Cloud Publications
International Journal of Advanced Remote Sensing and GIS
2017, Volume 6, Issue 2, pp. 2033-2049
ISSN 2320 – 0243, Crossref: 10.23953/cloud.ijarsg.35

Case Study | Open Access

Horticultural Fruit Crop Plantations Mapping using Geo-informatics Technology in Gujarat State, India

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Publication Date: 18 February 2017

DOI: https://doi.org/10.23953/cloud.ijarsg.35

Abstract The cultivation and production of horticultural crops is known as "Golden Revolution" and India has emerged as the second largest producer of fruits and vegetables in the world. The Central Government of India has started National Horticulture Mission (NHM) for overall development of Horticulture and Gujarat Government has also started Gujarat State Horticulture Mission (GSHM). This mission being implemented in 16-potential districts and covers major fruit crops in the state like mango, sapota, Aonla, banana, coconut etc. Under the GSHM, mapping of fruit crop plantations using Indian Remote Sensing Satellite (IRS) data in Gujarat State was carried out jointly by the Directorate of Agriculture, Govt of Gujarat and Bhaskaracharya Institute for Space Applications and Geo-informatics (BISAG), Govt of Gujarat. The major objective of this project was mapping of fruit crop plantations at village-level and preparation of village-level Horticultural Atlas of Gujarat State. High spatial resolution digital data from IRS LISS-IV and CARTOSAT-1 with spatial resolutions of 5.8m and 2.5m respectively, covering major fruit growing districts in Gujarat state was analysed for identification and delineations of fruit crop plantations in each survey number on cadastral map. The cadastral maps of each village were geo-referenced with satellite data and survey number boundaries were superimposed on the satellite data. Fruit crop plantations were located during field visits and their GPS locations were transferred to the satellite images with cadastral maps for unique identification and accurate mapping. The fruit crops in different districts of Gujarat State were identified on the high resolution satellite data based on the planting pattern and tree-crown density. The survey numbers having fruit crop plantations were delineated on the CARTOSAT-1 data. The fruit crop plantation maps of each village were prepared and complied at village and taluka level using open-source Quantum GIS software for preparation of village-level horticultural atlas of Gujarat State. The area under fruit crop plantations was also estimated. The results of this alternate method of mapping fruit crop plantations using high resolution, single-band CARTOSAT-1 panchromatic data on cadastral maps with survey numbers gave very good results for preparation village-level horticultural atlas of Gujarat State. Field survey in different villages was also carried out for accuracy assessment of survey numbers mapped as horticultural plantations.

Keywords *CARTOSAT-1; Gujarat State Horticultural Mission (GSHM); High spatial resolution; Indian Remote Sensing Satellite (IRS); Cadastral maps*

1. Introduction

The term “Horticulture” which is a part of agriculture is concerned with the raising of so called garden crops. At present, fruits, vegetables, flowers etc. are grown not only within the backyards, but also in large areas in open fields on a commercial scale. Traditionally garden crops include fruits, vegetables and flowers. But today‘s horticulture deals not only the fruits, vegetables and flowers but also other important crops like spices, condiments, plantation crops, medicinal and aromatic plants etc. Besides cultivation of these crops, present day horticulture deals with the utilization and improvement of these crops. Horticultural crops play a unique role in India’s economy by improving the income of rural people. The cultivation and production of horticultural crops is known as **"Golden Revolution**” and India has emerged as the second largest producer of fruits and vegetables in the world. Horticulture crops have inherent advantage of providing higher productivity per unit of land compared to other crops, resulting in higher income and higher employment generation in rural Areas. Fruit trees have been cultivated since time immemorial in India. Today, India is the second largest producer of fruits in the world after China and almost all kind of fruit crops can be favourably grown in India due to its diverse agro-climatic zones. The area under fruit crops in 2011-12 was 6.58 million ha with a production of 77.52 million tonnes, which contributes to a 32 percent share in total horticultural production (Anon, 2012). Among the major fruit producing countries, India ranks number two after China (Hand Book on Horticulture Statistics, 2014) (Figure 1).

