Mapping Multiple Horticulture Crops using Object Oriented Classification Techniques

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ABSTRACT

The fundamental requirement for proper planning in the Indian horticultural sector is the availability of reliable statistical database in terms of area and production at different spatial hierarchies (tehsil, district, state). Remote sensing and Geo-ICT tools offer a simple, fast, efficient and cost-effective method of not just updating the horticulture crop inventory but also integrating the database, thus making it conducive for easy retrieval, analysis and decision-making. Medium and high resolution remote sensing data like LISS-IV and PAN prove to be effective in inventorying crops like mango, citrus and oil palm. Object oriented techniques work best in identifying and mapping fruit orchards as against per pixel classifiers, which are more useful for field crops. This is because the information needed for image analysis and classification is represented in meaningful image objects and their mutual relations. This study aims at mapping multiple crops, viz. mango and oil palm in Krishna district of Andhra Pradesh. Multi-resolution segmentation has been done after assigning scale parameter and weightages to various parameters like shape, compactness, color, smoothness and NDVI. Subsequently, the potential mango and oil palm areas have been delineated based on texture and shape/geometry information obtained from high resolution PAN data. Field validation of the crop map indicated 89% agreement with field data. Hence multiple high resolution datasets have the potential to map the spatial distribution of mango and oil palm plantations at district and sub-district level. Object oriented classification techniques use the form, texture and spectral information in a sequential manner to delineate multiple horticulture crops.

1. INTRODUCTION

India is the second largest producer of fruits and vegetables in the world and occupies first position in the production of fruits like mango, banana, citrus, papaya, sapota and pomegranate. Among various horticultural crops, fruits account for the major share in terms of both in area and production. Horticultural crops are highly localized when compared to agricultural crops. Area under horticulture as increased 29% in 8 years, from 18.7 million ha in 2005-06 to 24.2 million ha in 2013-14. Horticulture production increased from 167 million tonnes in 2004- 05 to 283 million tonnes in 2014- 15 or 69% increase in 9 years. Productivity of horticulture crops increased by about 34% between 2004-05 and 2014-15. A National Horticulture Mission was launched in 2005-06 as a Centrally Sponsored Scheme to promote holistic growth of the horticulture sector. The scheme has been subsumed as a part of Mission for Integration Development of Horticulture (MIDH) during 2014-15.

High resolution remote sensing data offers a solution for inventorying horticultural crops at regular intervals. This will aid policy-makers in deciding suitable strategies for micro-level planning, as well as monitoring the changes/expansion in cropping patterns. A fully developed geospatial database on horticulture will also provide a faster and efficient method of updating information. Current study is for the inventory and mapping of mango and oil palm crops in Krishna district of Andhra Pradesh. An object oriented approach has been attempted for classification of the two horticulture crops of interest as against the conventional per-pixel classification. Mango and oil palm have distinctive pattern, texture, geometry and color that delineates them from other field crops. It is these parameters that help in classification of the two crops at plantation/field level through objected oriented techniques using high resolution satellite data.

2. OBJECTIVE

- To map the spatial distribution of mango and oil palm plantations in Krishna district of Andhra Pradesh, using multi-temporal high resolution data
- Estimation of acreage of mango and oil palm crops

3. ABOUT MANGO AND OIL PALM CROPS AND THEIR CULTIVATION IN ANDHRA PRADESH

India ranks first among world's mango producing countries, accounting for 52.6% of the total world's mango production. It is grown over an area of 1.2 million hectares in the country, producing 11.0 million tonnes. Andhra

Pradesh contributes significantly to horticulture crop area and production at the national level, the production being of 2.73 m MT from an area of 2.79 lakh ha. Area-wise, Andhra Pradesh occupies 17% of the total area under mango in the country, next to Maharashtra (18%). In terms of production, Andhra Pradesh is next only to Uttar Pradesh, with 22% average production. Figure 1 shows the average area and production share of leading mango producing states in India from 2009 to 2015. The commercial mango varieties grown are Banganapalli, Suvarnarekha, Neelum and Totapuri.

