



Agroforestry Area Mapping using Medium Resolution Satellite Data and Object-based Image Analysis

T. Chaitanya¹, T.L. Neelima², A.V. Ramanjaneyulu¹, A. Krishna¹

10.18805/ag.D-6099

ABSTRACT

Background: The current view of agroforestry is not as a collection of technologies, but of trees included in agricultural landscapes. India's sub-national climate change action plans acknowledge agroforestry's potential for climate change adaptation and mitigation. Understanding the extent and distribution of trees on agricultural land, at the landscape level, including the numbers and characteristics of farmers and farming communities within those landscapes, can help to assess the importance and role of agroforestry both to the climate change mitigation as well as to overall global agricultural production. With this perspective of agroforestry, site specific studies are required to delineate different agroforestry systems and estimation of exact area under agroforestry.

Methods: In this study, the area under agroforestry was estimated by using remote sensing and GIS techniques with medium resolution satellite (Sentinel 2A and 2B) data in e-Cognition developer software (10.0 version) through multi-resolution segmentation and object-based image analysis (OBIA).

Result: The agroforestry area was estimated in erstwhile Khammam district of Telangana, India, which is 30,038 ha covering 1.87% of the total district geographical area (16,02,900 ha) with an overall accuracy of 81.5%. The major agroforestry systems observed in erstwhile Khammam district were Eucalyptus, Subabul, Malabar Neem, Teak, Sandalwood and Red Sanders. Agroforestry gained momentum after adopting the National Agroforestry Policy (NAP) in 2014, which aimed to organize the sector and reform any legislative barriers. This area estimation is useful to policy makers as there is only rough estimates of agroforestry area unlike agricultural area.

Key words: Agroforestry, Area mapping, E-Cognition software, Multi-resolution segmentation, OBIA, Remote sensing.

INTRODUCTION

In India agroforestry was included in agricultural and forestry research agendas when Indian Council of Agricultural Research launched an All India Coordinated Research Project (AICRP) on Agroforestry with 20 centres in 1983. Currently, there are 37 AICRP on agroforestry centres representing all the agro-climates in the country (Rao *et al.*, 2018). During the past 30 years, agroforestry has progressed from being a traditional practice with great potential to the point where development experts agree that it provides an important science-based pathway for achieving important objectives in natural resource management and poverty alleviation (Garrity *et al.*, 2006). Agroforestry gained momentum after adopting the National Agroforestry Policy (NAP) in 2014, which aimed to organize the sector and reform any legislative barriers (Department of Agriculture, Co-operation and Farmers' Welfare, 2014). With the adoption of the National Agroforestry Policy in the country, India became a pioneer in promoting the inclusion of woody perennials (trees, shrubs, palms and bamboos) in food production systems, i.e. agricultural land. Effective planning and management are vital for the success of any policy and in this regard, it is mandatory to estimate the area under agroforestry.

Agroforestry area mapping is important and necessary to know the present extent of area under it, scope of increasing the area in future and finally in achieving the

¹AICRP on Agroforestry, Professor Jayashankar Telangana State Agricultural University, Hyderabad-500 030, Telangana, India.

²Water Technology Centre, Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad-500 030, Telangana, India.

Corresponding Author: T. Chaitanya, AICRP on Agroforestry, Professor Jayashankar Telangana State Agricultural University, Hyderabad-500 030, Telangana, India.
Email: chaitanya@agsu.ac.in

How to cite this article: Chaitanya, T., Neelima, T.L., Ramanjaneyulu, A.V. and Krishna, A. (2024). Agroforestry Area Mapping using Medium Resolution Satellite Data and Object-based Image Analysis. Agricultural Science Digest. 1-8. doi: 10.18805/ag.D-6099.

Submitted: 26-06-2024 **Accepted:** 23-10-2024 **Online:** 31-12-2024

goals set up for its promotion. Without remote sensing, agroforestry area mapping might be difficult, because traditional methods of area assessment require longer, human and financial resources. Also, it can give near real-time data about large areas, human access limited areas and is comparatively cost effective. A major problem in estimating area under agroforestry is lack of procedures for delineating the area under trees in a mixed stand of trees and crops (Nair *et al.*, 2009). Use of geospatial technologies to estimate agroforestry area was initiated in 2007 by the Central Agroforestry Research Institute (CAFRI),

