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Estimation of Paddy Area in Nagapattinam District Using Sentinel-2 Data

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A B S T R A C T

Accurate estimation of crop area is crucial for agricultural planning and food security. This study focuses on mapping the *kharif* paddy area in Nagapattinam district, Tamil Nadu, using Sentinel-2 satellite imagery. The high-resolution multispectral data from Sentinel-2A and 2B were processed and analysed through supervised classification using the Maximum Likelihood Classifier (MLC) in ArcGIS. Ground truth data comprising 109 field samples were used for training and validation. False Color Composite (FCC) band combinations were applied to distinguish paddy from other land covers. Results revealed a total paddy area of 41,170.07 ha, with Mayiladuthurai block showing the highest coverage. Accuracy assessment using a confusion matrix yielded an overall accuracy of 91.7%, confirming the reliability of optical remote sensing for large-scale paddy mapping. This approach demonstrates the potential of satellite-based techniques for cost-effective and timely agricultural monitoring, contributing to enhanced decision-making in resource management and policy development.

Introduction

More than half of the world's population depends on rice as a staple diet, making it the most significant food crop in the world. In India, 44.6 million hectares are planted to rice, yielding 80 million tonnes of paddy with an average productivity of 1855 kg/ha. It accounts for 92% of both area and production and is grown in practically every state.

Tamil Nadu, West Bengal, Punjab, and Uttar Pradesh are the main states that grow rice. Forty percent of India's rice-growing land is in these four states alone. In Tamil Nadu, rice is grown during the summer, rabi, and *kharif* seasons. The total land that may be used for rice cultivation is 4.2% in Tamil Nadu, of which 3.1% is used for *kharif* paddy cultivation. This makes it a crucial component of the country's food security and calls for crop area data. Planning at the federal and state levels requires accurate and consistent data on the production area. The policy decisions pertaining to imports, exports, and pricing that directly affect food security depend on this information.

Because they need human resources, are expensive, and can exhibit bias, traditional statistical methods of data collection are not always able to match the requirements. Accurate and economical estimations of the crop area can be obtained by remote sensing. So, there are some studies done by Kannan *et al.,* (2021a) and Kannan *et al.,* (2021b) in Cauvery delta region and Nagapattinam districts for the rice area using sentinel-1 data.

The reflectance of objects in the visible and infrared portions of the electromagnetic spectrum is used by optical remote sensing devices. Since the bio-physical features of crops continue to alter during vegetative stages, optical images have been used for crop mapping research (Forkuor *et al.,* 2014).

Since there was no obstruction to the sun's radiation during the entire crop growth stages, optical data has been successfully used to monitor irrigated land in semi-arid circumstances (Forkuor *et al.,* 2014; Liu *et al.,* 2013). With this brief, the current study aims to estimate the paddy area in the Nagapattinam district using sentinel-2 data.

Materials and Methods

Study area

The Nagapattinam district in Tamil Nadu is 9 meters above mean sea level and spans 2715.8 km2. It is located between 10′ 10’ and 11′ 20’ in the east and 79′ 15’ to 79′ 50’ in the north. The Bay of Bengal to the east, the Palk Strait to the south, the districts of Thiruvarur and Thanjavur to the west and northwest, respectively, and Cuddalore District to the north enclose Nagapattinam.

In the district, paddy is the most significant crop. In addition, cotton, sugarcane, gingelly, legumes, and groundnuts are farmed. Therefore, the district of Nagapattinam was chosen to examine the paddy area.

Satellite data

Sentinel-2 satellite data was used. Sentinel-2, a Multi-spectral Instrument (MSI), produces all-world multispectral images with high spatial resolution that are superior in terms of radiometrics and geometry. Five days are allotted for the revisit at the Equator.