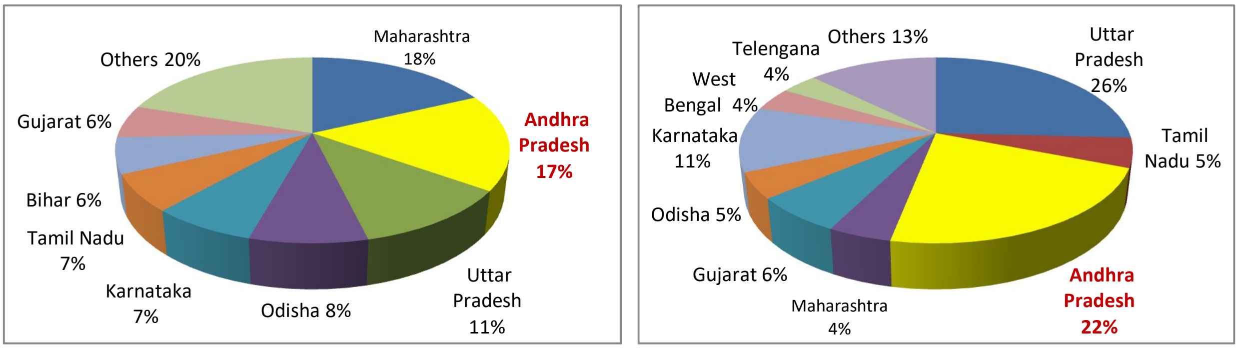

Figure 1 Average area and production share of leading mango producing states in India (2009-2015)
(Source: http://www.mospi.gov.in)

Oil palm has become an important vegetable oil source - one of the highest edible oil yielding crops – providing 4 to 6 tonnes of oil/ha for a period of 3 to 25 years of its life span. A renewed interest in oil palm is due to the fact that it has the potential to play a major role in the vegetable oil economy. It is also being seen as a source for diversification, adding nutritional value and in import substitution. Oil palm is a perennial crop that grows in humid tropics with good irrigation. In India, Andhra Pradesh, Karnataka, Mizoram, Tamil Nadu, Odisha and Telangana account for over 93% area under oil palm, with Andhra Pradesh alone contributing to 51% area. Figure 2 shows the area under the oil palm in different states.

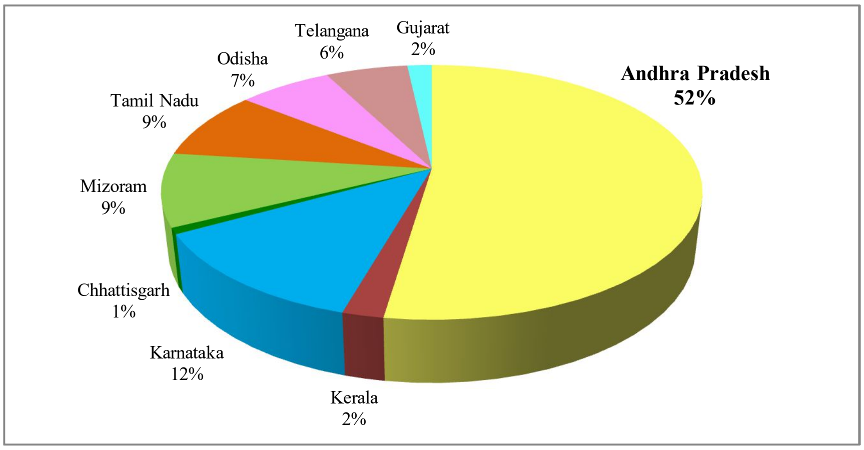

Figure 2 Area under oil palm in different states of India – 2015-16 *(Source: http://nmoop.gov.in)*

4. STUDY AREA

In the present study, Krishna district has been selected for mapping and acreage estimation of mango and oil palm crops (Figure 3). The climate of the district is tropical – with extremely hot summers and moderately hot winters. The district consists of 50 mandals, and is spread over 8727 sq.km, divided into upland and delta area. The annual rainfall in the region is about 1028 mm and most of it is contributed by the south-west monsoon. The soil types are black cotton (57.6%), sand clay loams (22.3%) and red loams (19.4%). The main source of irrigation is tanks and canals of Krishna river. Paddy, black gram, cotton, maize, groundnut, tobacco and chillies are the major field crops. In horticulture crops, 90% area is under mango, while oil palm, coconut, banana, guava and acid lime are among others. Krishna district is the second largest contributor to mango crop in terms of its acreage in Andhra Pradesh. It is also one of the eight districts identified for oil palm cultivation.

