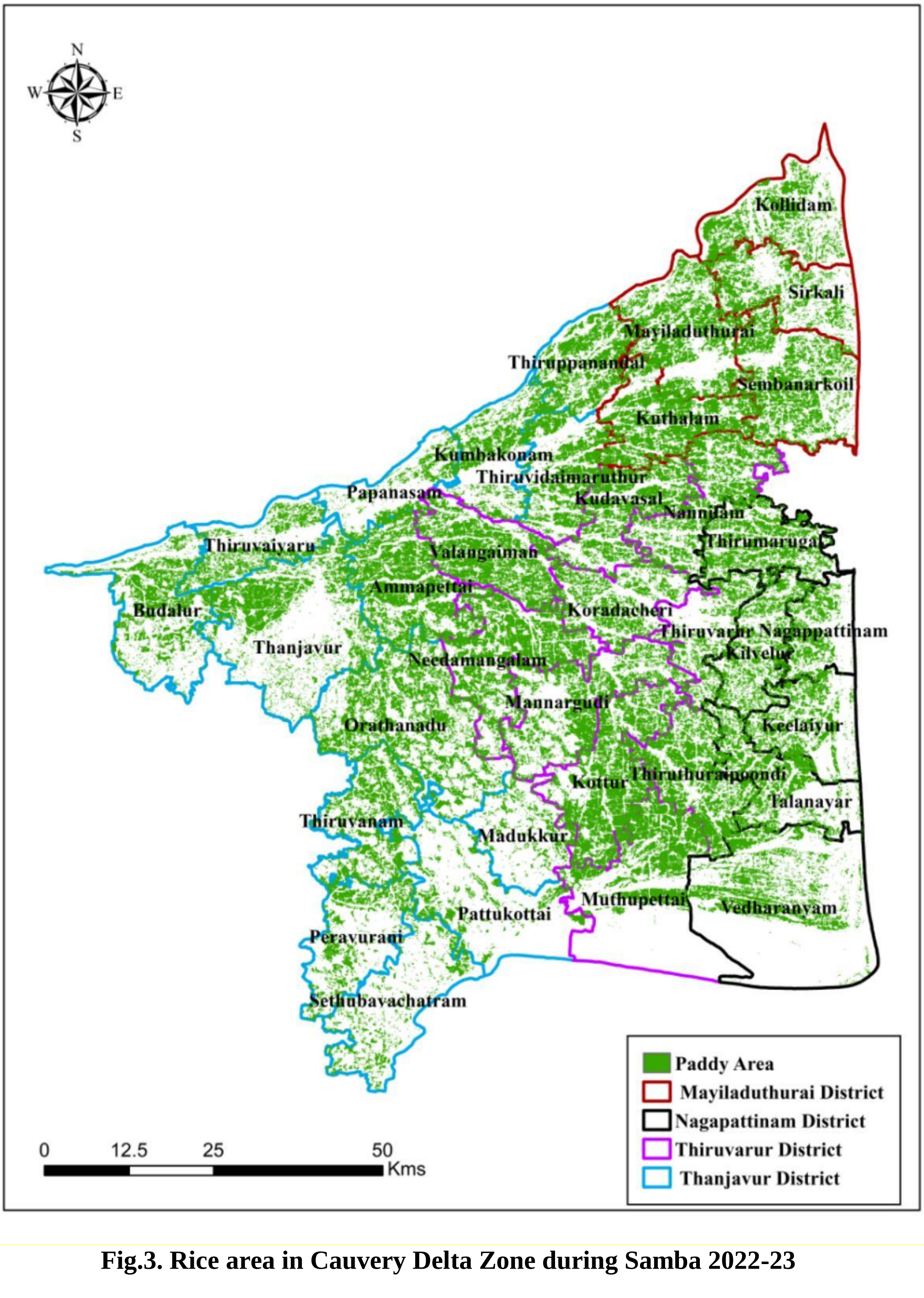


**Fig.3. Rice area in Cauvery Delta Zone during Samba 2022-23**

**Table 2. Confusion Matrix for accuracy assessment**

| Actual class from survey | Predicted class from the map | | | |
|---|---|---|---|---|
| | | Rice | Non-Rice | Accuracy |
| | Rice | 95 | 8 | 92.2% |
| | Non-Rice | 3 | 14 | 82.4% |
| | Reliability | 96.9% | 63.6% | 90.8% |
| **Average accuracy** | | | | 87.3% |
| **Average reliability** | | | | 80.3% |
| **Overall accuracy** | | | | 90.8% |
| **Kappa index** | | | | **0.82** |