Thirteen bands within the optical NIR and SWIR components of the electromagnetic spectrum comprise the 290 km wide-field coverage of the data (Drusch *et al.,* 2012). June 23, 2015, saw the launch of Sentinel-2A, and March 2017 saw the launch of Sentinel-2B. The Multispectral Imager (MSI), which has a 290 km swath width 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), covers the specifics of Sentinel-2 data. Thirteen spectral bands (443–2190 nm) are covered by the MSI. The Sentinel-2 data's many product types are listed in Table 1. Sentinel-2A and Sentinel-2B, respectively Using optical data, the area was approximated during the 2019 *kharif* season.

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Ground truth collection

Around 109 paddy points comprising 73 paddy and non-paddy points comprising 36 points were collected with attributes viz., the status of the field, stage of the crop, planting date and management practices.

Pre-processing of Satellite data

The Sentinel-2 optical data has many product levels ranging from Level-0 to Level-2A; Level-1C and Level-2A data are available to users. Telemark creation, decompression, radiometric correction, poor co-registration, enhancement of the geometric viewing model, resampling, and conversion to reflectance data for the study are all included in the telemetry analysis package, Level-2A. Table 1 lists the bands along with a description of each.

Composite band function

In monochrome, each band in the multispectral image can be displayed independently; in color composite images, a combination of bands can be displayed simultaneously. A multiband image's several raster representations are combined using the Composite Bands function. Understanding the spectrum reflectance patterns of various features is the goal of band combinations. A real or natural color composite is made up of bands that are blue, green, and red and exhibit their individual colours. Multispectral photographs having any bands other than the obvious red, green, and blue bands are known as false-color images. False Color Composite (FCC) is the preferred technique for agricultural research because it offers additional plant information at the infrared spectrum. Since the research involves classifying photos to differentiate across paddy crops, an FCC was created for additional analysis using the composite band tool in ArcGIS software that uses Sentinel-2's B3, B4, and B6 bands. Subsetting the produced raster data might reduce the time required for further analysis. The Extract by Mask module in ArcGIS was used to subset the Sentinel-2 optical image.

Classification

According to the remote sensing literature, a variety of supervised methods have been created to tackle the problem of classifying multispectral data (Richards *et al.,* 2022). In supervised classification, training sites—representative sample sites of a certain cover type—are selected, and each class is associated with distinct pixel values or spectral signatures. Forty percent of the ground truth points collected were used to create training sites.

These variables can be used to determine the statistical probability that a particular pixel belongs to a particular class. MLC was used to classify the composited FCC of the Sentinel-2 image in order to detect the *kharif* paddy crop. About six different types of signatures were gathered from the ground truth spots, which included paddy, waterbodies, settlements, barren lands, other crops, and miscellaneous. The training sites designed to define the *kharif* paddy crop following supervised classification were used to analyse the Sentinel-2A data.

Masking

The non-agricultural areas were concealed and the agricultural areas were eliminated from the Tamil Nadu Land Use Land Cover map, which was available at a scale of 1:50,000 from 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.

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

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

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

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

The maximum likelihood classifier in ArcGIS software used the training sites created from the Sentinel-2A satellite data using the ground truth points as an input to create the paddy region. Until a significant level of accuracy was achieved, training site improvements, rerun classification, and accuracy evaluation were carried out repeatedly. Sentinel-2A optical data is used to estimate the acreage of *kharif* paddy in the study districts. The statistical correctness of the analysis's conclusions was assessed after district and block-level maps and data about the rice region were eliminated.

The methodology is shown in Fig. 1 and includes preprocessing of Sentinel-2 data, band composting using False Color Composites, mosaicking the research region, and selecting the training locations using the collected Ground Truth data. The rice vegetable was then chosen using maximum likelihood classification out of all the other classes. After that, accuracy was assessed using the error matrix and kappa index.

