PLANT SCIENCE TODAY
Vol 12(2): 1-6
https://doi.org/10.14719/pst.8760

eISSN 2348-1900

RESEARCH ARTICLE

Mapping of mango cropping area using machine learning techniques in Tamil Nadu

Chinnu Raju[1], Sellaperumal Pazhanivelan[2*], N K Sathyamoorthy[1], Irene Vethamoni Perianadar[3], Kaliaperumal Ragunath[2], Sendhilvel Vaithiyanathan[1] & M Harish[4]

[1]Agro Climate Research Centre, Tamil Nadu Agricultural University, Coimbatore 641 003, Tamil Nadu, India
[2]Centre for Water and Geospatial Studies, Tamil Nadu Agricultural University, Coimbatore 641 003, Tamil Nadu, India
[3]Horticultural College & Research Institute, Tamil Nadu Agricultural University, Coimbatore 641 003, Tamil Nadu, India
[4]Department of Remote Sensing and GIS, Tamil Nadu Agricultural University, Coimbatore 641 003, Tamil Nadu, India

*Correspondence email - pazhanivelans@tnau.ac.in

Received: 08 April 2025; Accepted: 09 May 2025; Available online: Version 1.0: 24 May 2025; Version 2.0 : 09 June 2025

Cite this article: Chinnu R, Sellaperumal P, Sathyamoorthy NK, Irene VP, Kaliaperumal R, Sendhilvel V, Harish M. Mapping of mango cropping area using machine learning techniques in Tamil Nadu. Plant Science Today. 2025; 12(2): 1-6. https://doi.org/10.14719/pst.8760

Abstract

Mango area mapping is crucial for forecasting production prior to harvest and developing policies that ensure food and nutritional security. This study focuses on the integration of remote sensing and machine learning algorithms for real time prediction of mango cropped area in Krishnagiri and Dharmapuri districts of Tamil Nadu state in India. The cloud free images of Sentinel 2 were acquired corresponding to the fruit setting stage of the crop during the main crop season (January to June 2024) and pre-processed in ArcGIS 10.8 software. Supervised classification was carried out using eCognition Developer 10.3 software by combining object-based image analysis (OBIA) and Random Forest algorithm. Based on the analysis, the area under mango cultivation in Krishnagiri district was 3182422 hectares, showing a 1.5 % deviation from the Department of Economics and Statistics data. The overall classification accuracy was 0.85, with a kappa index of 0.70. In Dharmapuri district, the mango area was slightly overestimated (14950.24 ha) compared to the government data (14589 ha), with a percent deviation of -2.5 %. The overall classification accuracy was 0.88, with a kappa index was 0.76. Accurate mango area mapping supports precision agriculture, efficient resource management and yield optimization, thereby aiding farmers, scholars and policymakers in informed decision-making.

Keywords: area mapping; machine learning; mango; object-based image analysis; random forest

Introduction

Mango is considered one of the most prominent fruit crops cultivated globally, particularly in India, which is the top producer (50 % of world production) and consumer of mangoes, thus significantly influencing the nation's economy and the livelihoods of farmers. The total area under mango cultivation in India is 2.396 million hectares, with an overall production of 22.398 million metric tons and productivity of 9.35 tons/hectare (1). In Tamil Nadu, mango is cultivated over 1.45 million hectares with a total production of 9.49 million metric tons and a productivity of 6.5 tons/ha. The districts of Krishnagiri and Dharmapuri in Tamil Nadu is renowned for its vast mango plantations, occupying 32 % of the total mango area in the state. These districts fall in the northwestern zone of Tamil Nadu, with well-drained soils and moderate rainfall. This area is perfect for establishment of mango orchards. The popular varieties of this region are Alphonso, Bangalora, Senthura, Banganapilli, Malgoa, Neelam and Imam Pasand.