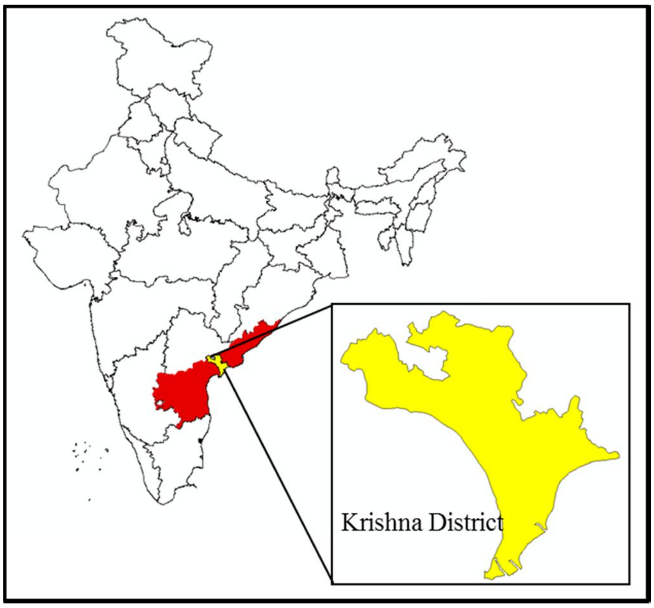

Figure 3 Map showing study area

5. DATA USED

5.1 SATELLITE DATA

High resolution Resourcesat-2 LISS-IV and Cartosat-1 PAN data have been used, covering the study area. Table 1 shows the specifications of both these sensors as well as the data that has been used for the study. In case of LISS-IV, April-June period data was selected so as to avoid spectral mixing/overlap with competing crops. Cartosat-1 PAN data was selected based on availability (1 year offset) since both mango and oil palm are long duration crops. Both these datasets were used in stand-alone as well as in merged mode in order to ensure maximum separability.

Table 1 Specifications of LISS-IV and PAN sensors and data used for study

	Resourcesat-2 LISS-IV	Cartosat-1 PAN
No. of bands	3 (MX)	1 (Mono)
Spectral bands (μ)	B2 0.52 - 0.59 B3 0.62 - 0.68 B4 0.77 - 0.86	0.5 - 0.85
Resolution (m)	2.5	5.8
Quantisation	10 bit	10 bit
Data used	Apr – May, 2014 (7 scenes)	Mar – Dec 2014 (16 scenes)

5.2 ANCILLARY DATA/SOFTWARE

The following data/software have been used in the study:

a. Vector layer of study area
b. Smart mobile with CHAMAN app for field data collection
c. eCognition – for object oriented classification
d. ERDAS Imagine - for manual editing
e. ArcGIS – for extracting vector-based statistics
f. Statistics on mango and oil palm plantations/area from State Horticultural Department

6. APPROACH AND METHODOLOGY

Object oriented approach has been adopted in the project. Hybrid classification technique employing both visual and digital interpretation techniques have been used for delineation of spatial extent of mango and oil palm crops. The broad methodology is given in Figure 4. The spatial statistics have been compared with the data from Bureau of Economics & Statistics.

