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Research Article

Rice area mapping in Palakkad district of Kerala using Sentinel-2 data and Geographic information system technique

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Abstract

Proper calculation of rice cultivation area well before harvest is critical for projecting rice yields and developing policies to assure food security. This research looks at how Remote Sensing (RS) and Geographic Information System (GIS) can be used to map rice fields in Palakkad district of Kerala. The area was delineated using three multi-temporal cloud free Sentinel-2 data with 10 m spatial resolution, matching to crop's reproductive stage during *mundakan* season (September-October to December-January), 2020-21. To make classification easier, the administrative boundary of district was placed over the mosaicked image. The rice acreage estimation and land use classification of the major rice tract of Palakkad district comprising five blocks was done using Iterative Self-Organisation Data Analysis Technique (ISODATA) unsupervised classification provision in ArcGIS 10.1 software, employing False Colour Composite (FCC) including Blue (B2), Green (B3), Red (B4) and Near-infrared (B8) Bands of Sentinel-2 images. The classification accuracy was determined by locating a total of 60 validation points throughout the district, comprising 30 rice and 30 non-rice points. The total estimated area was 24742.76 ha, with an average accuracy of 88.33% and kappa coefficient 0.766 in five blocks of Palakkad district. The information generated will be helpful in assessing the anticipated production as well as the water demand of the rice fields.

Keywords: Area mapping, Remote sensing, Rice, Sentinel-2 images, Unsupervised classification

INTRODUCTION

Rice (*Oryza sativa* L.) is the primary source of sustenance for greater than 50% of global population. According to United States Department of Agriculture (USDA), the production and consumption of rice is mainly concentrated in Asia, with China being the largest producer accounting for 30% of world production, followed by India with 24% of production. The current production may not be sufficient to ensure food security as per the population growth forecasts. This problem is aggravated by the reduction in area under rice cultivation due to several reasons like urbanization, the introduction of cash crops, reduced labour availability and less profitability *etc.* Kerala's rice acreage has decreased from 8.7 lakh hectares in 1970-71 to 1.98 lakh hectares in 2019-20 and the state is facing food insecurity with 90 percent deficit in production (Abraham, 2019). The accurate estimation of the area under cultivation will give a clear picture of agricultural production in the state and could be effectively used to develop policies to deal with the contingencies in food grain availability.

Rice acreage estimation was customarily done using laborious, expensive and time-consuming surveying approaches. Currently, the availability of very high-resolution (VHR) satellite data and advances in deep learning-based image analysis have demonstrated the possibility for automated rice area demarcation and estimation (Mosleh *et al*., 2015). Remote sensing-based methods could be effectively used for delineating rice area and forecasting rice production, with spatial coverage over a large geographic area with less expenses except in monsoon when the presence of clouds are high (Mostafa, 2015). Several researchers have attempted rice acreage estimation over extensive areas using satellite data. The rice area was mapped in Bangladesh using Moderate Resolution Imaging Spectroradiometer (MODIS) Normalized Difference Vegetative Index (NDVI) with 16 days temporal resolution and 250 m spatial resolution product and the results were in good agreement with ground-based estimates at both country level and district level (Persello *et al*., 2019). Ajith *et al.* (2017) estimated area under rice during the Samba season in Thanjavur district, Tamil Nadu using Landsat 8 Operational Land Imager (OLI) data and the total area estimated was 1,09,799 ha during 2015-16 period. The potential of combined use of Sentinel-1/2 data for rice area mapping in China was studied by Xiao *et al.* (2021) and showed promising results.

The Palakkad district of Kerala is considered the ‘rice bowl’ of the state, with the major rice growing tract spread over five blocks *viz,* Alathur, Nenmara, Kollengode, Chittur and Kuzhalmannam. Each block has more than 10,000 hectares of land under rice cultivation during the three crop seasons in a year. The rice area delineation using remote sensing in first crop season i.e. *viruppu* (April-May to September-October) is difficult due to severe interferences of monsoon clouds, so this method was employed in the second crop season ie; *mundakan* (September-October to December-January) to find the suitability. Sentinel-2 data is open source and available at a very high spatial resolution of 10 m. This study focused on exploring the potential of this data in the rice area delineation of the major rice tract of Palakkad district during *mundakan* season 2020-21.