Accurate mapping of mango growing regions is essential for yield forecasting, which primarily depends on two factors; cultivated area and yield per unit area (2). The conventional methods used for area estimation like field surveys, census and other manual techniques are laborious and time consuming (3, 4). The use of Geographic Information System (GIS) for area estimation started in 1980s. The primary function of early GISs was to digitally preserve final area sampling frames. But as technology advanced, GIS software and associated image processing applications started using high resolution satellite images for generating land use land cover maps and crop area maps. With the advent of machine learning (ML) and Neural Networks (NN), crop area mapping has become more accurate and efficient.

Mapping of mango orchards was done by researchers on an extensive scale using different satellite images. The mango area was estimated with an accuracy of 70.66 % to 86.69 % in the Lucknow region of India using Landsat 8 OLI (30 m spatial resolution and 16 days temporal resolution) (5). High resolution satellite imagery like Gaofen-1 (6), IRS-Resources at 2 - LISS IV (7, 8), WorldView-3 (9), Sentinel 2 (10), were used in different parts of the world for mango area mapping. The Sentinel 2 images were used for cashew area mapping in Ariyalur district of Tamil Nadu and obtained an accuracy of 85 % and 0.7 kappa index (11). This indicates that Sentinel-2 imagery can be effectively used for horticultural crop area mapping in Tamil Nadu.

Area mapping typically involves either supervised or unsupervised classification. The supervised classification is found to be superior; it can be either pixel based or object-based image classification. While identifying horticultural crops, particularly orchards, pixel-based classification sometimes falls short of capturing the spectral variability in high-resolution photos. In pixel-based classification, individual pixels are often categorised based on the presumption that each class exhibits consistent spectral behaviour; however, contextual information like as texture, shape, etc. are not included. The Object Based Image Analysis (OBIA) overcomes these issues by combining similar neighbouring pixels into meaningful geographical objects while maintaining pixel topology. The spectral and spatial characteristics of the pixel are also considered while producing such objects (12, 13). The object-based classifiers improve the overall classification accuracy by 2-7 % as compared to pixel-based classifiers (6, 7). The classification accuracy could be further enhanced by combining object-based classifiers with ML algorithms like Random Forest (RF), Support Vector Machines (SVM) and Convolutional Neural Networks (CNNs). The literature shows that the use of Sentinel-2 data produces high accuracies (>80 %) with machine-learning classifiers such as RF and SVM (14). RF show higher classification accuracy when the input variables are more than 20, while SVM performs better under less number of input variables (6). This research focuses on exploring the combined application of OBIA and ML for mapping mango-growing areas in Krishnagiri and Dharmapuri districts of Tamil Nadu using Sentinel-2 images during the 2024 crop season.

Materials and Methods

Study area

The Krishnagiri district is located at 11º 12'N to 12º 49'N latitude, 77º 27'E to 78º 38'E longitude and at an elevation of 632 m above the Mean Sea Level (MSL). The district is bounded by Vellore and Thiruvannamalai to the east, Karnataka state to the west, the state of Andhra Pradesh to the north and Dharmapuri district to the south (Fig. 1). The Dharmapuri district is between 11° 47' N to 12° 33' N latitude and 77° 02' to 78° 40' E longitude with an average elevation of 468 m (above MSL). This district bordered by Tiruvannamalai and Villupuram to the east, the Kaveri River to west, Krishnagiri district to north and Salem district to south.

Satellite data

The Sentinel 2 mission of European Union consists of twin satellites (Sentinel 2A and Sentinel 2B) has 13 spectral bands, each with a different spatial resolution. In this study, three spectral bands (B2- Blue (492.1-496.6 nm), B3- Green (559-560 nm), B4- Red (664.5-665 nm)) with high spatial resolution of 10 m and temporal resolution of 5 days were used. The cloud free satellite images were acquired in March 2024 corresponding to the fruit setting stage of the mango in the study area. The study area was covered by four scenes; hence the scenes were mosaicked together and the area of interest was clipped using extract by mask option in ArcGIS 10.8 software. The three bands were composited together to produce a single image which was used for further analysis. The methodology followed for mango area mapping is given in Fig. 2.