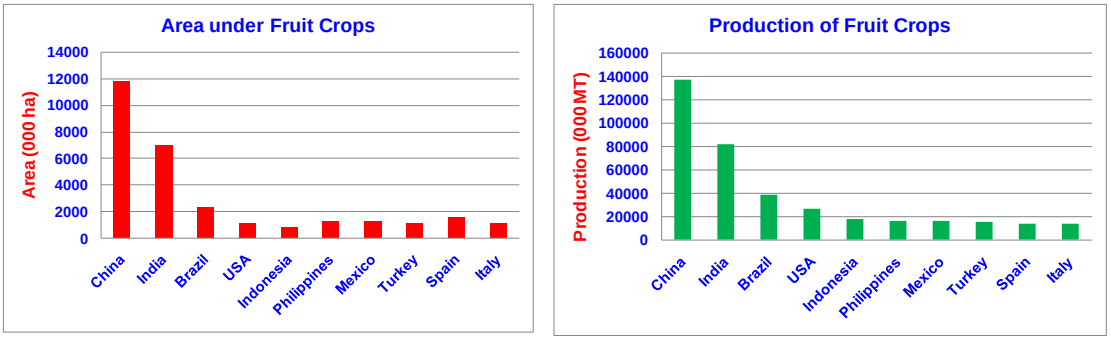

Figure 1: *Area and production of fruit crops in major fruit producing countries in the world (2012-13)*

India is one of the leading producers of horticultural crops in the Globe. Horticultural crops cover 13.08 % of the total area under agriculture and contribute to about 28 % of the GDP. These crops accounts for 37 % of the total exports of agricultural commodities. Due to planned emphasis laid on horticulture, India is accredited as the second largest producer of fruits and vegetables. India is the largest producer and consumer of cashew nut, tea and spices and it is third largest producer of coconut. India exports fruits, vegetables, processed products, flowers, seeds and planting materials, spices, cashew nut, tea, coffee etc. India is the largest producer of mango, banana, grape and litchi. However, the bulk of the production is consumed domestically. Of the total global exports for fruits, India’s share is only 0.3%. Fruits accounts for about 11% of total horticultural export from country. Grape and mango together constitute 60% of India‘s exports of fresh fruits. Citrus, banana, apple and papaya are other important fruits for export.

1.1. Horticulture in India

Over the years, horticulture has emerged as one of the potential agricultural enterprise in accelerating the growth of economy. Its role in the country's nutritional security, poverty alleviation and employment

generation programmes are becoming increasingly important. It offers not only a wide range of options to the farmers for crop diversification, but also provides ample scope for sustaining large number of Agro-industries which generate huge employment opportunities. On account of significant increase in production in horticultural crops across the country, a Golden Revolution is in the offing and India has emerged as a leading player in the global scenario. It has now emerged as the world's the largest producer of and exporter of Tea, Coffee, Cashew nut, Spices Exports of fresh and processed fruits, vegetables, cut flowers, dried flowers have also been picking up. As a result of a number of thoughtful research, technological and policy initiatives and inputs, horticulture in India, today, has become a sustainable and viable venture for the small, marginal & big farmers. It is a matter of satisfaction that their food consumption levels and household income have increased.

Presently our country is next to China in area and production of fruits and vegetable crops and has been contributing 10% of fruits and 14% of vegetable of the total world production. India leads the world in the production of mango, banana, sapota, acid lime and cauliflower while the highest productivity of grape is also recorded here. India occupies second position in production of onion and third in cabbage production globally. Fruits such as mango, banana, citrus, guava and apple account for 75 per cent of the total fruit production in the country. The horticulture sector constituted nearly 20 per cent of agricultural GDP and contributes 4 per cent in the national economy (Netherlands Enterprise Agency, 2015).