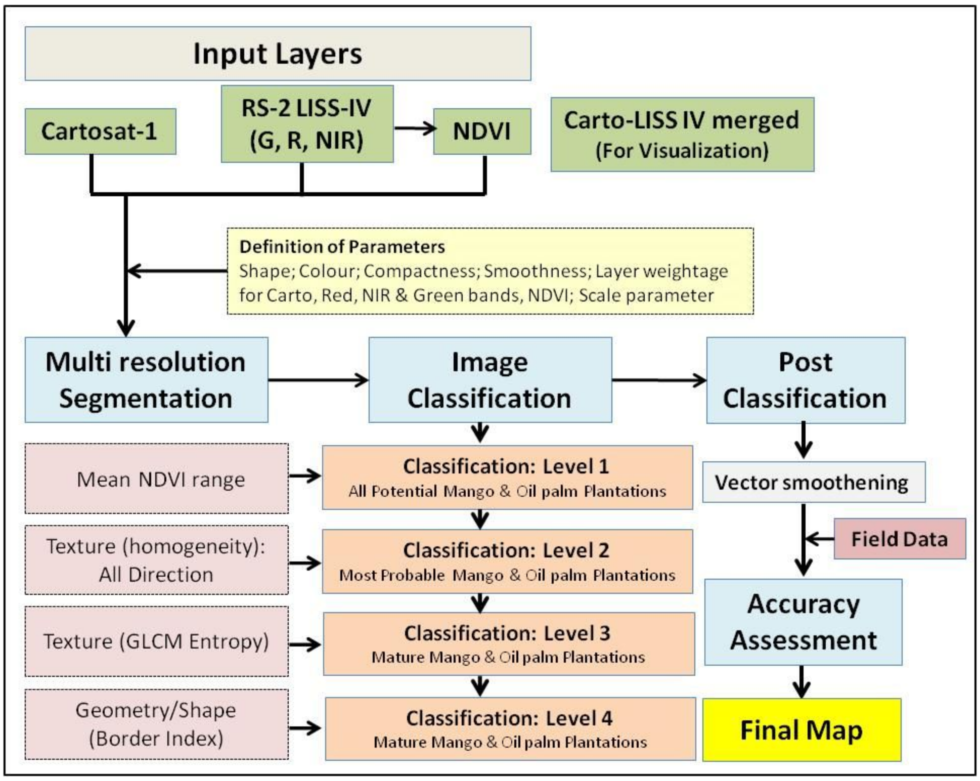

Figure 4 Methodology for Classification of Mango and Oil palm Plantations

6.1 PRE-PROCESSING

Automated co-registration of 5.8m LISS-IV and 2.5m PAN data is done to bring them to a common scale. Next step is to carry out data fusion. High resolution panchromatic data has been merged with multi-resolution LISS-IV data. This results in a high resolution multispectral image which is an improvement in terms of both spatial and spectral resolutions. The transformation method that has been used is Brovey Transformation, also called the color normalization transform as it involves a Red-Green-Blue (RGB) color transform method. This simple technique integrates the imagery of different spatial resolutions using a ratio algorithm. Each band is divided by sum of the three channels to normalize the data and then multiplied by panchromatic data to generate fused images. It retains the corresponding spectral feature of each pixel, and transforms all the luminance information into a panchromatic image of high resolution.

The three new channels are calculated according to the formula –

$$DN\_red\ (new) = \frac{DN\_red}{DN\_red + DN\_green + DN\_blue} * DN\_PAN$$

$$DN\_blue\ (new) = \frac{DN\_blue}{DN\_red + DN\_green + DN\_blue} * DN\_PAN$$

$$DN\_green\ (new) = \frac{DN\_green}{DN\_red + DN\_green + DN\_blue} * DN\_PAN$$

Brovey Transform increases the visual contrast in the low and high ends of an images histogram, providing contrast in shadows, water and high reflectance areas such as urban features. In case of mango and oil palm orchards, this results in easy delineation, as can be seen from Figure 5.

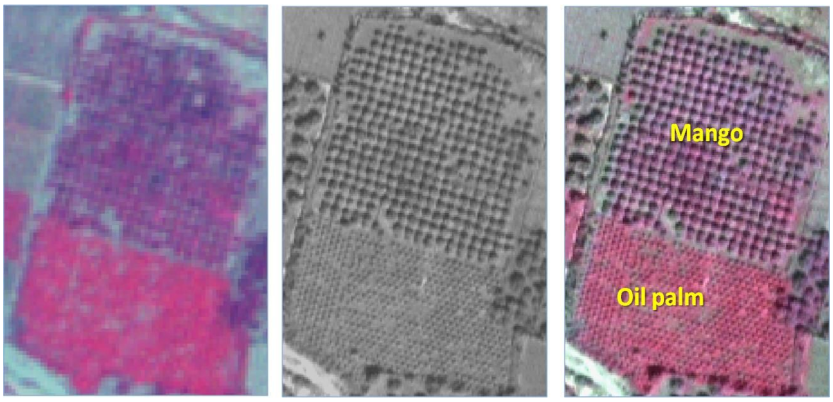

Figure 5 Mango and oil palm plantations seen through LISS-IV, PAN and LISS-IV + PAN merged image