Ground truth data

The ground truth points collected in Krishnagiri district include 148 mango points and 99 non-mango points, while in Dharmapuri district 136 mango and 114 non-mango points were considered for the study. The geographical coordinates of the location were collected using GPS during the main crop season (January to June 2024), along with other details like the age of the tree, management practices, current and previous year weather condition, pest and disease incidence, crop health status and yield data were also collected from each ground truth points.

Supervised classification and mango area mapping

The eCognition 10.3 software was used for supervised classification. Based on the spatial and spectral properties of the pixels the meaningful objects were created through the process of 'multiresolution segmentation' by considering scale, shape-colour and compactness-smoothness

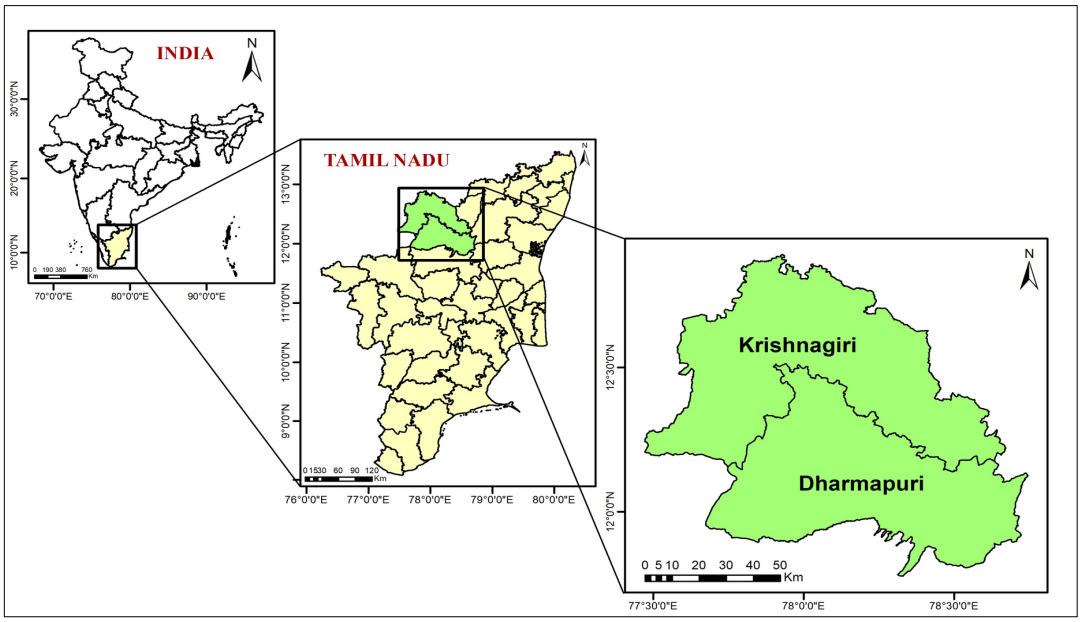

Fig. 1. Location map of the study area.