1.1.1. *Area and Production of Horticulture Crops in India during last two Decades*

The area under horticulture crops which was 12.77 million hectares during 1991-1992 has increased to 23.69 million hectares during 2012-13. The total production during this period has increased from 95.56 million tons during 1991-1992 has increased to 268.85 million tons during 2012-13 (Figure 2). The production share of various horticultural crops in India is given in (Figure 3). The share of vegetables and fruits production is around 61 % and 30 %, respectively. A large variety of fruit crops are grown in India. Of these, mango, banana, citrus, papaya, guava, pineapple, sapota, jackfruit, litchi, grapes, apple, pear, peach, plum, walnut etc. are the important ones. India accounts for 10 per cent of the total world production of fruits. It leads the world in the production of mango, banana, sapota and acid lime besides recording highest productivity in grape. The leading fruit growing states in India are Maharashtra, Karnataka, Andhra Pradesh, Bihar and Uttar Pradesh (Naik and Thippesh, 2014). The area and production of major fruit crops in leading fruit producing states in India are given in Figure 4. Among the major fruit producing states in India, Gujarat State ranks number three in terms of both area and production of fruit crops after Andhra Pradesh and Maharashtra States (Hand Book on Horticulture Statistics, 2014).

1.2. Horticulture in Gujarat

Horticulture is a priority sector in agriculture by virtue of its vast potential in improving the socio economic condition of the farmers in Gujarat State. Gujarat has tropical & sub-tropical climate, with temperature ranging from a minimum of 13^{o}C to 27^{o}C in January and a maximum of 45^{o}C in May-June. The normal annual rainfall of Gujarat state is 852 mm and has about 1600 Km long coastal area. However, there is a wide annual variation in rainfall, affecting the productivity of the crops. The climate favours for development of fresh fruits like; Kesar-Alphanso Mangoes, Sapota, Banana, Aonla and Dates. The vegetables like; Okra, Beans, Cucurbits, Onion Potato, the spices like, Cumin, Fennel, Chilly, Coriander, Garlic and the flowers like, Rose, Lily, Marigold, Jasmine and Tuberose. Grapes, Cashew nut Medical and Aromatic crops like Aloevera, Palmarosa are emerging as potential new crops in suitable areas of the state. Investment in protected cultivation of floriculture and medical plant projects, tissue culture units, fruit and vegetable processing units are initiated in the state which shows shining future of Horticulture in the Gujarat State.

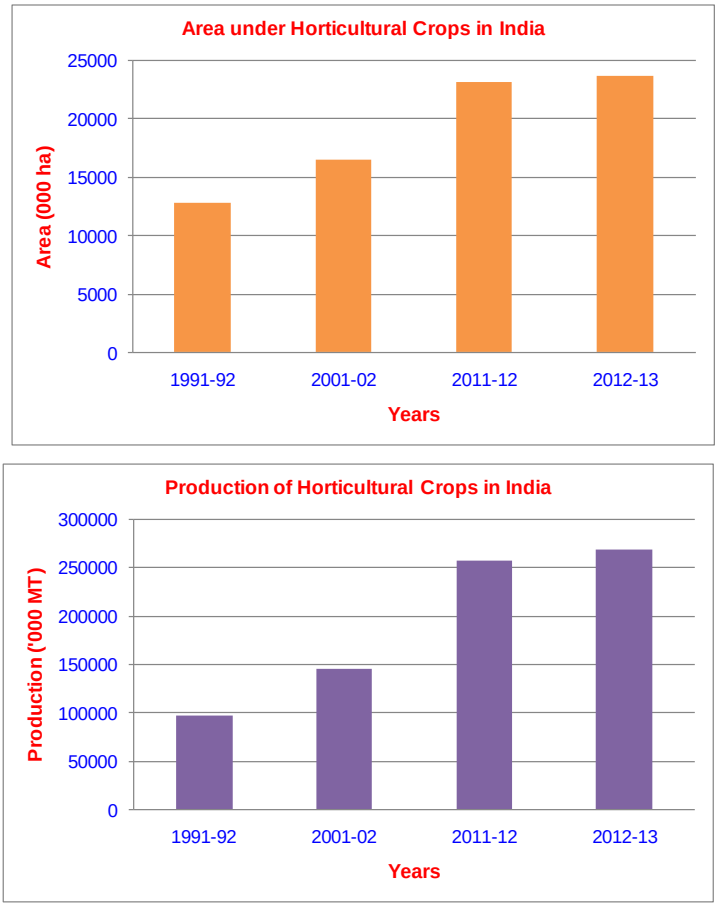

Figure 2: *Area and production of horticultural crops in India during last two decades*