The next step is the generation of Normalised Difference Vegetation Index (NDVI). NDVI, which is an indicator of vegetation cover, vigour, biomass and crop condition, uses the reflectance in red and near-infrared bands to give a numerical indicator that is the most commonly used index for condition assessment and monitoring. NDVI values range from -1 to +1. Red and NIR bands of LISS-IV have been used to generate NDVI image of study area. The vector layer of the study area is used to clip all these outputs to required area. Hence, the outputs obtained after pre-processing are –

- Co-registered LISS-IV and PAN datasets of the study area
- LISS-IV + PAN merged datasets of the study area
- NDVI images of the study area

6.2 COLLECTION OF FIELD DATA

Field information on the distribution of different land cover classes in general, and mango and oil palm crop in particular, has been collected in major mango and oil palm growing mandals of Krishna district. These included parameters like crop, its age and condition, spacing, mode of irrigation, etc. A customised mobile application - CHAMAN app - has been developed at NRSC. This aids in faster and more efficient collection of ground information about the crop along with field photographs, as well as in building up a geodatabase which can be directly uploaded on to Bhuvan server. The parameters collected from CHAMAN app are seen in Table 2.

Table 2 Parameters collected through CHAMAN app

Sl.	Parameter	Information
1	Location	In terms of lat/long taken through the GPS in mobile phone
2	Field photos	Two photos of the field
3	Village name	Name of the village
4	Crop name	Name of the crop
5	Crop variety	Crop variety
6	Fruit bearing age	Young/old
7	Orchard type	Mixed or pure
8	Spacing	Spacing between the crops/plants
9	Water source	Weather irrigated or rain-fed
10	Inter-crop	Name of the crop grown along with crop of interest
11	Soil type	Red, black or loamy
12	Management	Good, average or poor
13	Stress, if any	Water, pest or any other
14	Yield	Information from farmer
15	Any other information	Additional information not included in the above

6.3 IMAGE CLASSIFICATION

In the analysis of high spatial resolution data, texture is also an important parameter. There are several paradigms for measuring texture mathematically. A commonly used one is based on Grey Level Co-occurrence Matrix (GLCM), a two-dimensional histogram of grey levels for a pair of pixels, separated by a fixed spatial relationship. The GLCM approximates the joint probability distribution of a pair of pixels. Most of the texture measures are computed from GLCM directly. Some of the texture measures used here are:

- Homogeneity - is high when GLCM concentrates along the diagonal. This occurs when the image is locally homogeneous.
- Entropy - is high when the elements of GLCM have relatively equal values. Low when the elements are close to either 0 or 1 (i.e. when the image is uniform in the window).
- Angular Second Moment - is the opposite of Entropy. It is high when the GLCM has few entries of large magnitude, low when all entries are almost equal. This is a measure of local homogeneity.

PAN, LISS-IV, NDVI and PAN+LISS-IV merged images have been used as input layers. Multi resolution segmentation has been done after assigning scale parameter and weightages to various parameters like shape, compactness, color, smoothness and NDVI. The scale of segmentation is fixed based on the objective of the study. Figure 6 shows the same image with three different scales of segmentation. As it can be seen, the segmentation 'density' changes as the scale changes. If the purpose of the study is tree count, a low segmentation scale will help in classifying the same. However, for classification of larger units like orchards/plantations, a moderate scale of segmentation serves the purpose. A segmentation scale of 40 has been selected for the present study, based on the experience of a pilot study that was carried out earlier. Similarly, the values of other parameters have been chosen so as to best it the objectives of current study.