MATERIALS AND METHODS

The Palakkad district in the state of Kerala, which extends over an area of 4,48,200 ha is located at 10° 95’ North latitude and76° 54’ East longitude, with Malappuram district and Thrissur district of Kerala bordering the northwest and the southwest, respectively. Nilgiris district and Coimbatore district of Tamil Nadu are in the

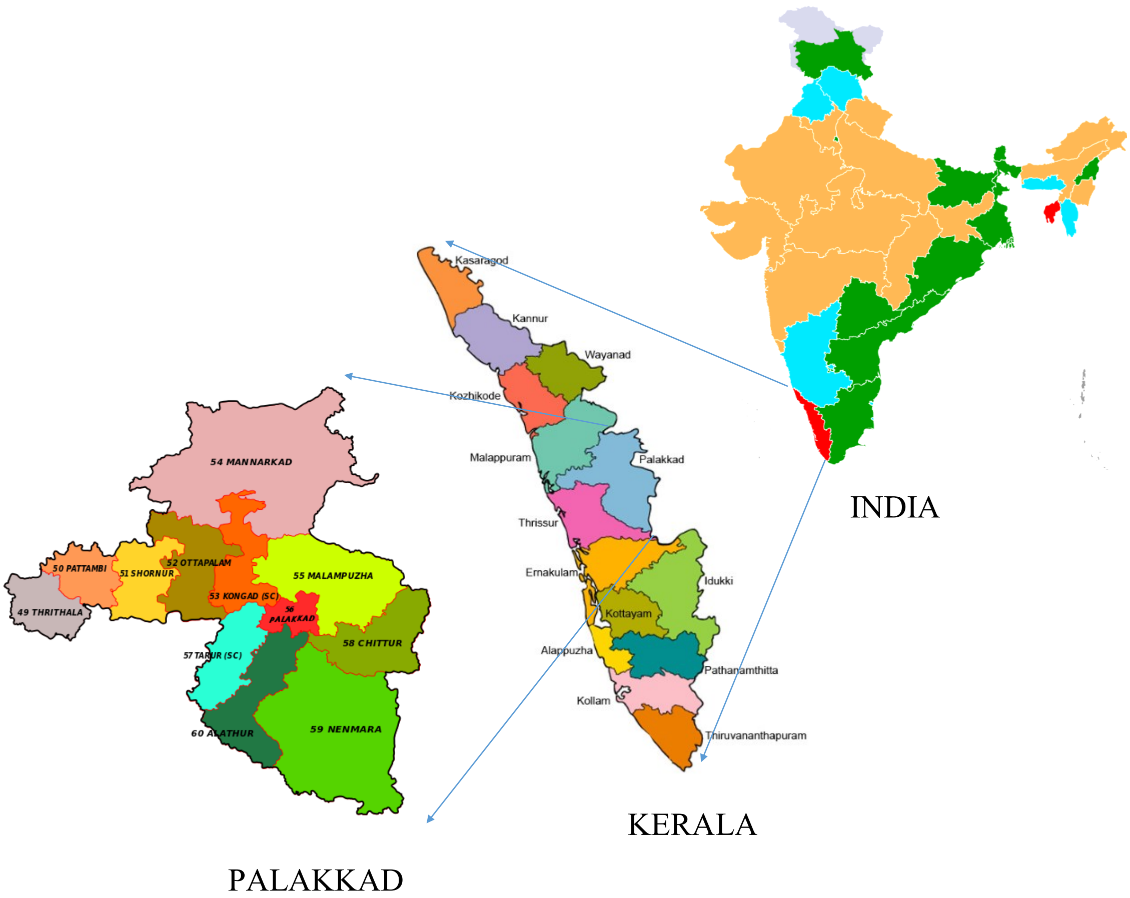

Fig. 1. *Palakkad district location map*

northeast and east (Fig. 1). Palakkad district was chosen in the study because it accounts for a major share of paddy production in the state with *viruppu* (April-May to September-October) and *mundakan* (September-October to December-January) as the prominent rice growing seasons. This study was conducted during 2020-2021 for medium duration rice variety 'Uma' released from Kerala Agricultural University, which is widely grown during this season.