Jhansi, using medium-resolution data with a methodology in which areas under agroforestry, forest and plantation are separately identified (Rizvi *et al.*, 2020). The actual area estimation under agroforestry in India was done by Central Agroforestry Research Institute, Jhansi using sub-pixel classification and object-based image analysis methods for medium-resolution (LISS III – 23.5 m) and high resolution (LISS IV/Sentinel 2 – 5.8/10 m) remote sensing data, respectively. The accuracy of the estimation was >75% and >90% for sub-pixel classification and object-based image analysis methods, respectively. The overall area under agroforestry of India was 28.427 M ha, which is about 8.65% of the total geographical area of the country (328.747 M ha) (Arunachalam *et al.*, 2022). Remote sensing and GIS are not only used for area mapping but also used in different fields like mapping Salt Affected Soils (Kumar *et al.*, 2021), Water Erosion Assessment (Kumar *et al.*, 2020), Soil Nutrient Status evaluation (Jeyasingh Immanuel Alex, 2023) *etc.*

Object-based image analysis (OBIA) approach has been widely utilized for remote sensing studies as an alternate and also comparatively better classification approach to the traditional pixel-based image classification techniques (Chaudhary *et al.*, 2016). The OBIA consists of image segmentation, object attribution and classification. The image segmentation is the first step in OBIA. The process of segmentation is to group the pixels to form objects. As an object is a group of pixels, object characteristics such as mean value, standard deviation, ratio, *etc.* can be calculated; besides there are shape and texture features of the objects available which can be used to differentiate land cover classes with similar spectral information. This additional information facilitates the OBIA techniques to produce land cover thematic maps with higher

accuracies than those produced by traditional pixel-based method (Khadanga, 2014). OBIA approach could be an appropriate method for mapping all types of agroforestry (scattered trees, boundary and block plantations) existing on farmlands and also a widely used method in many study areas for getting accurate results (Rizvi *et al.*, 2019; Hassanin *et al.*, 2020). Though there are many preliminary studies and works on delineation of agroforestry area in India through sub-pixel and OBIA methods. So far estimation of area under agroforestry in different districts of the Telangana state has not yet done using geospatial technology. With this perspective an attempt was made to delineate and estimate agroforestry area in one of the districts of Telangana state with the help of multi-resolution segmentation and object-based image analysis in e-Cognition software and survey was conducted to collect the ground truth data for agroforestry area mapping.

MATERIALS AND METHODS

Study area

Khammam district in Telangana State, India is located in the south-eastern part of the Indian sub-continent. The geographical location of the district is between 16.45 degrees and 18.35 degrees north latitude and 79.47 degrees and 80.47 degrees east longitude (Fig 1).

Ground truth data

Ground truth data (GPS locations) was collected during survey across the district using mobile based GPS application. Epicollect is a mobile and web application for free and easy data collection. It is used for the generation of forms (questionnaires) and is freely hosted in the project websites for data collection. The projects are created by using the web application at five.epicollect.net and then by

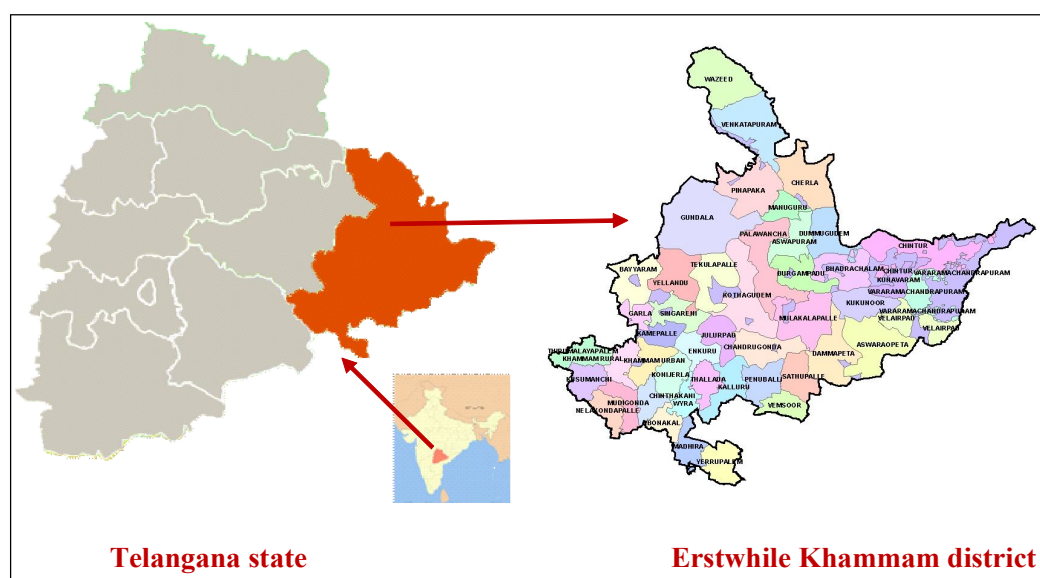


Fig 1: Erstwhile Khammam District in the Indian state of Telangana with administrative boundaries.