Results and Discussion

Nagapattinam district registered a total *kharif* paddy area of 41170.07 ha. Block wise area statistics in the 10 blocks viz., Keelaiyur, Kilvelur, Kollidam, Kuthalam, Mayiladuthurai, Nagappattinam, Sembanarkoil, Sirkali, Talanayar, Thirumarugal and Vedharanyam was performed to understand the distribution of paddy area in the district. The area statistics and per cent area coverage is presented in Table 2. The spatial distribution of *kharif* paddy area is presented in Fig.2.

Among the 11 blocks in Nagapattinam district, the highest area was recorded in the Mayiladuthurai block with 6089.49 ha and the lowest was recorded in the Talanayar block with 1613.70 ha. Kuthalam, Kollidam, Sembanarkoil, and Kilvelur blocks remained in the top five with the highest paddy area covering 5287.84, 5287.68, 4804.20 and 4033.90 ha respectively. Following these blocks, Sirkali, Vedharanyam, Keelaiyur, Thirumarugal blocks accounted for 3672.02, 3144.99, 2607.24 and 448.83 ha. Nagapattinam block had a 4.89 per cent paddy area with an 1876.83 ha area.

Table.1 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)

Table.2 Block wise paddy area in Nagapattinam district – Optical data

S. No.	Block Name	Area in ha	Per cent distribution of area
1.	Mayiladuthurai	6089.49	14.80
2.	Kuthalam	5287.84	12.85
3.	Kollidam	5287.68	12.85
4.	Sembanarkoil	4804.20	11.67
5.	Kilvelur	4033.90	9.80
6.	Sirkali	3672.02	8.92
7.	Vedharanyam	3144.99	7.64
8.	Keelaiyur	2607.24	6.33
9.	Thirumarugal	2448.83	5.95
10.	Nagappattinam	1876.83	4.89
11.	Talanayar	1613.70	4.20

Table.3 Confusion matrix for accuracy assessment Paddy estimate

Actual class from the survey	**Predicted class from the map**			
	Class	**Paddy**	**Non-Paddy**	**Accuracy (%)**
	Paddy	67	6	91.7 %
	Non-Paddy	3	33	91.6 %
	Reliability	95.7 %	84.6%	**91.7 %**
Average accuracy		91.6%		
Average reliability		90.1%		
Overall accuracy		**91.7%**	**Good Accuracy**	

Figure.1 Methodology for Estimation of Rice area in Thiruvarur district using Sentinel 2 satellite data