Satellite data

The study employed Sentinel-2 data with a resolution of 10 m and three cloud-free scenes from the website https://earthexplorer.usgs.gov were accessed as the study region required three scenes for complete coverage (Table 1). The administrative boundary was superimposed over the composite image so as to extract pixels relating to the concerned area.

Composite image preparation from Sentinel-2 images

Sentinel-2 data of four spectral bands (Blue (B2), Green (B3), Red (B4) and Near-Infrared (B8) were layer stacked to highlight vegetation features (Table 2). Natural colour combination obtained using colour composite of B2, B3 and B4, representing the objects in the same way as we see the world with our eyes. The near-infrared (NIR) band (B8) is highly reflected by chlorophyll pigment in leaves. The combination of colour and infrared helps to distinguish between healthy and unhealthy vegetation. A new colour composite was created using B3, B4, and B8 for False Colour Composite (FCC). So as to obtain complete coverage of the study area, three nearby composite images were mosaicked into a single raster dataset. Mosaicking is a technique for combining two or more raster datasets into a single, unified raster dataset. The pixels corresponding to the study area were clipped using the provisions present in the ArcGIS 10.1 software. The mosaicked and clipped image showing the study area in Palakkad district is shown in Fig. 2.

ISODATA classification and rice area delineation

Unsupervised classification, Iterative Self-Organisation Data Analysis Technique (ISODATA) algorithm, is a technique for recognizing, assembling and classifying attributes present in a satellite image based on their value of spectrum. This technique of classification is based on grouping of pixels in accordance with homogeneity as well as spectral distance. Rice area was drawn out by identifying and removing classes such as water bodies, forests, other vegetation, agricultural crops and settlements from the mosaicked composite image.

Validation of rice area estimation

The land cover information generated by classification analysis representing rice was validated using information from ground truth locations representing rice and non-rice area (reference data) to assess the correctness of classification. A total of 60 ground truth points, including 30 rice and 30 non-rice plots, were selected from 29 panchayats through a random sampling technique in order to represent the whole area. During the *mundakan* rice season (2020-21), ground truth data was acquired with the aid of a hand held Global Positioning System (GPS) and camera. Accuracy is assessed using error matrix, which is a table of classified data versus reference data, is also named as the confusion, contingency or validation matrix in the literature (Stephen, 1997). The cross tabulation of this error matrix enables the calculation of a number of standard reporting, including overall accuracy, as well as the accuracy of users and producers. These accuracy statistics indicate the degree to which the classified data is correct and how reliable it is. The validation in this study was done to estimate the accuracy of rice area estimation.

Confusion matrix

A confusion matrix provides inferences about actual and derived classifications in a classification system. The information in the matrix is widely used to evaluate the efficiency of such systems. While evaluating the thematic accuracy of a land-cover map, an error matrix is widely used to organise and present data (Stephen, 1997). The confusion matrix used for rice area classification validation is presented in Table 3. In the context of our investigation, the meaning of the entries in the confusion matrix are as follows.

a is True positive, *i.e.,* rice area was predicted and it turned out to be rice area

b is False negative, *i.e.,* rice area was anticipated, but it turned out to be a non-rice area

c is False positive, *i.e.,* non-rice area was anticipated, but it turned out to be a rice area

d is True negative, *i.e.,* non-rice area was predicted and it turned out to be a non-rice area

The average accuracy and percentage of accuracy for the classification of rice and non-rice areas were computed using the confusion matrix. The computation formula is depicted below.

Percentage accuracy of classification of rice area (R) =

$$\frac{a}{(a+b)} X\ 100 \qquad \text{Eq.1}$$

Percentage accuracy of classification of non-rice area

$$(NR) = \frac{d}{(c+d)} X\ 100 \qquad \text{Eq. 2}$$

$$\text{Average accuracy} = \frac{R+NR}{2}$$

Kappa coefficient

The Cohen's kappa coefficient, often known as the kappa coefficient, is a statistical method for determining compliance of agreement for qualitative items. It is typically considered as a more reliable statistic methodology than the calculation of percent agreement estimates since it represents the probability of the agreement occurring by probability (Cohen, 1960). The steps for calculating the Kappa coefficient are represented below.