**Table 3. Block wise rice area during samba season 2022-23**

| S.No | District | Block | Area in Ha |
|---|---|---|---|
| 1. | Mayiladuthurai | Kollidam | 7867.16 |
| | | Sirkali | 6962.44 |
| | | Mayiladuthurai | 11851.20 |
| | | Sembanarkoil | 12630.80 |
| | | Kuthalam | 11936.60 |
| 2. | Nagapattinam | Thirumarugal | 9167.28 |
| | | Nagappattinam | 4465.72 |
| | | Kilvelu | 7398.12 |
| | | Keelaiyur | 6494.56 |
| | | Talanayar | 7894.84 |
| | | Vedharanyam | 10515.00 |
| 3. | Thiruvarur | Kudavasal | 9975.560 |
| | | Nannilam | 9895.4 |
| | | Kordacheri | 7458.20 |
| | | Thiruvarur | 4932.36 |
| | | Needamangalam | 13651.70 |
| | | Mannargudi | 11215.10 |
| | | Kottur | 15477.00 |
| | | Muthupettai | 11567.40 |
| | | Thiruthuraipoondi | 11497.90 |
| 4. | Thanjavur | Thiruppanaadal | 8463.36 |
| | | Kumbakonam | 6214.04 |
| | | Thiruvidaimaruthur | 8370.00 |
| | | Papanasam | 3428.20 |
| | | Ammapettai | 14496.50 |
| | | Thanjavur | 12378.60 |
| | | Thiruvaiyaru | 5447.60 |
| | | Budalur | 9312.04 |
| | | Orathanadu | 17635.10 |
| | | Thiruvanam | 8641.72 |
| | | Madukkur | 3223.08 |
| | | Pattukottai | 4908.80 |

| | | | |
|---|---|---|---|
| | | Sethubavachatram | 4441.48 |
| | | Peravurani | 5573.72 |

Block wise statistics were collected to understand the pattern of rice area distribution throughout the research region's blocks. The Orathanadu block of Thanjavur district recorded the largest area with 17635.10 ha, followed by Kottur block of Thiruvarur district, Sembanarkoil block of Mayiladuthurai district and Vedharanyam block of Nagapattinam dostrict with 15477.00 ha, 12630.80 ha, and 10515.00 ha, respectively. The Madukkur block in Thanjavur District reported the lowest rice area of 3223.08 ha, followed by Nagappattinam block, Thiruvarur block, and Sirkali block, with 4465.72 ha, 4932.36 ha and 6962.44 ha respectively (Table 3).

**4.Discussion:**

The study was conducted by Tamilmounika, R., et al.,using Sentinel-2A data for estimation of rice area .During (2020-2021)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 and46250 ha, respectively.A total paddy area of 345328 ha.Similar to this Kannan, Sugavaneshwaran, et al.(2021) used Sentinel-2A , calculated rice area Around 1,41,639 ha, 1,25,497 ha, and 1,17,703 ha were rice-growing areas in Thanjavur, Thiruvarur, and Nagapattinam districts, respectively.The accuracy of the rice area map was assessed through the confusion matrix using the ground truth points to classify rice and non-rice pixels (Stroppiana *et al.*, 2019).Rice points were classified with an accuracy of 95.3 *per cent*, while non-rice points were classified with an accuracy of 92.0 *per* cent. Considering the efficiency of the methodology of mapping rice area with SAR data, the overall accuracy of the rice area map was 94.5 *per* cent.

**5.Conclusion**

The Cauvery Delta Zone (CDZ) of Tamil Nadu rice area estimation approach was found to be successful in detection, delineation, and estimation, as shown by the high classification accuracy of 90.8% and a kappa value of 0.82. Due to its weather and time independence, SAR satellite data is perfect for immediate area mapping. In order to create policies and focus interventions, policymakers, the government, farm managers, and farmers used information regarding the paddy area and crop growth conditions. The results derived will be of much use in policy decisions due to its high accuracy estimates.

COMPETING INTERESTS

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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