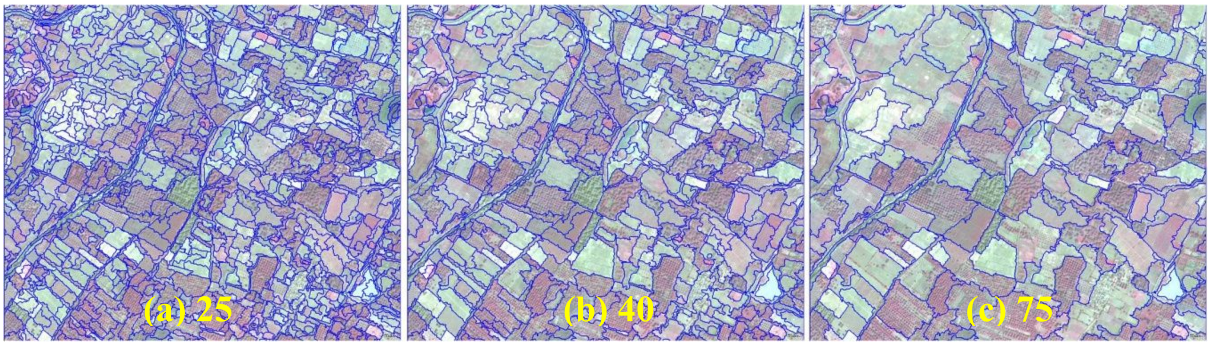

Figure 6 Satellite images split into polygons created with different segmentation parameters

The next step is to classify the output obtained after segmentation. Then, in a step-wise hierarchical mode, segregation is done, first based on NDVI, to delineate cropped/plantation areas from non-cropped and other classes. In the next step, the potential mango and oil palm areas are delineated based on the texture and shape/geometry information obtained from high resolution PAN data, computed through the parameters of entropy, homogeneity, border index etc., derived from GLCM. Next, post-classification is carried out by smoothening of vector file by applying a tolerance limit. Table 3 shows a list of the parameters and their assigned values in order to carry out segmentation and classification of mango plantations.

Table 3 Definition of parameters for segmentation and classification

Parameter	Assigned value	
Segmentation		
Shape, Colour, Compactness, Smoothness	0.1, 0.9, 0.5, 0.5	
Layer weight	Carto - 3, R - 1, NIR - 2, G - 1, NDVI - 2	
Scale parameter	40	
Classification		
Mean NDVI - NDVI range (-0.019 to 0.472)	> 0.245, <= 0.355 as Mango	> 0.34, <= 0.565 as Oil palm
Texture (homogeneity): All Direction; range (0.668 to 0.996)	>= 0.077 to =< 0.09 as Mango	>= 0.045 to =< 0.065 as Oil palm
Texture (GLCM Entropy) - Entropy range (0.071 to 2.51)	>= 1 to =< 1.7 as Mango	>= 0.8 to =< 1.3 as Oil palm
Geometry/Shape (Border Index); Border index range (1.09 to 4.57)	<1.8 as Mango orchard	<2.1 as Oil palm orchard

Fine-tuning of these maps has been done with limited visual interpretation technique. Figure 7 and Figure 8 show the classified images of mango and oil palm plantations in part of the study area.

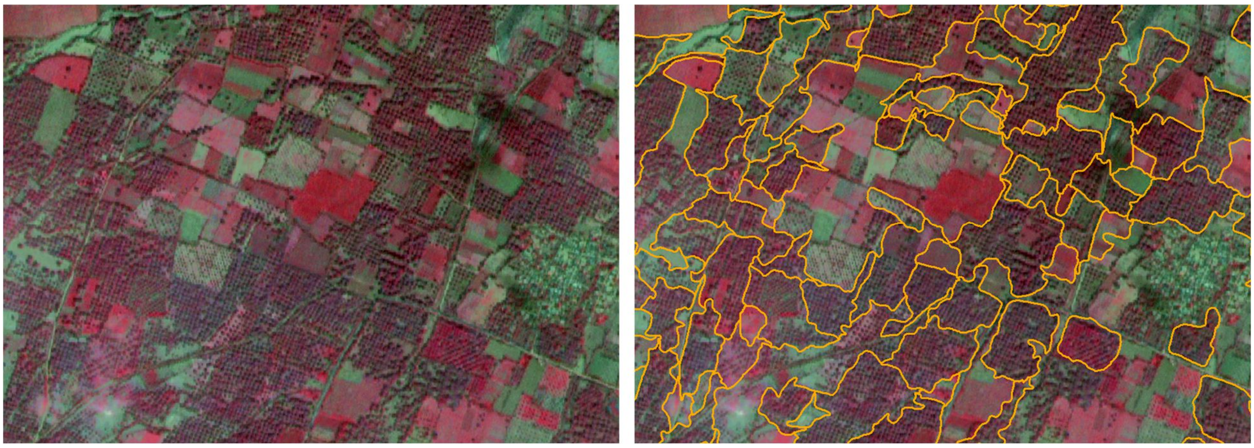

Figure 7 Satellite image showing classified mango plantations in part of Krishna district