Observed agreement (OA) = $\frac{a+d}{a+b+c+d}$ Eq. 3

Agreement of chance (AC) =

$$\frac{a+c}{a+b+c+d} X \frac{a+b}{a+b+c+d} + \frac{b+d}{a+b+c+d} X \frac{c+d}{a+b+c+d}$$ Eq. 4

Kappa coefficient = $\frac{(OA-AC)}{(1-AC)}$

Kappa coefficient is never greater than or equal to one. A value of one indicates perfect conformity, while values less than one indicate less than perfect agreement. Table 4 represents one possible interpretation of the Kappa coefficient.

RESULTS AND DISCUSSION

Three multi temporal cloud free Sentinel-2 data were used for land use classification and maps were generated representing the land use pattern in five blocks of Palakkad district based on six classes as represented in Fig. 3. Rice area maps were generated for five blocks of Palakkad district and are given in Fig. 4. The total rice area assessed for the five blocks was 24742.76 ha, slightly less than the actual area reported during the *mundakan* season during 2018-19 period *i.e.* 26952.2 ha as per Agricultural Statistics Report (2018-19). The area under other classes was estimated as follows; water bodies (5513.65 ha), forest (24806.33 ha), other vegetation (48390.49 ha), urban area or build -up structures (27506.51 ha) and agricultural land where crops other than rice are grown (48208.16 ha). The rice area was estimated to be 13.8% of the study area and was validated by grouping the entire study area into rice and non-rice areas. In order to improve accuracy, all the remaining classes without rice cultivation was considered as one group representing non rice area. The 60 validation points throughout the study area spread across five blocks of the district, with 30 rice and 30 non-rice points are represented in Fig. 4 . Confusion matrix and kappa coefficient were generated to compare predicted and actual land coverage based on information obtained from rice and non-rice areas to measure the correctness. Table 5 shows an overview of the accuracy of classification. An average accuracy of 88.33% and kappa coefficient 0.766 was observed in five blocks of Palakkad district. Small and extended rice fields were classified equally well through this technique. Similar results were observed when Ajith *et al.* (2017) mapped rice area in Thanjavur district of Tamil Nadu using Landsat 8 OLI images with an accuracy of 87% and kappa coefficient 0.74. In another study, Chen *et al.* (2019) estimated the area under rice cultivation in Taiwan with an average accuracy of 85% and 0.72 kappa coefficient using Sentinel-2 data. The area delineation using satellite data was useful for efficient irrigation water management and yield prediction in fields. The delineation of areas suitable for rice cultivation in Punjab region of Pakistan was done by Raza *et al*. (2018) using Landsat 8 data and GIS techniques and identified that out of the total area currently under rice cultivation, 6.8% area was least suitable and 24.85% area was not suitable for cultivation and this in turn lead to decreased rice productivity in that region. Similarly, Sethi *et al*. (2014) estimated the rice area in the state of Haryana using Landsat ETM+ satellite data employing ISODATA unsupervised classification. It believes that crop coverage variability and mapping cropped area provide information on agricultural water demand at regional scales and yield estimation. The variations in surface and groundwater resources in a region during different seasons may vary and this variation could be traced out by delineating area under irrigated agriculture during each season and a study was conducted in South India to detect the area under irrigated agriculture based on Sentinel-1 and 2 images. The study gave promising results, teffectively used to estimate ground water use in kharif and rabi seasons during 2016-17 (Ferrant *et al*., 2017). The high special resolution of 10 m of Sentinel-2 satellite imageries used in the study gives a definite edge over the LANDSAT 8 OLI images available at present.

