Plant Archives Vol. 25, Supplement 1, 2025 pp. 2743-2748 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2025.v25.supplement-1.380

ESTIMATION OF RICE AREA IN THIRUVARUR DISTRICT USING SENTINEL-2 SATELLITE DATA

Sugavaneshwaran Kannan*, Ragunath Kaliaperumal, S. Pazhanivelan, R. Kumaraperumal and K. Sivakumar
Department of Remote Sensing and GIS, Tamil Nadu Agricultural University, Coimbatore, India.
*Corresponding author - sugavaneshwarank@gmail.com
(Date of Receiving : 29-10-2024; Date of Acceptance : 31-12-2024)

ABSTRACT

Accurate estimation of rice cultivation areas is essential for agricultural planning and food security. This study utilizes Sentinel-2 satellite data and optical remote sensing techniques to estimate *kharif* paddy areas in Thiruvarur district, Tamil Nadu. The methodology includes preprocessing Sentinel-2 data, developing False Color Composites, and employing supervised classification through Maximum Likelihood Classification (MLC) to delineate paddy fields. Ground truth data collected from 103 points supported the classification process. The analysis estimated the district's kharif paddy area at 18,815.92 hectares, with the Mannargudi block accounting for the largest share (20.43%). Accuracy assessment using a confusion matrix yielded an overall accuracy of 91.3% and a Kappa index of 0.82, demonstrating the reliability of the results. This study underscores the potential of optical remote sensing for large-scale agricultural monitoring, offering a cost-effective and precise tool to support agricultural planning and resource management.
***Keywords* :** Sentinel-2; Optical remote sensing; Paddy

Introduction

Agriculture plays an important role in development of Indian econnomy (Gupta *et al.,* 2024). The most significant food crop in the world, rice is a staple that provides over 60% of the world's population with wholesome food. The entire area planted to rice in India is 44.6 million hectares, and the country produces 80 million tons of paddy with an average yield of 1855 kg/ha. Nearly every state grows it, accounting for 92% of both area and production (Kannan *et al.*, 2021). West Bengal, Punjab, Tamil Nadu, and Uttar Pradesh are the main states that grow rice. Just these four states make about 40% of India's total territory that can be used for rice cultivation. Rice is grown in Tamil Nadu throughout the summer, rabi, and kharif seasons. Tamil Nadu makes up 4.2% of the total area that can be used for rice cultivation, with 3.1% going toward kharif paddy cultivation (Kannan *et al.*, 2021). This necessitates knowledge on crop areas and makes it an important component of national food security.

National and state-level planning requires accurate and consistent data on the production area (Cruze *et al.,* 2019). This data has a direct impact on food security and is essential for policy choices pertaining to imports, exports, and prices (Brown *et al.,* 2012). Because they are labor-intensive, expensive, and occasionally biased, traditional statistical methods of data collection are not always able to satisfy the requirements. Remote sensing offers the potential to provide accurate and economical crop area estimates. LANDSAT, SPOT, IRS, and other polar-orbiting earth observation satellites have multi-spectral (visible, near-infrared) sensors that are launched and conveniently maintained, making remote sensing an informative field. For estimating space and yield, remote sensing (RS) data has become essential. It can offer a quick, precise, objective, synoptic, and synoptic way to assess crop identification, crop observance, and area estimation. Because of its high temporal precision, broad coverage, and affordability, remote sensing has been used extensively in earth observation operations and is a great instrument for large-scale crop identification and planting area observance.

Optical remote sensing systems rely on the reflectance of objects in the visible and infrared portions of the electromagnetic spectrum. Crop mapping research have employed optical images since the bio-physical features of plants still vary during vegetative phases (Forkuor *et al*., 2014). Since the sun's energy was unhindered during the entire crop growth stages, irrigated land has been successfully monitored by optical data in semi-arid circumstances (Forkuor *et al*., 2014; Liu *et al*., 2013). Therefore, cloud-free optical data is essential during the growth season of crops. Comparing Sentinel-2A and 2B with the other optical satellite systems for crop monitoring, Segarra et al. (2020) preferred Sentinel MSI for various applications like Crop monitoring, Abiotic and Biotic stress detection, crop type classification, crop water requirements due to their Pledging technical features and public availability of the data. The most regularly practiced classification method in remote sensing is maximum likelihood classification. The specific characteristic of spectral response patterns like variance and covariance are quantitatively estimated while classifying unknown patterns (Mutihac *et al.,* 2008). The model assumes a Gaussian distribution pattern for a training set, and its distribution class through the mean vector and covariance matrix. The statistical probability of any given pixel is determined using these parameters. Hence a study was conducted to identify the crop area of rice in Thiruvarur region using Optical remote sensing.