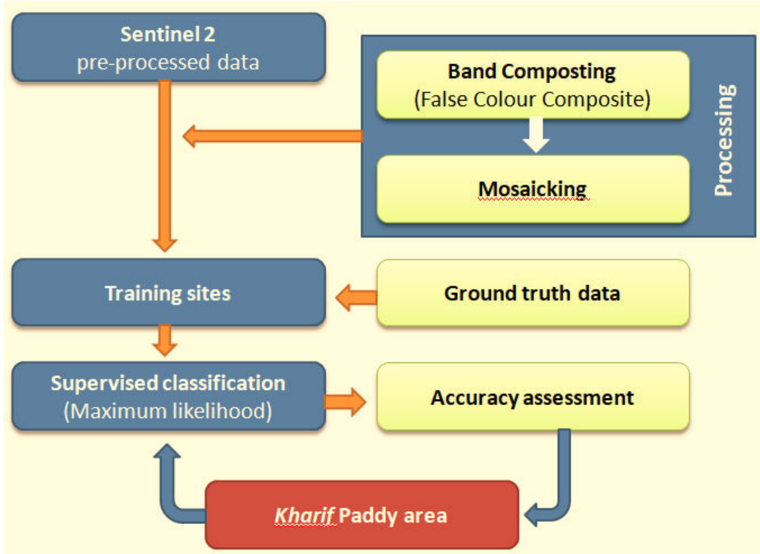
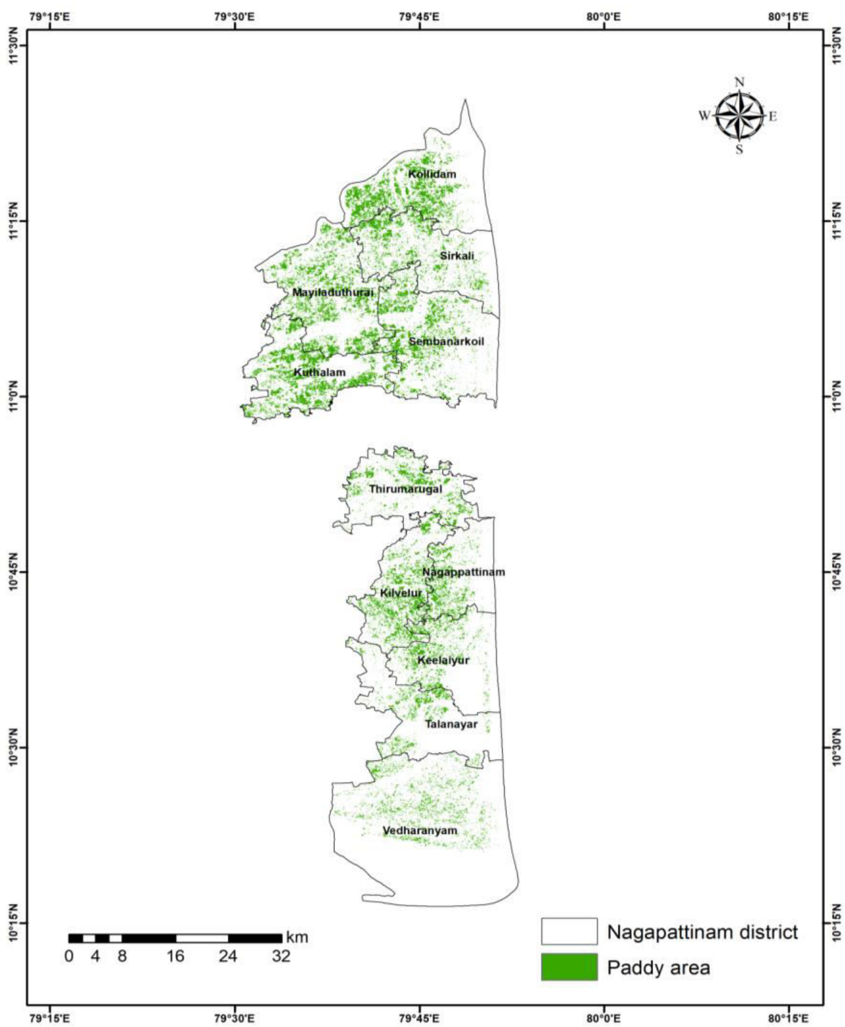


Figure.2 Spatial distribution of *kharif* paddy area in Nagapattinam district from Sentinel-2A



The confusion matrix for accuracy assessment of the paddy area estimated by the optical remote sensing data was done using a total of 73 paddy points and 36 non-paddy ground truth points. The results showed that out of 73 paddy points, 67 were classified in paddy and 6 got misclassified as Non paddy showing accuracy of 91.7%.

The non paddy points showed 91.6% accuracy with 3 non-paddy points misclassified as paddy. The overall accuracy was found to be 91.7% which is showing Good Accuracy as shown in Table 3.

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 Nagapattinam 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 41170.07 ha, with notable variations in distribution across the 11 blocks. The classification accuracy, assessed through confusion matrix achieved a commendable overall accuracy of 91.7%, 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.

Author Contribution

Sugavaneshwaran Kannan: Investigation, formal analysis, writing—original draft. Ragunath Kaliaperumal: Validation, methodology, writing—reviewing. S. Pazhanivelan:—Formal analysis, writing—review and editing. R. Kumaraperumal: Investigation, writing—reviewing. K. Sivakumar: Resources, investigation writing—reviewing.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

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