The *virippu* crop season commences with the southwest monsoon, while *mundakan* season coincides with northeast monsoon period. As southwest monsoon season is more prominent in Kerala, cloud interference in satellite images corresponding to the viruppu season will be more than in the *mundakan* season. Even during the early stages of the mundakan season, the availability of images free of clouds is less due to the prevalence of northeast monsoon. Hence, cloud free images corresponding the reproductive stage of rice crop was used in this study for rice area delineation. Further, the fine resolution of Sentinel-2 images helped to clearly distinguish different land forms and accurately map the rice area using iso-cluster unsupervised classification technique.

Based on the fact that each crop has a distinct spectral signature allowing crop recognition and classification, the capability of optical remote sensing data was explored in the study for delineating various land cover features. The typical spectral reflectance of a crop de-

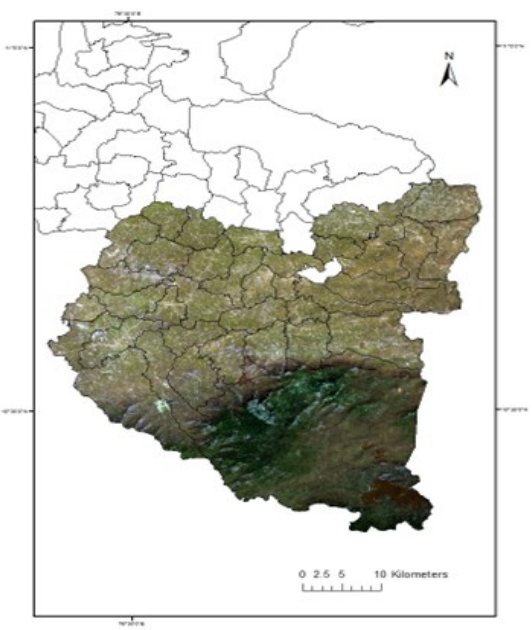

Fig. 2. *Mosaicked composite image of the study area*

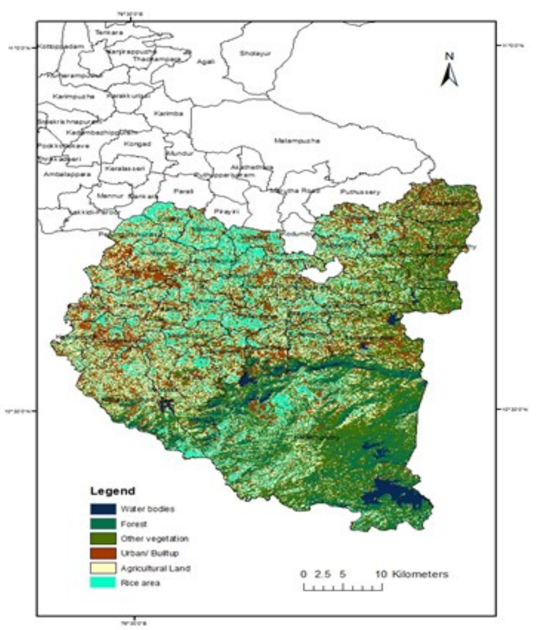

Fig. 3. *Land use classification of study area*

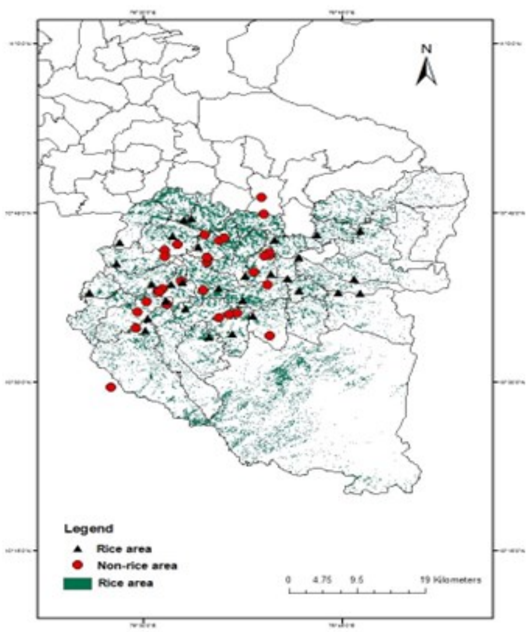

Fig. 4. *Rice area map validation points across the study area in Palakkad district*

pends upon the absorption of visible light (0.62- 0.68 m) due to the presence of various pigments. Because of the interior structure of cells in the leaves, the near-infrared region (0.7 to 1 m) is highly reflected and the crop vigour could be assessed based on the ratio of absorption in the red region to reflection in the near-infrared region (Dadhwal and Ray, 2000). Hence, using Sentinel images, area delineation of different crops like maize (Munghemezulu *et al*., 2021) and mung bean (Kamal *et al*., 2020).