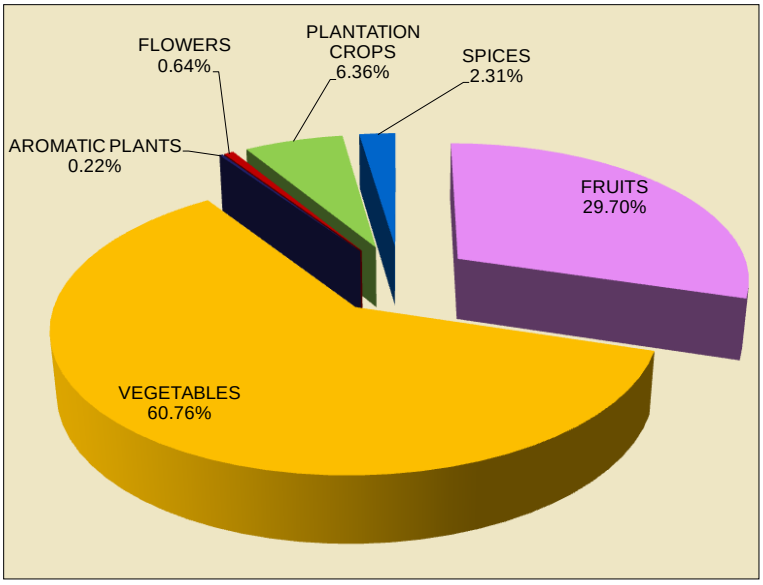

Figure 3: *Production share of various horticultural crops in India*

1.2.1. *Gujarat Horticulture Mission*

The Central Government has started National Horticulture Mission (NHM) from the year 2005-06 for overall development of Horticulture. The Gujarat Government has also registered "Gujarat Horticulture Mission" under the Chairmanship of Principal Secretary of Agriculture. At the district level district

mission committee has been formed under the Chairmanship of District Development Officer. The work of Horticulture Mission has been done in the State by this registered mission. Gujarat State Horticulture Mission (GSHM) a registered society has been formed for implementation of NHM in the state. The mission is being implemented in 16 potential districts and covers important horticultural crops of the state viz, Mango, Chiku, Aonla, Banana, Papaya, Lime, Cumin, Fennel, and Flowers, Medicinal and Aromatic crops, etc.

1.2.2. *Area & Production of Fruit Crops in Gujarat State*

The major crops covered under fruit crops are Mango, Chiku, Citrus, Ber, Banana etc in the Gujarat State. The estimated area under fruit crops has increased from 160.02 thousand ha during the year 1995-96 to 398.37 thousand ha during the year 2012-13. Similarly the estimated production of fruit crops has increased from 21.29 lakh M.T., during the period 1995-1996 to 85.31 lakh MT., during the year 2012-13. The area and production of major fruit crops in Gujarat State during the period of 1987-88 to 2012-13 are given in Figure 5.

(Horticulture in Gujarat 2011-12 & 2012-13)