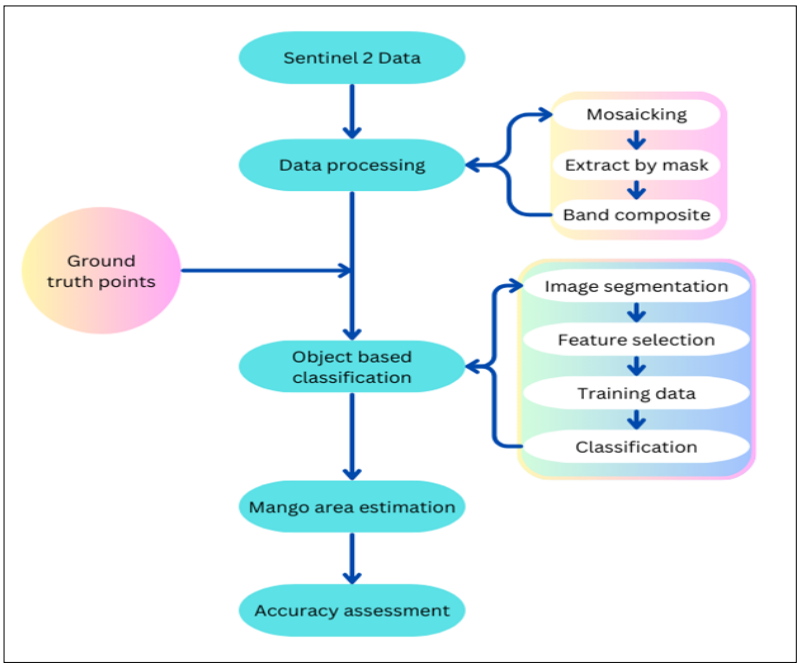

Fig. 2. Flow chart depicting the methodology for mango area mapping.

parameters. After segmentation classes were assigned and samples were selected for each class. Initially, 60 % of the ground truth points were used to train the software for Object Based Image classification using Random-Forest algorithm. Remaining 40 % of the sample was used for validation. The ArcGIS 10.8 software was used for the development of mango area map and calculation of block wise and overall district mango area (in ha) from the classified image.

Accuracy assessment

The accuracy of classification is represented using a confusion matrix. The 40 % of the ground truth data is used for validation. The confusion matrix provides user's accuracy, producer's accuracy overall accuracy and Kappa coefficient. The producer accuracy refers to how well an area is being classified. But user accuracy refers to the probability of area identified as a particular class belongs to that class itself (15). Overall accuracy represents the proportion of all correctly classified samples. Kappa coefficient is a statistical tool for estimation the percent agreement of estimates. The maximum value of kappa coefficient is one, values in the range of 0.8-1 shows very good agreement, 0.6-0.8 good agreement, 0.6 -0.4 moderate agreement, <0.4 poor agreement (16).

Results and Discussion

The mango area maps generated for Krishnagiri and Dharmapuri districts are presented in Fig. 3 and Fig. 4, respectively. Table 1 gives a summary of the area estimated and the percent deviation from Department of Economics and Statistics data provided by Government of Tamil Nadu for the year 2024. The estimated mango area for Krishnagiri district was 31824.22 ha, while as per the government data, area under mango cultivation in the district was 32302 ha. Hence, the mango area was slightly underestimated with a percent deviation of 1.5 % from government data. Similarly, the mango area in Dharmapuri district was slightly overestimated, with a deviation of 2.5 % above the government data. The estimated area was 14950.24 ha while the mango area according to government sources was 14589 ha. The cause of deviation can be traced back to the spectral similarity between mango trees and other tree crops, such as those found in forests, that can lead to misclassification during mango area mapping.

The primary mango-growing regions in each district are identified by the calculation of block wise mango area for each district. In Krishnagiri district, Bargur (6156.17 ha), Kaveripattinam (5314.33 ha) and Krishnagiri (4850.2 ha) blocks have highest area whereas Hosur (404.19 ha), Thally (1203.02 ha) and Veppanapalli (1531.56 ha) have lowest area under mango cultivation (Table 2). There are fewer mango orchards in the Hosur and Veppanapilli blocks because these areas are well-known for producing flowers and vegetables (8). In Dharmapuri district, Karimangalam (3492.12 ha) and Palacode (2377.34 ha) blocks are having highest area while Nallampalli (793.57 ha) and Dharmapuri (823.53 ha) are having the least area under mango (Table 3).