downloading the app in the mobile. The data collected (including GPS and media) using multiple devices can be exported in CSV format. The mobile app is available for both Android (5+) and iOS (8+) using the web application at five.epicollect.net. One can create as many projects and upload as many entries as like. This is an open-source technology that provide its service for free. Ninety-six (96) GPS coordinates of different agroforestry tree plantations were collected during the survey.

Software used for mapping

Quantum GIS (version 3.8.0), ERDAS imagine (version 16.5.0) and e-Cognition developer (10.0 version) software were used for the present study and the methodology adopted for generation of agroforestry map was depicted in the Fig 2.

Delineation of the study area

The study area toposheets (1: 50,000) were downloaded from Survey of India 2021 website (<https://soinakshe.uk.gov.in>). Preprocessing of toposheets includes:

- (i) Georeferencing of the downloaded toposheets in QGIS software .
- (ii) Subsetting of the georeferenced toposheets in ERDAS imagine software.
- (iii) Mosaicking of toposheets in ERDAS imagine software.
- (iv) Digitizing study area boundary in QGIS software.
- (v) Superimposing of the mosaic image on shape file.
- (vi) Delineation of the study area.

District shape files are also available with Survey of India.

Downloading of satellite data

Remote sensing data for the research work was obtained from Sentinel-2 mission a constellation of two satellites, Sentinel 2A and Sentinel 2B. These satellites systematically acquire Optical data at high resolutions (10 m, 20 m and 60 m). Level-1C products of Top-of-atmosphere reflectance's in cartographic geometry (combined UTM projection 43N and WGS84 ellipsoid) were taken. Level-1C products are tiles of 250 km '250 km each one with a volume of approximately 500 MB. The projection system

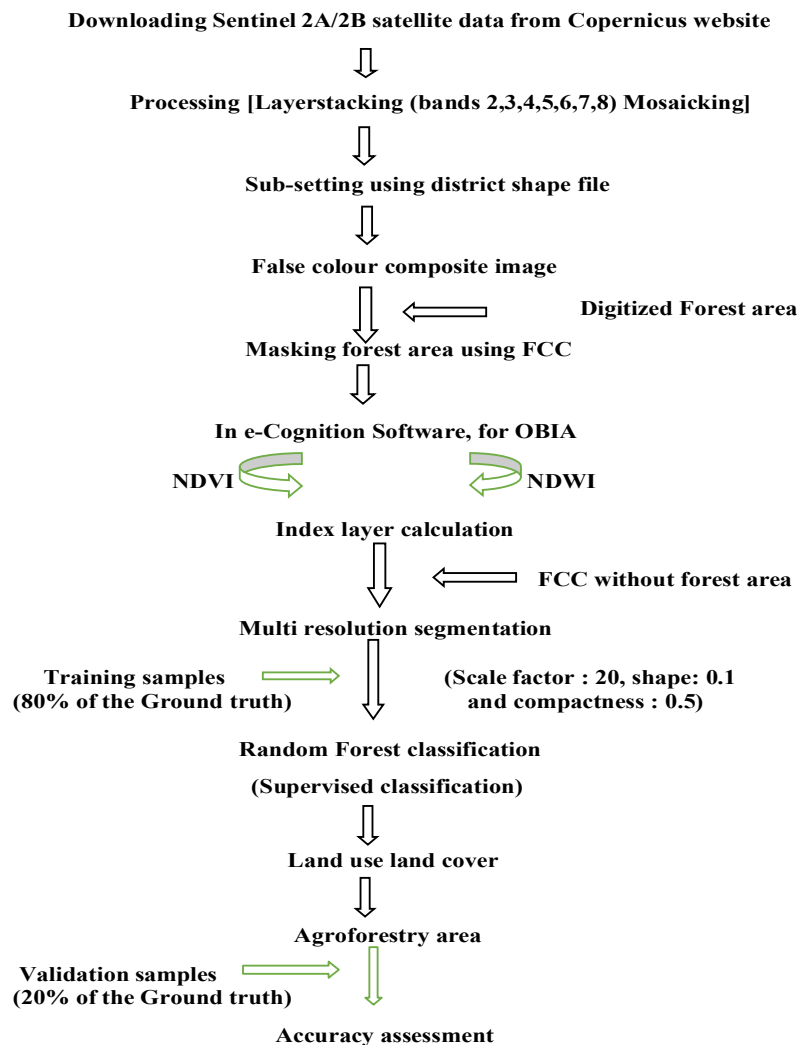


Fig 2: Methodology adopted for mapping agroforestry area.