Materials and Methods

Study Area

Thiruvarur district lies between 10° 20′ N to 11° 07’ N latitude and 79° 15′ E to 79° 45′ E longitude. The district occupies 2374sq.km of an area with an average elevation of 10m above MSL. Thiruvarur district has been one of the districts in the state Tamil Nadu with a creditable agricultural production performance with the farmers relatively more responsive and receptive to changing technologies and market forces. Ninety *per cent* of the district population is engaged in Agriculture and allied activities. The district has a net cultivated area of around 3,22,859 ha.

Satellite data

The Multispectral Imager (MSI) covering 13 spectral bands (443–2190 nm), with a swath width of 290 km and a spatial resolution of 10 m (four visible and near-infrared bands), 20 m (six red edges and shortwave infrared bands), and 60 m (three atmospheric correction bands) are the details of Sentinel-2 data (Huang *et al.,* 2016). The various product types of Sentinel-2 data are given in table 1. Sentinel-2A and Sentinel-2B Optical data was used for the area estimation in the kharif season of 2019. The levels of Sentinel-2 data and their description are given in the table 1.

Table 1 : The levels of Sentinel-2 data and their description

Name	High-level Description	Production & Distribution	Data Volume
Level-1C	Top-of-atmosphere reflectances in cartographic geometry	Systematic generation and on-line distribution	600 MB (each 100x100 km^2)
Level-2A	Bottom-of-atmosphere reflectance in cartographic geometry	Systematic generation and on-line distribution and generation on the user side (using Sentinel-2 Toolbox)	800 MB (each 100 x100 km^2)

Ground truth Collection

Around 103 paddy points comprising 66 points in Thiruvarur district and non-paddy points comprising 37 points were collected with attributes viz., the status of the field, stage of the crop, planting date and management practices.

Pre-processing of Sentinel-2 optical data

The Sentinel-2 optical data have various levels of products ranging from Level-0 to Level-2A, of which Level-1C and Level-2A data are available for the users. Level-2A is a telemetry analysis product, telemark generation, decompression, coarse co-registration, radiometric correction, geometric viewing model refinement, resampling, and conversion to reflectance data used for the study. The list of bands with their description is given in Table 2.

Table 2 : Details of Bands from Sentinel-2A satellite data

Band	Resolution	Wavelength	Description
B1	60 m	443 nm	Ultra-Blue (Coastal and Aerosol)
B2	10 m	490 nm	Blue
B3	10 m	560 nm	Green
B4	10 m	665 nm	Red
B5	20 m	705 nm	Visible and Near Infrared (VNIR)
B6	20 m	740 nm	Visible and Near Infrared (VNIR)
B7	20 m	783 nm	Visible and Near Infrared (VNIR)
B8	10 m	842 nm	Visible and Near Infrared (VNIR)
B8a	20 m	865 nm	Visible and Near Infrared (VNIR)
B9	60 m	940 nm	Short Wave Infrared (SWIR)
B10	60 m	1375 nm	Short Wave Infrared (SWIR)
B11	20 m	1610 nm	Short Wave Infrared (SWIR)
B12	20 m	2190 nm	Short Wave Infrared (SWIR)

Composite Band Function

Every single band in the multispectral image can be displayed as a single band at monochrome or a combination of bands at a time for color composite images. The Composite Bands function combines different raster forms of a multiband image. Band combinations are done to understand the spectral reflectance profiles of various features. True or Natural Color Composite consists of the combination of blue, green, red bands displaying their corresponding colors and false-color images represent multispectral images having any bands other than visible red, green, and blue. False Color Composite (FCC) is preferred for agricultural studies due to more information on vegetation at Infrared band. Since the research involves the classification of imageries to discriminate paddy crop, an FCC was prepared using the composite band function available in ArcGIS software with B3, B4, and B6 bands of Sentinel-2, which was used for further analysis. Subsetting the processed raster data can reduce the time required for further analysis. The Extract by mask module in ArcGIS was used to subset the Sentinel-2 optical image.

Supervised classification

The remote sensing literature presents with a number of supervised methods that have been developed to tackle the multispectral data classification problem (Richards *et al.,* 2022) In Supervised classification, various pixel values or spectral signatures will be specified to associate with each class by selecting representative sample sites of a known cover type called training sites**.** Forty *per cent* of the ground truth points collected were used for developing training sites. By these parameters, we may compute the statistical probability of a given pixel being a member of a particular class. The composited FCC of the Sentinel-2 image was classified using MLC for the identification of the *kharif* paddy crop. Around six classes were made from the signatures derived from the ground truth points viz., Paddy, Waterbody, Settlements, Barren lands, other crops and miscellaneous. The training sites developed were used to analyse the Sentinel-2A data for delineating *kharif* paddy crop following supervised classification.