The Synthetic Aperture Radar (SAR) based images are not affected by cloud interferences, so researchers are experimenting with rice area mapping using these images (Xiao *et al*., 2021). But this method is laborious and requires more sophisticated software. Though disturbances due to cloud interference were faced during the study period, it was overcome by the high resolution of images obtained in the clear sky. This methodology requires only a few satellite images during clear sky coinciding with the crop growth period. So, this methodology can be successfully utilized to assess paddy areas during *virippu* season during monsoon breaks. This helps to save time spent on data acquisition, analysis and interpretation. Using this technique, the estimated area is only 11.67 per cent less with respect to previous years in the various blocks under study. However, conducting such a study with ground truthing data would be less time-consuming and cost-effective. The procedure for analysing remote sensing images to identify the rice area followed in this work can be used in other places. As the classification clearly distinguishes between areas with high and low levels of rice coverage, the rice area map developed may be useful to the planners and extension personals to assess the availability of food grains well in advance and to get an idea about the irrigation water demand during the season over an extended area with high accuracy. The technique may be used in other places for precise calculation of rice crop area one or two months before harvest, and it is critical for food security.

Table 1. Sentinel-2 data acquisition schedule

Sentinel-2 data acquisition			
Date	**Platform**	**Orbit No.**	**Product**
26/01/2021	SENTINEL-2A	62	LIC_T43PFN_A029231_20210126T052106
28/01/2021	SENTINEL-2B	19	LIC_T43PFN_A020351_20210128T051756
28/01/2021	SENTINEL-2B	19	LIC_T43PFM_A020351_20210128T051756

Table 2. Band designation for Sentinel-2

Bands	Wavelength (nanometres)	Resolution (meters)
Band 2 - Blue	490 nm	10 m
Band 3 - Green	560 nm	10 m
Band 4 - Red	665 nm	10 m
Band 8 – Near Infrared	842 nm	10 m

Table 3. Confusion matrix for validation of rice area

	Predicted class from the map			
	Class	**Rice**	**Non-rice**	**Accuracy**
Actual class from survey	Rice	a	b	%
	Non-rice	c	d	%
	Average accuracy			%

Table 4. Interpretation of Kappa coefficient

Interpretation levels	Kappa coefficient
Poor agreement	< 0.20
Fair agreement	0.20 to 0.40
Moderate agreement	0.40 to 0.60
Good agreement	0.60 to 0.80
Very good agreement	0.80 to 1.00

Conclusion

Remote sensing technology relies on the spectral signatures of the vegetation and other land covers in an area. Proceeding with the analysis of remote sensing products, the major rice growing areas in Palakakd district were delineated using multi temporal cloud-free Sentinel-2 data with spatial resolution 10 m following ISODATA unsupervised classification. Three Sentinel-2 datasets were used in this study for area delineation with an average classification accuracy of 88.33% when compared to facts generated by ground truthing. The methodology followed in the study is especially good for delineating rice areas in rice during *mundakan* season (September-October to December-January) due to the high accuracy of predictions with less cost. Further cloud-free optical satellite images are readily available during the season with high resolution. The technique can be replicated in extended rice fields for the accurate estimation of area under rice cultivation one or two months prior to harvest and it plays a vital role in ensuring food security.

Conflict of interest

The authors declare that they have no conflict of interest.

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Table 5. Confusion matrix for accuracy assessment of rice classification

	Predicted class from the map			
	Class	**Rice**	**Non-rice**	**Accuracy**
Actual class from survey	Rice	24	6	80 %
	Non-rice	1	29	96.66 %
	Reliability	96 %	82.85 %	
	Average accuracy	88.33 %		
	Average reliability	89.4 %		
	Kappa coefficient	0.77		

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