used was EPSG: 32643 which was ideal for countries in the Northern hemisphere between 72°E to 78°E. Satellite data of Sentinel 2A and 2B (Optical) with 10 m spatial and 5 days temporal resolution along an accuracy of 85.2 (%) of level 1C was downloaded from the Copernicus Open Access hub of the European Space Agency (ESA) website (<https://scihub.copernicus.eu/dhus/#/home>). during the month of October, 2022 by registering into it. Care was taken to choose the cloud free data to the possible extent. Satellite images were preprocessed in ERDAS imagine software (version 16.5.0). The processes used were layerstacking by the process of composting of necessary bands (here bands 2,3,4,5,6,7 and 8) one after another to create false colour composite (FCC) image, mosaicking where all the layerstacked images were joined together to form the complete study area into single image and subsetting by delineating the area of interest with the help of district boundary vector layer. The whole satellite data processing was done in ERDAS imagine software.

Removal of forest layer from the study area

Forest area was masked out from study area with help of 2015 LULC forest layer and digitised portions by overlaying on the FCC image using the QGIS software (version 3.8.0) and ERDAS imagine software (version 16.50). Methodology adopted for removal of forest layer was depicted in the Fig 3.

Classification

ERDAS Imagine software was chosen for classifying agroforestry areas because of its Multiresolution Segmentation and Object Based Image Analysis (OBIA) techniques unique for this software. OBIA includes image segmentation and grouping pixels into homogeneous

objects or segments that can be analysed based on the objects instead of analysing individual pixel (Holloway and Mengersen, 2018). Through an algorithm "Index layer calculation" NDVI and NDWI calculation were directed for detection and identification of vegetation cover and water body areas respectively on the imagery and separate during classification.

$$NDVI = \frac{\text{Near-infrared band} - \text{Red band}}{\text{Near-infrared band} + \text{Red band}}$$

$$NDWI = \frac{\text{Green-NIR}}{\text{Green+NIR}}$$

Multiresolution segmentation (Fig 4) is an algorithm for segmentation procedure, run under artificial intelligence (AI) direction that facilitates Object based image analysis (OBIA) where image can be analysed based on the objects instead of analysing individual pixel. OBIA includes image segmentation and grouping pixels into homogeneous objects or segments (Holloway and Mengersen, 2018). The segmentation process begins by initially recognizing each individual pixel in the image as one segment. These single pixel segments are then successively merged into larger segments using a pair-wise clustering process. The algorithm uses three parameters: scale, shape weighting and compactness weighting. The scale parameter determines the areal size of the segments generated whereas the shape and compactness weighting values are used to determine the shape of the segments. A small scale value (e.g., 10) produces small segments and a large scale value (e.g., 300) produces large segments. The shape and compactness parameter values range from 0 to 1. A low shape value (e.g., 0.1) places a high emphasis on color which is normally the most