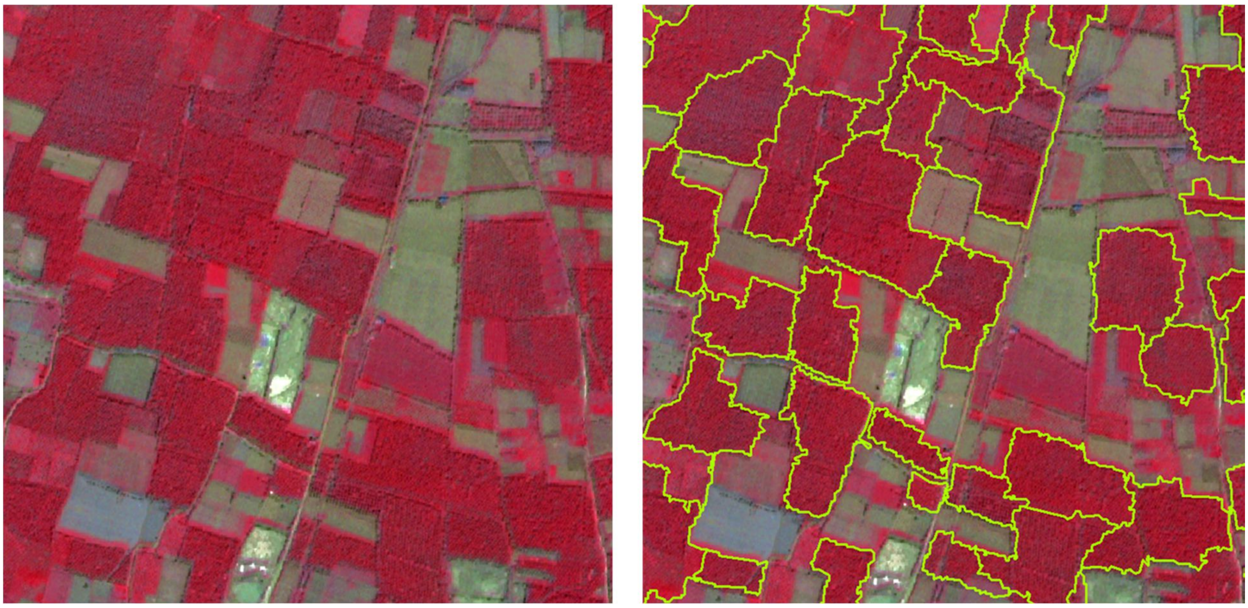

Figure 8 Satellite image showing classified oil palm plantations in part of Krishna district

Based on the field data collected, a second level and final classification was done. Assessment was carried out using data from mobile app collected on crop locations. The possible sources of classification error include – (a) omission of young mango/oil palm plantations (< 2 years old) to other classes, (b) very few isolated fields of dense miscellaneous trees are commissioned, (c) omission of mango/oil palm plantations where the intra-tree spacing is very large. After accounting for omissions and commissions, the classification accuracy is found to be 89%.

7. RESULTS

Figure 9 shows the classified image of Krishna district showing spatial extent of mango and oil palm plantations. Satellite based estimation indicated that 55,835 ha was under mango while 6,542 ha area was under oil palm plantations.

The marginal disagreement in final area estimates for both the crops with respect to the estimates of the State government is due to the fact that even from high resolution satellite data, it is difficult to delineate between mango and oil palm/any other plantations that are less than 5 years of age. Also, some of the plantations have very large intra-tree spacing, thus hampering the classification.