The accuracy of mapping mango area in Krishnagiri district is given in Table 4. For mango points producer accuracy is 0.87 which indicates that 87 % of mango area was correctly identified as mango. The user accuracy of the classification is 0.82 i.e., 82 % of the area identified as mango depicts actual mango areas. The overall accuracy of the classification is 85 % and the Kappa coefficient is 0.7 which shows good agreement. The confusion matrix for accuracy assessment in Dharmapuri district is presented in Table 5. The producer accuracy of mango is 0.98 and user accuracy is 0.78. The overall accuracy of classification is 0.88 and Kappa

Table 1. Percent deviation of estimated area with DES data in 2024

Region	Overall accuracy (%)	Spatial area under mango orchard (ha)	Mango orchard area as per DES (ha)	Percent deviation (%)
Krishnagiri	85	31824.22	32302	1.5
Dharmapuri	88	14950.24	14589	-2.5

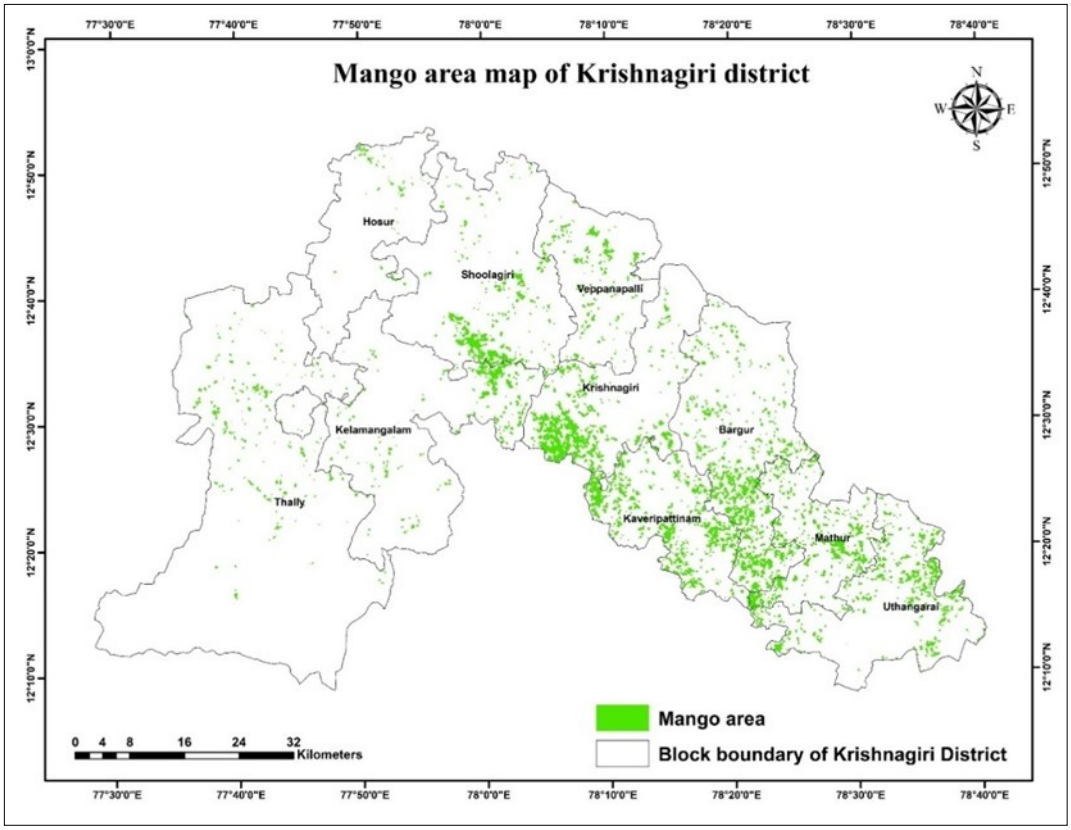

Fig. 3. Mango area map of Krishnagiri district.