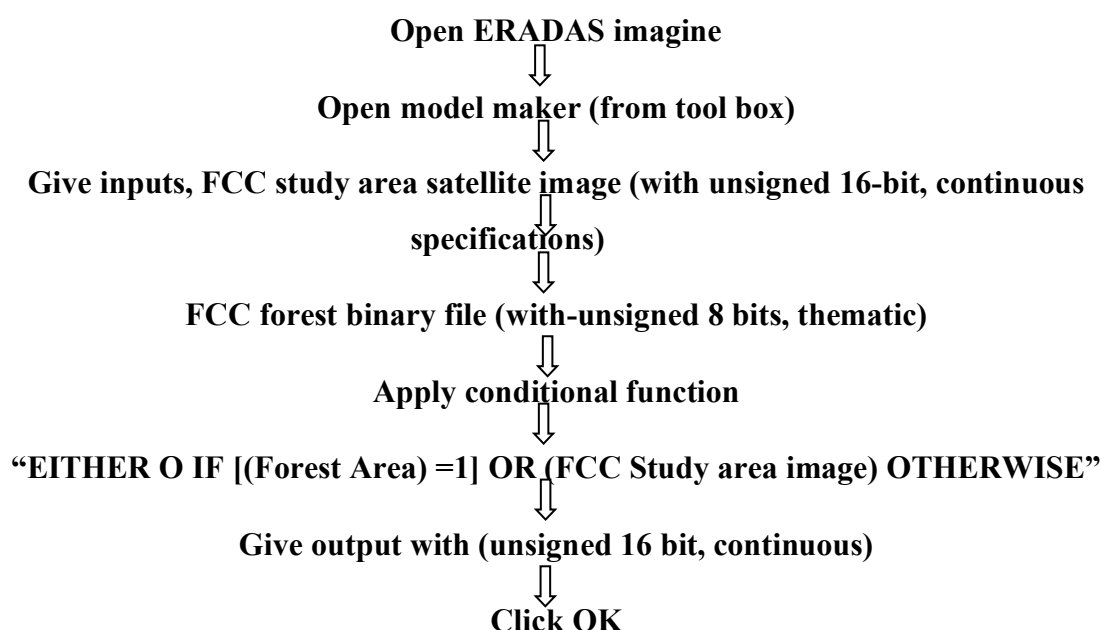


Fig 3: Methodology for the removal of forest layer from the study area.

important for creating meaningful objects. Higher compactness weightings (e.g., 0.9) result in more compact object boundaries, such as is typical with crop fields or buildings (Khadanga, 2014).

In the present study segmentation was performed with a scale parameter = 20 (polygon size), shape = 0.1, compact = 0.5, for spectral difference calculation maximum 10 or more no. of pixels as grouped feature was chosen. The image is segmented to supply meaningful polygonal image objects by setting certain parameters of homogeneity and heterogeneity in colour and shape (Kumar *et al.*, 2008).

Classification was done on the basis of representative training samples for each land cover classes. The image object hierarchy was based on seven classes: agroforestry, crop, harvested, settlements, orchards, scrubland cloud. Each class was assigned a different colour to determine which class an object belongs. Agroforestry objects were defined using ground truth and high resolution google earth sample points. Samples for training areas *i.e.*, for agroforestry (1634), crop (841), harvested (1285), orchards (920), scrub (3602), settlements (359) were given. Of the total ground truth data collected, 80% was utilised in training the agroforestry samples and the remaining samples were used for accuracy assessment.

An algorithm Supervised classification was chosen to run Random Forest type of classification process. Random forest classifier is a feature space optimization technique in the mapping of tree species. It is an ensemble classifier that produces multiple decision trees, using a randomly selected subset of training samples and variables. This classifier has become popular within the remote sensing community due to the accuracy of its classifications. It has its sensitivity when training samples are class balanced, representative of the target classes and are large enough to accommodate the increasing number of data

dimensions (Mariana and Lucian, 2016).

Post classification smoothening was done by removal of mixed pixels through an algorithm "Remove Objects" with the help of fill and merge filter options based on pixel shape and colour.

Accuracy assessment

Accuracy in classification of agroforestry areas was done with the remaining GPS points by overlaying them on classified map and crosschecking it with classified agroforestry parcels. Technically, classification accuracy was determined by using error matrix or confusion matrix to evaluate the accuracy. The confusion/error matrix indicates the accuracy of classification (Foody, 2002). The relationship between the reference field data (ground truth) with the corresponding results of a classification was compared in the matrix. The Producer's accuracy describes the number of errors of omission which is a measure of how well real-world land cover types can be classified. The user's accuracy describes the number of errors of omission which represents the likelihood of a classified pixel matching the land cover type of its corresponding real-world location (Jensen, 2005). The accuracy assessment was indicated through the following; user's accuracy, producer's accuracy, overall accuracy and Kappa coefficient.

KHAT statistics is computed as:

$$\hat{k} = \frac{N \sum_{i=1}^r x_{ii} - \sum_{i=1}^r (x_{i+} \cdot x_{+i})}{N^2 - \sum_{i=1}^r (x_{i+} \cdot x_{+i})}$$

N = Total number of observations included in the error matrix.

x_{i+} = Total of observations in row *i* (shown as marginal total to right of matrix).