Masking

The non-agricultural areas were masked out and agricultural areas were extracted from the Land Use Land Cover map of Tamil Nadu at the scale of 1:50,000 available with the Department of Remote Sensing and GIS, Tamil Nadu Agricultural University, Coimbatore.

Accuracy assessment

The Error matrix and Kappa statistics are used for evaluating the accuracy of the estimated rice area.

$$\text{Overall Accuracy} = \frac{\sum(\text{Correctly classifed classes along diagonal})}{\sum(\text{Row Total or Column Total})}$$

$$\text{User's Accuracy} = \frac{\text{Number of correctly classified item in a row}}{\text{Total number of items verified in that row}}$$

$$\text{Producer's Accuracy} = \frac{\text{Number of correctly classified class in a column}}{\text{Total number of items verified in that column}}$$

$$\hat{K} = \frac{NA - B}{N^2 - B}$$

To create the paddy region, the maximum likelihood classifier in ArcGIS software used the training sites created from the Sentinel-2A satellite data utilizing the ground truth points as an input. Until a significant level of accuracy was achieved, training site improvements, re-run classification, and accuracy evaluation were repeated. Sentinel-2A optical data is used to estimate the area of kharif paddy in the study districts. The correctness of the analysis's result was assessed statistically, and district- and block-level maps and data of the rice region were taken out.

The methodology as shown in Fig. 2. includes the preprocessing of Sentinel 2 data followed by Band composting by False colour composites and mosaicking the study area and selecting the training sites using the collected Ground Truth data. Then, Maximum likelihood classification was done to choose the rice vegetaion among all the other classes. Followed by accuracy assessment was done using Error matrix and kappa index.

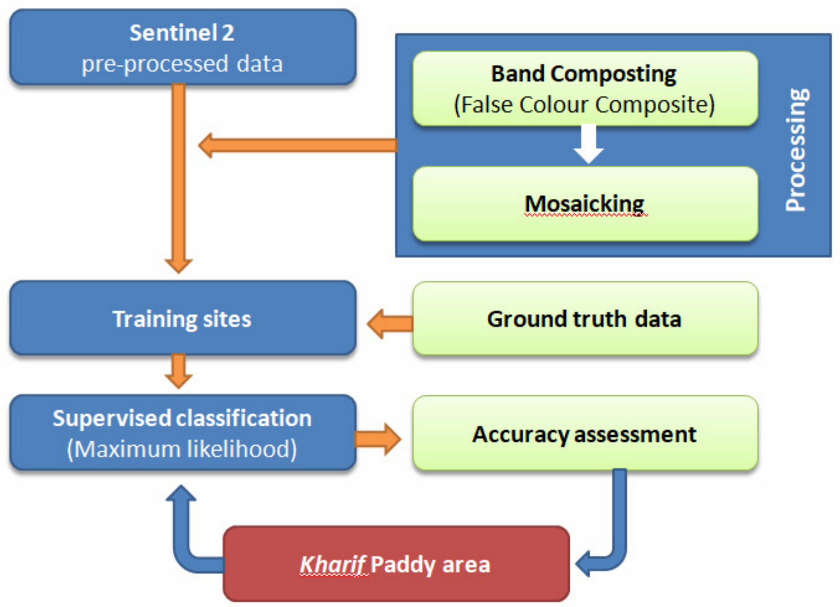

Fig. 2 : Methodology for Estimation of Rice area in Thiruvarur district using Sentinel 2 satellite data

Results and Discussion

Thiruvarur district registered a total *kharif* paddy area of 18815.92 ha. Block wise area statistics in the 10 blocks viz., Koradacheri, Kottur, Kudavasal, Mannargudi, Muthupettai, Nannilam, Needamangalam, Thiruthuraipoondi, Thiruvarur and Valangaiman was performed to understand the distribution of paddy area in the district. The area statistics and *per cent* area coverage is presented in Table 3. The spatial distribution of *kharif* paddy area is presented in Fig.3.

The Maximum rice area in the Thiruvarur district was recorded in the Mannargudi block with 3846.05 ha covering 20.43 *per cent* of the total rice area. Needamangalam, Koradacheri, Thiruvarur, Kottur and Nannilam blocks recorded 3410.36, 2206.37, 2085.6, 1746.02 and 1514.25 ha of rice area respectively. With Kudavasal covering the lowest area of 598.02 ha with 3.18 *per cent* distribution. Muthupettai, Valangaiman and Thiruthuraipoondi cover an area of 774.09, 1216.67 and 1423 ha with 4.11, 6.46 and 7.56 *per cent* distribution to the total paddy area.