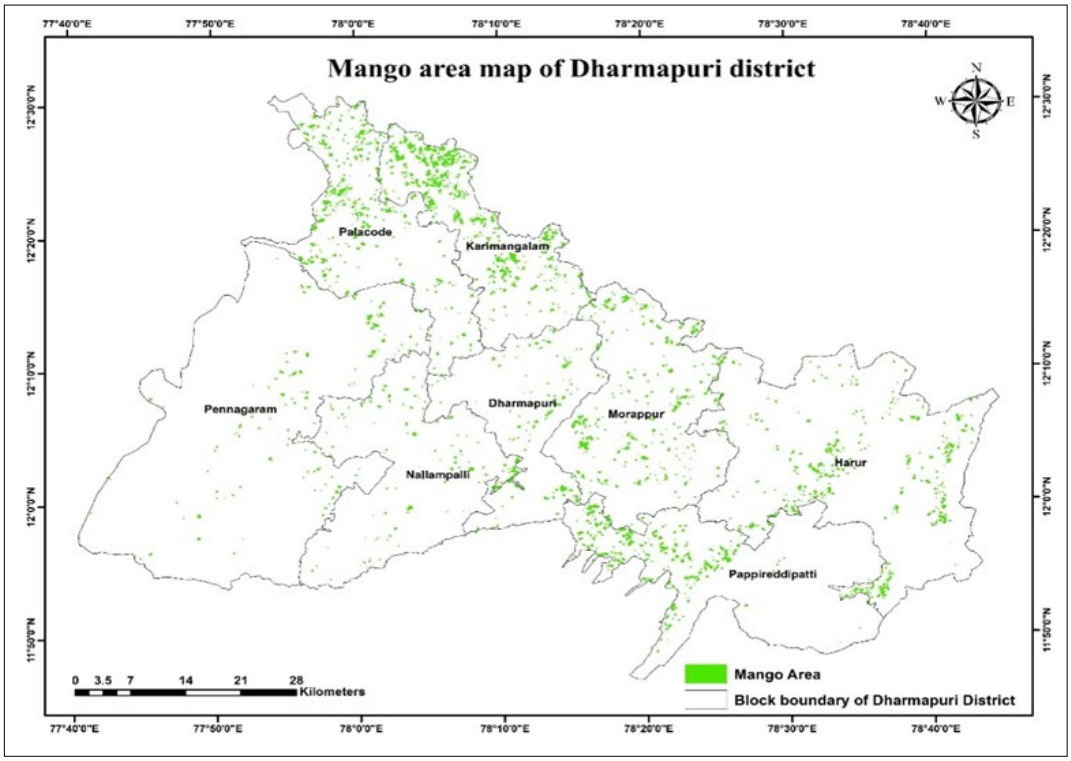

Fig. 4. Mango area map of Dharmapuri district.

Table 2. Block wise mango area in Krishnagiri district

Block name	Area (in ha)
Hosur	404.19
Shoolagiri	2868.02
Veppanapalli	1531.56
Krishnagiri	4850.2
Thally	1203.02
Kelamangalam	2074.73
Bargur	6156.17
Kaveripattinam	5314.33
Mathur	3617.41
Uthangarai	3804.59
Total	**31824.22**

Table 3. Block wise mango area in Dharmapuri district

Block name	Area (in ha)
Palacode	2377.34
Karimangalam	3492.12
Pennagaram	925.29
Morappur	1979.34
Dharmapuri	823.53
Harur	2563.72
Nallampalli	793.57
Pappireddipatti	1995.33
Total	**14950.24**

Table 4. Confusion matrix for accuracy assessment in Krishnagiri district

	Mango	Non-mango	User accuracy
Mango	41	9	0.82
Non-Mango	6	44	0.88
Producer accuracy	0.87	0.83	**0.85**
Kappa			**0.7**

Table 5. Confusion matrix for accuracy assessment in Dharmapuri district

	Mango	Non-mango	User accuracy
Mango	39	11	0.78
Non-Mango	1	49	0.98
Producer accuracy	0.98	0.82	**0.88**
Kappa			**0.76**

coefficient is 0.76. Pal et al., have used Sentinel 2 images for mango area mapping of Jabalpur district of Madhya Pradesh using ERDAS IMAGINE software and obtained an accuracy of 87.75 % (17). Similar results were observed (11) when Sentinel 2 images were used for area mapping of horticultural crops like Cashew nut in Ariyalur district of Tamil Nadu. The accuracy of classification was 85 % and with Kappa index of 0.7. Recent studies focusses on the integration of Sentinel 1 and Sentinel 2 images for mapping area of fruit plantations (18, 19).