x_{+i} = Total of observations in column *i* (shown as marginal

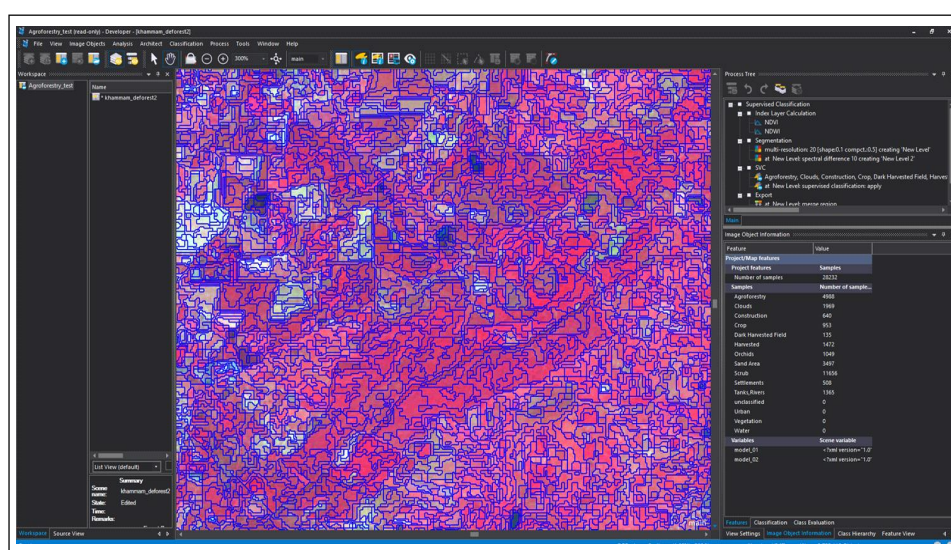


Fig 4: Multiresolution segmentation in e Cognition software.

total at bottom of the Matrix).

x_{ii} = Number of observations in row i and column i (on the major diagonal).

RESULTS AND DISCUSSION

The land use land cover map of erstwhile Khammam district, Telangana state was prepared using Multiresolution segmentation and Object Based Image Analysis (OBIA) techniques in e Cognition software (10.0 version). Object based image classification is one of the most adapted land cover classification techniques in recent time which also considers other parameters such as shape, colour, smoothness, compactness *etc.* apart from the spectral reflectance of single pixel.

The area estimated under agroforestry in erstwhile Khammam district was found to be 30,038 ha, covering 1.87% of the total district geographical area (16,02,900 ha). The estimated agroforestry area includes tree species of eucalyptus, malabar neem, subabul, teak, sandalwood and red sanders. Besides agroforestry area, other land use features were also classified *i.e.*, area under crop was 422600 ha (26.4%), orchards were 361680 ha (22.6%), scrub occupied 27381 ha (1.7%), river beds were 16863 ha (1.1%), construction covered 6286 ha (0.39%) and harvested fields occupied significant area of 119493 ha (7.5%) (Fig 5).

Accuracy of the agroforestry area was estimated through confusion or error matrices which compare the relation between the reference data (ground truth data)

and the corresponding results of the classification. The results of accuracy assessment portrayed that producer's accuracy in classification of agroforestry was 78% whereas the user's accuracy was found to be 76% with an overall accuracy of 81.5%. The kappa coefficient was 0.77, which was on par with overall accuracy as given in the Table 1. This indicated that the agroforestry locations omitted in the producer's category were included in the user's category and mixed with other samples of other classes. In this study, OBIA outperformed all test areas in terms of the quality of the classification outputs, as measured by the overall accuracy metric and in terms of computational time as well. Automated segmentation in e Cognition based algorithm generated satisfactory delineation of agroforestry area in erstwhile Khammam district. The object-based approach provided by e Cognition software is a big step forward in interpretations of remote sensing images and is an efficient and practical approach for information extraction. Varshitha *et al.* (2024) estimated an agroforestry area of 3753 hectares using the similar methods in e Cognition for the erstwhile Warangal district of Telangana, with an overall accuracy of 86% and a kappa coefficient of 0.84. Similar studies of LULC patterns for the Ahmedabad district in Gujarat, India, using LISS-IV imagery, were conducted using a combination of pixel-by-pixel image classification and object-based image classification using different platforms such as Arc GIS and e Cognition (Rawal *et al.*, 2020). Rizvi *et al.* (2021) and Hassanin *et al.* (2020)