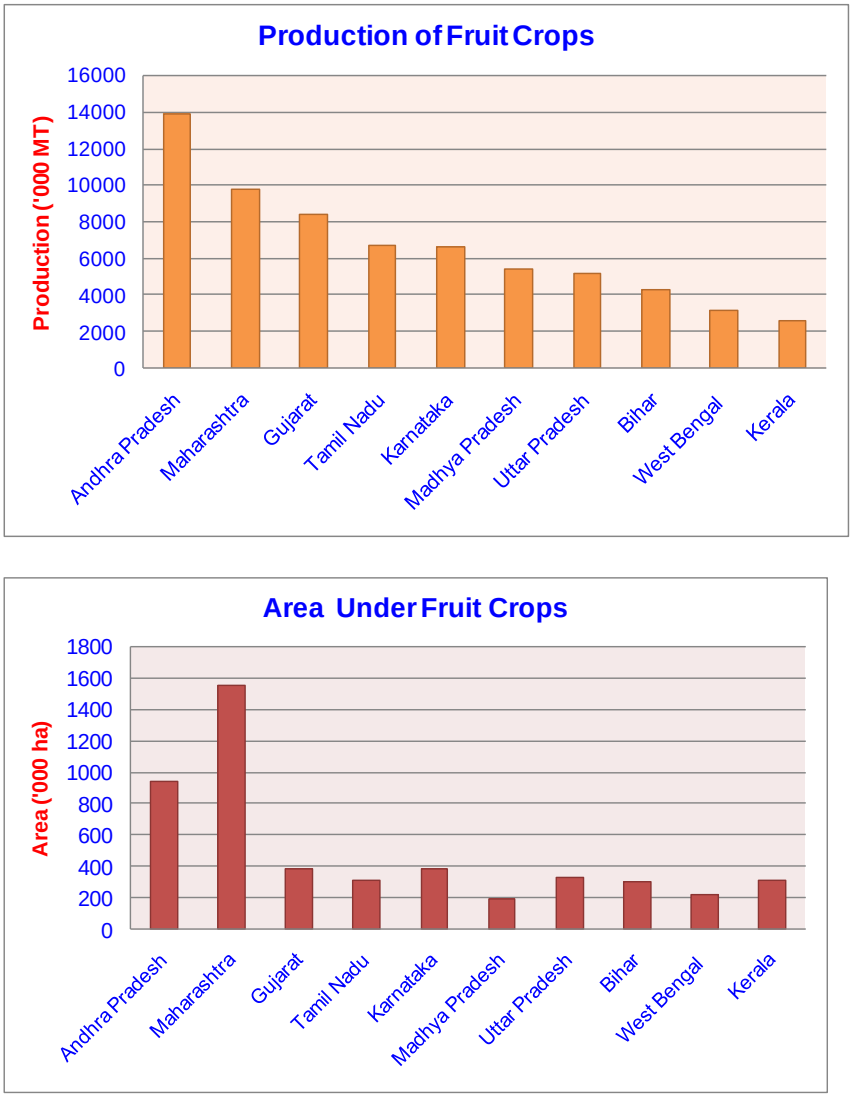

Figure 4: *Area and production of fruit crops in major states of India during 2012-13*

1.2.3. *Major Fruit Crops Producing Districts in Gujarat State*

The major crops covered under fruit crops are Mango, Chiku, Citrus, Ber, Banana etc. in the Gujarat State. The estimated area under fruit crops has increased from 160.02 thousand ha during the year 1995-96 to 398.37 thousand ha during the year 2012-13. Similarly the estimated production of fruit crops has increased from 21.29 lakh M.T., during the period 1995-1996 to 85.31 lakh MT., during the year 2012-13. The estimated area under fruit crops for mango, chiku, citrus and banana has increased in 2012-13 to 141.26 thousand ha., 28.81 thousand ha, 40.79 thousand ha, and 70.58 thousand ha as compared to 52.88 thousand ha., 13.73 thousand ha.,12.91 thousand ha., 24.09 thousand ha in the year 1996-97 respectively. The estimated production under fruit crops for mango, chiku, citrus, ber been, and banana has increased in 2012-13 to 1003.71 thousand M.T., 309.89 thousand M.T., 433.12 thousand M.T., 128.63 thousand M.T., 4523.49 thousand M.T., as compared to 288.93 thousand M.T., 120.76 thousand M.T., 68.70 thousand M.T., 115.74 thousand M.T., 903.66 thousand M.T., in the year 1996-97, respectively. In the case of fruits Crops, the percentage share to total fruits Crops for mango, Chiku, Citrus, and Banana, works out to percentage 11.77%, 3.63%, 5.08%, 53.02%, for the year 2012-13, respectively in the Gujarat State. The fruit crop-wise districts with share of production (%) in Gujarat state during 2012-13 for mango, chiku, citrus and banana crops is given in Figure 6.