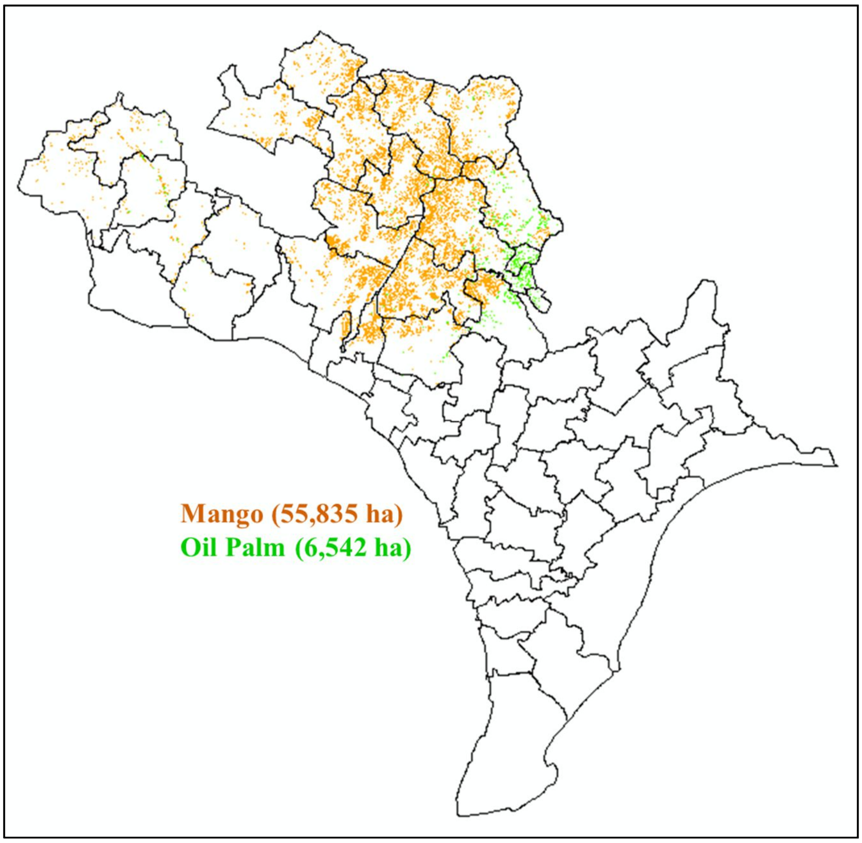

Figure 9 Crop map showing spatial extent of Mango and oil palm in Krishna district

8. CONCLUSIONS

Object oriented method has shown its potential in delineating mango and oil palm plantations at sub-district level. Conjunctive use of high resolution Cartosat-1 PAN data and multispectral LISS-IV data has the potential to delineate mango and oil palm plantations at sub-district level for assessing its acreage. Mapping of these plantations can be achieved with object oriented classification using a set of parameters (NDVI, texture homogeneity, texture entropy, border index etc.) in a sequential manner. Mango and oil palm plantations above 5 years age can be identified with automatic methods while young plantations have a scope of getting mixed up with competing crops. Delineation of young plantations needs more field data and a combination of both digital as well as visual techniques for interpretation. Mango and oil palm that are less than 2 years old show overlapping signatures with many other features such as current fallows, miscellaneous vegetation, etc. hence delineation of such crop with satellite images results in poor accuracies. A similar approach is being attempted for other horticulture crops, mainly citrus crops.

Close coordination with the State Horticulture Departments will help in building up a sound database of field information, which will lead to better accuracies in the estimation of acreages. Using the satellite data of previous years, the inter-annual changes in the distribution of crops in the district can be analysed. Such information products are useful to the planning activities intended to expand horticulture areas. Mobile technology for field data collection has paved the way for evolving a strong horticulture surveillance system for proactive monitoring of these high value crops in an efficient manner. Integration of weather, soil, irrigation and other datasets with crop distribution maps enable generation of a variety of information products that are crucial for horticulture planning in the district. Crop suitability analysis with multi-criteria approach would be useful for crop area expansion plans.

A part of this study was done under the national-level project namely Coordinated programme on Horticulture Assessment & Management using Geoinformatics (CHAMAN), which is a multi-institutional endeavour taken up at the specific request of Ministry of Agriculture, Government of India. Under this project, all field data collected for the analysis using mobile App is made available in the Bhuvan portal. Classified maps of specific crops for selected districts are also made available on Bhuvan portal.

9. ACKNOWLEDGEMENT

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