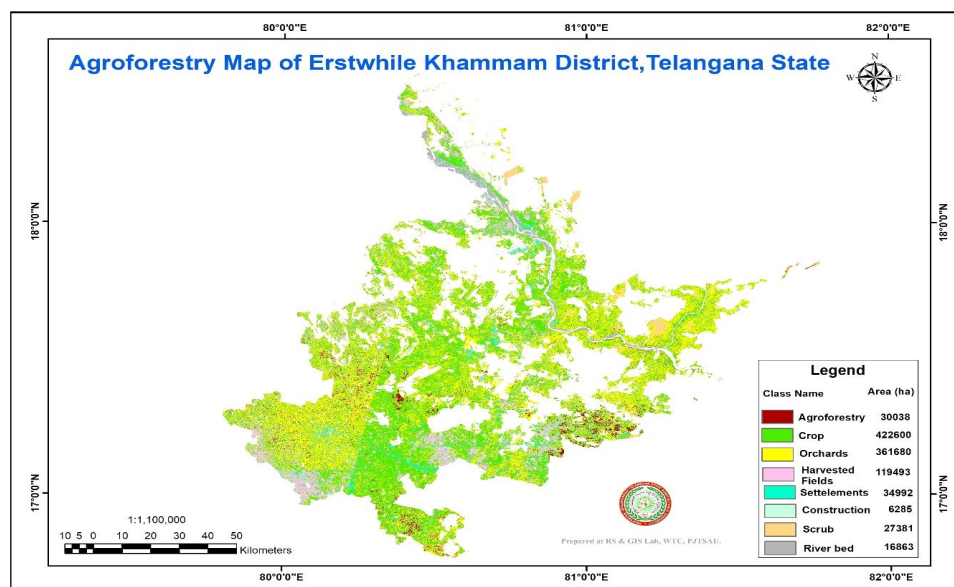


Fig 5: Agroforestry area map of Erstwhile Khammam District.

Table 1: Accuracy of all training sites as assessed through error matrix (Erstwhile Khammam district).

Accuracy	Agroforestry	Crop	Harvested fields	Settlements	Orchards	Scrub	Clouds
Producer	0.78	0.88	0.87	0.71	0.88	0.72	1.0
User	0.76	0.62	0.99	0.85	0.51	0.96	1.0
KIA Per Class	0.815	0.73	0.84	0.92	0.75	0.71	1.0

conducted related research on agroforestry area mapping and assessment of trees outside forests (ToF) utilizing object-based image analysis (OBIA) and a multiresolution segmentation approach in e Cognition software. High resolution satellite data with e Cognition software can help to decrease inaccuracies even further, as well as limits of medium resolution data for complex agroforestry systems.

CONCLUSION

The classification, mapping and estimation of agroforestry area through Object Based Image Analysis in e-Cognition software was accurate, efficient and reliable than pixel based classification. This is because OBIA can use more elements in the classification, such as texture, context and shape, which pixel-based classification often neglects. The mapped agroforestry area and the tree species grown in that specific area provide the basis for future planning and for the identification of agroforestry hotspots for appropriate interventions, such as the introduction of new, economical tree species in agricultural lands, the tracking of changes in agroforestry cover over time and promotion of appropriate tree species in waste lands for enhancing soil fertility and conserving water and soil.

Future line of research

Object Based Image Analysis in e-Cognition software with high-resolution imagery can be used to map the tree cover changes and assess the climatic change impact in a particular area over a period of time.

ACKNOWLEDGEMENT

The authors gratefully acknowledge to concerned authorities of university for providing funding to have e-Cognition software and also express gratitude to RS and GIS laboratory, Water Technology Centre, College of Agriculture, PJTSAU, Rajendranagar, Hyderabad, Telangana. The authors are very thankful to Central Agroforestry Research Institute, Jhansi, UP for the financial support to the project.

Conflict of interest

The authors declare that there are no conflict of interest.