Table 3 : Block wise paddy area in Thiruvarur district – Optical data

S.No.	Block Name	Area in ha	*Per cent* distribution of area
1	Mannargudi	3846.05	20.43
2	Needamangalam	3410.36	18.12
3	Koradacheri	2206.37	11.72
4	Thiruvarur	2085.6	11.08
5	Kottur	1746.02	9.28
6	Nannilam	1514.25	8.05
7	Thiruthuraipoondi	1423.48	7.56
8	Valangaiman	1216.67	6.46
9	Muthupettai	774.09	4.11
10	Kudavasal	598.02	3.18

The confusion matrix for accuracy assessment of the paddy area estimated by the optical remote sensing data was done using a total of 66 paddy points and 37 non-paddy ground truth points. The results showed that out of 66 paddy points, 60 were classified in paddy and 6 got misclassified as Non paddy showing accuracy of 90.9 %. The non paddy points showed 91.8% accuracy with 3 non-paddy points misclassified as paddy. The overall accuracy was found to be 91.3% with a kappa index of 0.82 which is showing Good Accuracy.

Table 4 : Confusion matrix for accuracy assessment of Optical based Paddy estimate.

Actual class from the survey	**Predicted class from the map**			
	Class	**Paddy**	**Non-Paddy**	**Accuracy (%)**
	Paddy	60	6	90.9%
	Non-Paddy	3	34	91.8%
	Reliability	95.3%	85%	**91.3%**
Average accuracy		91.3%		
Average reliability		90.2%		
Overall accuracy		**91.3%**	**Good Accuracy**	
Kappa index		0.82		