The complex topography, characterized by hilly areas and extensive forests, hinder the precise delineation of mango orchards in the study area. The Krishnagiri district has more forest area as compared to Dharmapuri district this can be the reason for lower accuracy in Krishnagiri district. In addition, the presence of intercrops within mango orchards can complicate accurate area estimation, as these crops may interfere with the spectral signature of mango trees.

Conclusion

The mango orchards were identified in the study with good accuracy through object-based analysis incorporating random forest algorithm in optical images of Sentinel-2. This method is better than the pixel-based classification using any satellite image processing software and use of machine learning techniques further improves the accuracy. The fragmented plantation of fruit crops could be identified with better accuracy when machine learning based classification is applied on fused images of Sentinel 1 and Sentinel 2. The integration of optical and SAR data could enhance mango area mapping in future studies.

Acknowledgements

This paper was supported by Agro Climate Research Centre and Centre for Water and Geospatial Studies of Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India. This research received external funding from Hindustan Coca-cola Beverages Pvt. Ltd. Creating spatial database on mango growing areas with varietal information using remote sensing, drone and mobile mapping techniques project (Coca-Cola- F-37 APT).

Authors' contributions

The overall framework and conceptualization of the manuscript was done by SP and CR. The literature review and data collection were carried out by CR. The original draft was completed by CR and it was analysed by CR and MH. SP supervised all the draft. The data was visualized by CR and MH. The review was edited further by SP, IVP, NKS, KR and SV. All authors have read and agreed to the published version of the manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

References

1. Indiastat. Selected state-wise Area, production and productivity of mango in India. 2025 Feb 21.
2. Craig M, AtkinsonD. A literature review of crop area estimation. 2013, UN-FAO, Rome, Italy.
3. Kaliaperumal R, Pazhanivelan S, Kumaraperumal R, Mugilan GR. Mapping mango area using multi-temporal feature extraction from Sentinel 1A SAR data in Dharmapuri, Krishnagiri and Salem districts of Tamil Nadu. Madras Agric J. 2019;106:647-51. https://doi.org/10.29321/MAJ.2019.000325
4. Paul NC, Sahoo PM, Ahmad T, Sahoo, RN, Krishna G, Lal SB, Acreage estimation of mango orchards using hyperspectral satellite data. Indian J Hortic. 2018;75(1):27-33. https://doi.org/10.5958/0974-0112.2018.00005.1
5. Verma HC, Ahmed T, Rajan S. Mapping and area estimation of mango orchards of Lucknow region by applying knowledge based decision tree to Landsat 8 OLI Satellite Images. Int J Innov Technol Explor Eng. 2020;9(3):3627-35. https://doi.org/10.35940/ijitee.B8109.019320
6. Luo HX, Dai SP, Li MF, Liu EP, Zheng Q, Hu YY, Yi XP. Comparison of machine learning algorithms for mapping mango plantations based on Gaofen-1 imagery. J Integr Agric. 2020;19(11):2815-28. https://doi.org/10.1016/S2095-3119(20)63208-7
7. Roy S, More R, Kimothi MM, Mamatha S, Vyas, SP, Ray SS, Comparative analysis of object based and pixel-based classification for mapping of mango orchards in Sitapur district of Uttar Pradesh. J Geom. 2018;12(1):1-8.
8. Harish M, Kaliaperumal R, Pazhanivelan S, Sivakumar C, Kumaraperumal R. Mango area mapping using very high resolution satellite data in major blocks of Krishnagiri district, Tamil Nadu, India. Int J Environ Clim Change. 2023;13(9):811-18. https://doi.org/10.9734/ijecc/2023/v13i92302
9. Anderson NT, Underwood JP, Rahman MM, Robson A. and Walsh KB. Estimation of fruit load in mango orchards: tree sampling considerations and use of machine vision and satellite imagery. Precis Agric. 2019;20:823-39. https://doi.org/10.1007/s11119-018-9614-1
10. Balakrishna B, Harshitha SN, Sankaran M, Rupa TR, Verma N. Development of standard protocols for assessment of cropped area using Sentinel 2 MSI (Spatial Resolution: 10 m) in mango. Prog Hortic. 2023;55(2):127-33. http://dx.doi.org/10.5958/2249-5258.2023.00019.2
11. Sabthapathy M, Kaliaperumal R, Pazhanivelan S, Velmurugan S. Cashew area mapping using Sentinel-2 in Ariyalur District of Tamil Nadu, India. Eco Env Cons. 2022;28:S512-S16. http://doi.org/10.53550/EEC.2022.v28i01s.068