REFERENCES

- Arunachalam, A., Rizvi, R.H., Handa, A.K and Suresh Ramanan, S. (2022). Agroforestry in India: area estimates and methods. *Current Science*. 123 (6): 743-744.
- Chaudhary, A.K., Acharya, A.K. and Khanal, S. (2016). Forest type mapping using object based classification method in Kapilvastu district, Nepal. *Banko Janakari*. 26(1): 38-44.
- Copernicus EU. Sentinel-2. <https://scihub.copernicus.eu/>. Department of Agriculture, Co-operation and Farmers' Welfare. (2014). National Agroforestry Policy of India. "Department of Agriculture Cooperation and Farmers Welfare", New Delhi.
- Foody, G.M. (2002). Status of land cover classification accuracy assessment. *Remote Sensing of Environment*. 80(1): 185-201.
- Garrrity, D., Okono, A., Grayson, M. and S. Parrott, eds. (2006). *World Agroforestry into the Future*. Nairobi: World Agroforestry Centre.
- Hassanin, M.O.H.D., Kanga, S.H.R.U.T. I., Farooq, M. A. J. I. D. and Singh, S.K. (2020). Mapping of Trees outside Forest (ToF) from Sentinel-2 MSI satellite data using object-based image analysis. *Gujarat Agricultural Universities Research Journal*. 207: 204-213.
- Holloway, J. and Mengersen, K. (2018). Statistical machine learning methods and remote sensing for sustainable development goals: A review. *Remote Sensing*. 10(9): 1365.
- Jensen, J.R. (2005). *Introductory digital image processing: A remote sensing perspective - 3rd edition*. Prentice Hall, United States of America. pp. 526.
- Jeyasingh Immanuel Alex, R., Devakumari Suguna, M., Poonguzhali Susan, R., Katharine Praveena S., Jeeva Carolin, S. (2023). Evaluating the Soil Nutrient Status using GIS and Remote Sensing Technology-A Case Study at Coimbatore District. *Agricultural Science Digest*. 43(3): 319-323. doi: 10.18805/ag.D-5698.
- Khadanga, G. (2014). Image Segmentation using OBIA in eCognition, Grass and Opticks- A Review of the Techniques and Approaches. Conference paper: Geomatrix 2014, At: IIT Bombay. (https://www.researchgate.net/publication/281820731_Image_Segmentation_using_OBIA_in_eCognition_Grass_and_Opticks).
- Kumar, A., Singh, K. N., Lal, B. and Singh, R. D. (2008). Mapping of apple orchards using remote sensing techniques in cold desert of Himachal Pradesh, India. *Journal of the Indian Society of Remote Sensing*. 36(4): 387- 392.
- Kumar Nirmal, Singh S.K., Reddy Obi G.P., Mishra V.N., Bajpai R.K. (2021). Remote Sensing Applications in Mapping Salt Affected Soils. *Agricultural Reviews*. 42(3): 257-266. doi: 10.18805/ag.R-2008.
- Kumar, N., Singh, S.K., Reddy, O.G.P., Mishra, V.N., Bajpai, R.K. (2020). Remote sensing and geographic information system in water erosion assessment. *Agricultural Reviews*. 41(2): 116-123. doi: 10.18805/ag.R-1968.
- Mariana, B. and Lucian, D. (2016). Random Forest in remote sensing: A review of applications and future directions. *ISPRS Journal of Photogrammetry and Remote Sensing*. 114: 24-31.
- Nair, P.K.R., Kumar, B.M. and Nair, V.D. (2009). Agroforestry as a strategy for carbon sequestration. *Journal of Plant Nutrition and Soil Science*. 172: 10-23.
- Rao, R.G., Prabhakar, M., Venkatesh, G., Srinivas, I. and Sammi Reddy, K. (2018). Agroforestry Opportunities for Enhancing Resilience to Climate Change in Rainfed areas Hyderabad. <http://www.nicraicar.in/nicrarevised/images/Books/Agroforestry%20Book%2>.
- Rawal, D., Chhabra, A., Pandya, M. and Vyas, A. (2020). Land use and land cover mapping – A case study of Ahmedabad District. *The International Archives of the Photogrammetry*,

- Remote Sensing and Spatial Information Sciences, 2020 XXIV ISPRS Congress. 43-B3: 189-193.
- Rizvi, R.H., Handa, A.K., Sridhar, K.B., Kumar, Bhaskar, S., Chaudhari, S.K., Arunachalam, A., Thomas, N., Ashutosh, S., Sapra, R. K. (2020). Mapping Agroforestry and Trees outside forest. ICAR, Central Agroforestry Research Institute (CAFRI), Jhansi and World Agroforestry Centre (ICRAF), South Asia Regional Programme, New Delhi. pp. 2.
- Rizvi, R.H., Newaj, R., Srivastava, S. and Yadav, M. (2019). Mapping trees on farmlands using OBIA method and high-resolution satellite data: A case study of Koraput District, Odisha. The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences. 42: 617-621.
- Rizvi, R.H., Vishnu, R., Handa, A.K., Ramanan, S., Yadav, M., Mehdi, A., Singh, R.K., Londhe, S., Dhyani, S.K., Rizvi, J. and Kumar, R. (2021). Mapping of agroforestry systems and Salix species in Western Himalaya agroclimatic zone of India. Current Science. 121(10): 743-744.
- Survey of India. (2021), <https://soinakshe.uk.gov.in>.
- Varshitha, M., Chaitanya, T., Neelima, T. L. and Jayasree, G. (2024). Agroforestry area mapping using medium resolution satellite data and object-based image analysis. Range Management and Agroforestry. 45(01): 20-25. <https://doi.org/10.59515/rma.2024.v45.i1.03>.