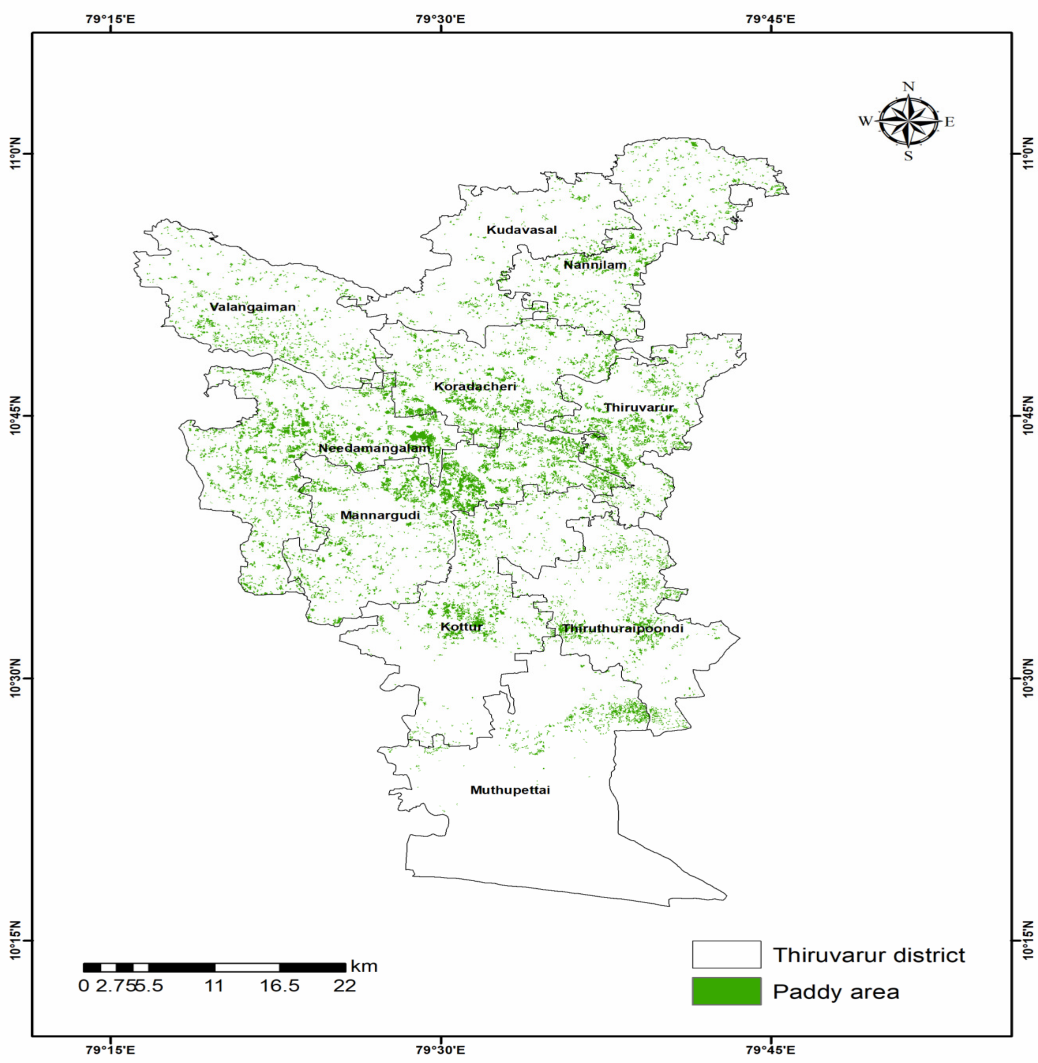

Fig. 3 : Spatial distribution of *kharif* paddy area in Thiruvarur district

Conclusion

In conclusion, this study demonstrates the potential of using optical remote sensing data from Sentinel-2 satellites for accurate and efficient estimation of kharif paddy areas in Thiruvarur district, Tamil Nadu. The use of Sentinel-2A and 2B data, in conjunction with maximum likelihood classification, enabled the identification and mapping of paddy fields with a high degree of accuracy. The district-wide paddy area was estimated to be 18,815.92 hectares, with notable variations in distribution across the 10 blocks. The classification accuracy, assessed through confusion matrix and Kappa index, achieved a commendable overall accuracy of 91.3%, indicating that optical remote sensing techniques provide reliable results for large-scale agricultural monitoring. This methodology offers an effective tool for agricultural planning, supporting food security efforts and enabling better resource management at both the state and national levels. The findings underscore the value of remote sensing in modern agriculture, particularly for crop monitoring and area estimation, and pave the way for future studies in similar regions to enhance the scope and precision of agricultural monitoring systems.

References

Gupta, P.C. (2024). *Indian economy and structural reforms: e-Book of Indian economy and structural reforms*. Thakur Publication.

Cruze, N. B., Erciulescu, A. L., Nandram, B., Barboza, W. J., & Young, L. J. (2019). Producing Official County-Level Agricultural Estimates in the United States. *Statistical science*, ***34***(2), 301-316.

Brown, M. E., Tondel, F., Essam, T., Thorne, J. A., Mann, B. F., Leonard, K., ... & Eilerts, G. (2012). Country and regional staple food price indices for improved identification of food insecurity. *Global Environmental Change*, ***22***(3), 784-794.

Forkuor, Gerald, Christopher Conrad, Michael Thiel, Tobias Ullmann, and Evence Zoungrana. 2014. "Integration of optical and Synthetic Aperture Radar imagery for improving crop mapping in Northwestern Benin, West Africa." Remote Sensing, **6**(7): 6472-6499.

Liu, Yang, Jianshu Lv, Bing Zhang, and Jun Bi. (2013). "Spatial multi-scale variability of soil nutrients in relation to environmental factors in a typical agricultural region, Eastern China." *Science of the Total Environment,* **450**: 108-119.

Segarra, J., Maria, L.B., Jose, L.A., and Shawn, C.K. (2020). "Remote sensing for precision agriculture: Sentinel-2 improved features and applications." *Agronomy* **10**(5):641.

Kannan, S., Kaliaperumal, R., Pazhanivelan, S., Kumaraperumal, R., & Sivakumar, K. (2021). Paddy area estimation in Nagapattinam district using sentinel-1A SAR data. *The Pharma Innovation Journal*, ***10***(2), 112-116.

Kannan, S., Kaliaperumal, R., Pazhanivelan, S., Kumaraperumal, R., & Sivakumar, K. (2021). Rice Area Estimation using Sentinel 1A SAR Data in Cauvery Delta Region. *Int. J. Curr. Microbiol. App. Sci*, **10**(2), 848-853.

Mutihac, L., & Mutihac, R. (2008). Mining in chemometrics. *Analytica Chimica Acta*, ***612***(1), 1-18.

Huang, H., Roy, D. P., Boschetti, L., Zhang, H. K., Yan, L., Kumar, S. S., ... & Li, J. (2016). Separability analysis of Sentinel-2A Multi-Spectral Instrument (MSI) data for burned area discrimination. *Remote Sensing*, ***8***(10), 873.

Richards, J. A., & Richards, J. A. (2022). Supervised classification techniques. *Remote sensing digital image analysis*, 263-367.