12. Benz UC, Hofmann P, Willhauck G, Lingenfelder I, Heynen M, Multi-resolution, object-oriented fuzzy analysis of remote sensing data for GIS-ready information. ISPRS J Photogramm Remote Sens. 2004;58 (3-4):239-58. https://doi.org/10.1016/j.isprsjprs.2003.10.002

13. Stephen S, Haldar D, Patel NR. Impact of various vegetation indices on mango orchard mapping using object-based image analysis. J Geom. 2022;16(2):159-66. https://doi.org/10.58825/jog.2022.16.2.45

14. Phiri D, Simwanda M, Salekin S, Nyirenda VR, Murayama Y, Ranagalage M. Sentinel-2 data for land cover/use mapping: A review. Remote Sens. 2020;12(14):2291. https://doi.org/10.3390/rs12142291

15. Congalton RG. A review of assessing the accuracy of classifications of remotely sensed data. Remote Sens Environ. 1991;37(1):35-46. https://doi.org/10.1016/0034-4257(91)90048-B

16. Raju C, Ajith K, Ajithkumar B, Anitha S, Vijayan VD. Rice area mapping in Palakkad district of Kerala using Sentinel-2 data and Geographic information system technique. J Appl Nat Sci. 2022;14 (4):1360. https://doi.org/10.31018/jans.v14i4.3898

17. Pal S, Pandey SK, Sharma SK, Nair R, Acreage estimation of mango orchards in Jabalpur district of Madhya Pradesh using Sentinel-2 imagery. Eco Env Cons. 2023;29(2):840-44. http://doi.org/10.53550/EEC.2023.v29i02.050

18. Chabalala Y, Adam E, Ali KA. Machine learning classification of fused Sentinel-1 and Sentinel-2 image data towards mapping fruit plantations in highly heterogenous landscapes. Remote Sens. 2022;14(11):2621. https://doi.org/10.3390/rs14112621

19. Nabil M, Farg E, Arafat SM, Aboelghar M, Afify NM, Elsharkawy MM. Tree-fruits crop type mapping from Sentinel-1 and Sentinel-2 data integration in Egypt's New Delta project. Remote Sens Appl Soc Environ. 2022;27:100776. https://doi.org/10.1016/j.rsase.2022.100776

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

Reprints & permissions information is available at https://horizonepublishing.com/journals/index.php/PST/open_access_policy

Publisher's Note: Horizon e-Publishing Group remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc
See https://horizonepublishing.com/journals/index.php/PST/indexing_abstracting

Publisher information: Plant Science Today is published by HORIZON e-Publishing Group with support from Empirion Publishers Private Limited, Thiruvananthapuram, India.