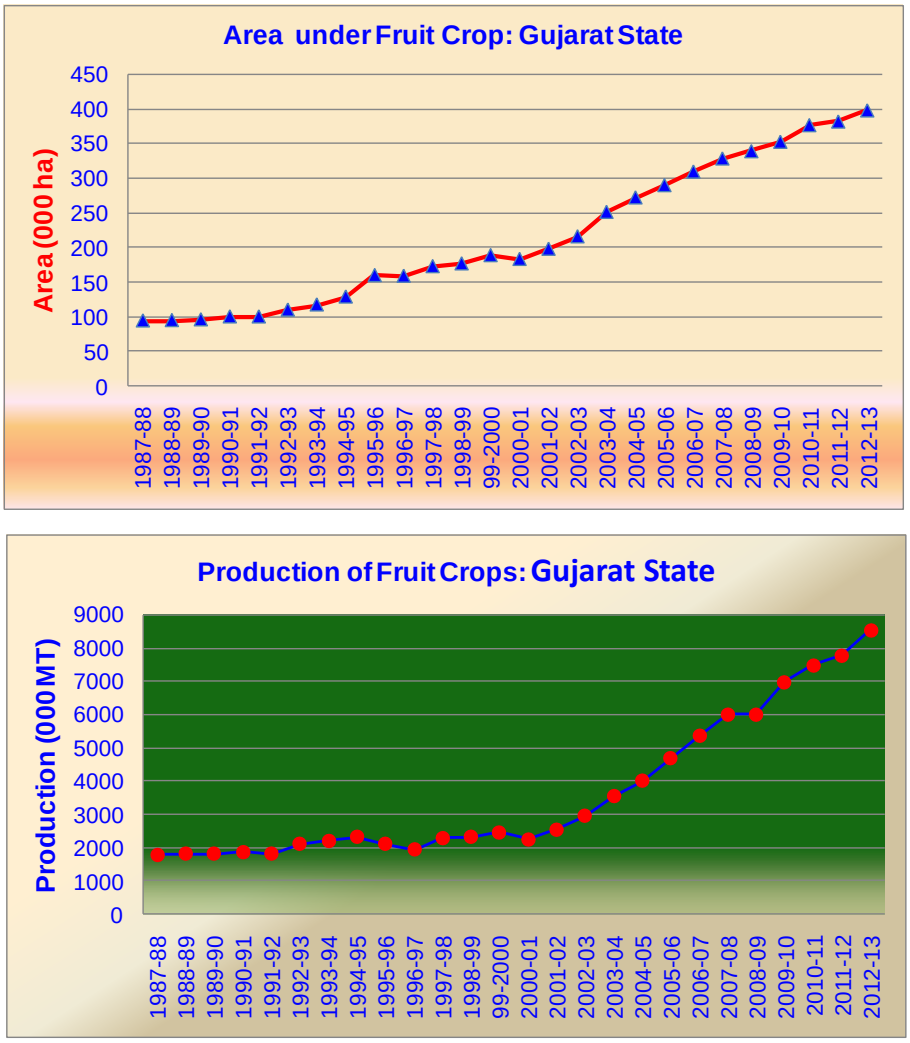

Figure 5: *Area and production of fruit crops in Gujarat state during last 25-years*

1.3. R S and GIS Studies for Horticultural Crops

The delineation of orchards and spatial analysis using geospatial technology can provide additional information for management decision making, such as the prediction of fruit yield, the quantification and scheduling of precise and proper fertilizer, irrigation needs, and the application of pesticides for pest and disease management. Therefore, today, the use of Remote Sensing (RS) has becoming importance for the general detection of the growth and health of orchards on a larger scale. Similarly, digital imaging technology is increasingly being used for intensive site-specific management of orchards (Panda et al., 2010). With an adequate database, GIS can serve as a powerful analytic and decision making tool for fruit culture development particularly in big country like India, where agro-ecological zones is so diverse. GIS is one of the most widely used techniques for mapping fruit trees. The determination of spatial distribution of slope exposure and slope inclination in fruit growing areas will help in determining the ecological suitability of an area for fruit growing and their influence to a large extent in both directions of fruit production and fruit quality.

The delineation of orchards and spatial analysis using geospatial technology can provide additional information for management decision making, such as the determination of fruit yield, the quantification and scheduling of precise and proper fertilizer, irrigation needs, and the application of pesticides for pest and disease management. Ultimately, it will improve profits for producers (Panda et al., 2009). Geospatial technology is a combination of four essential tools: remote sensing, geographic information systems (GIS), global positioning systems (GPS), and information technology or data management (Lobell et al., 2005).

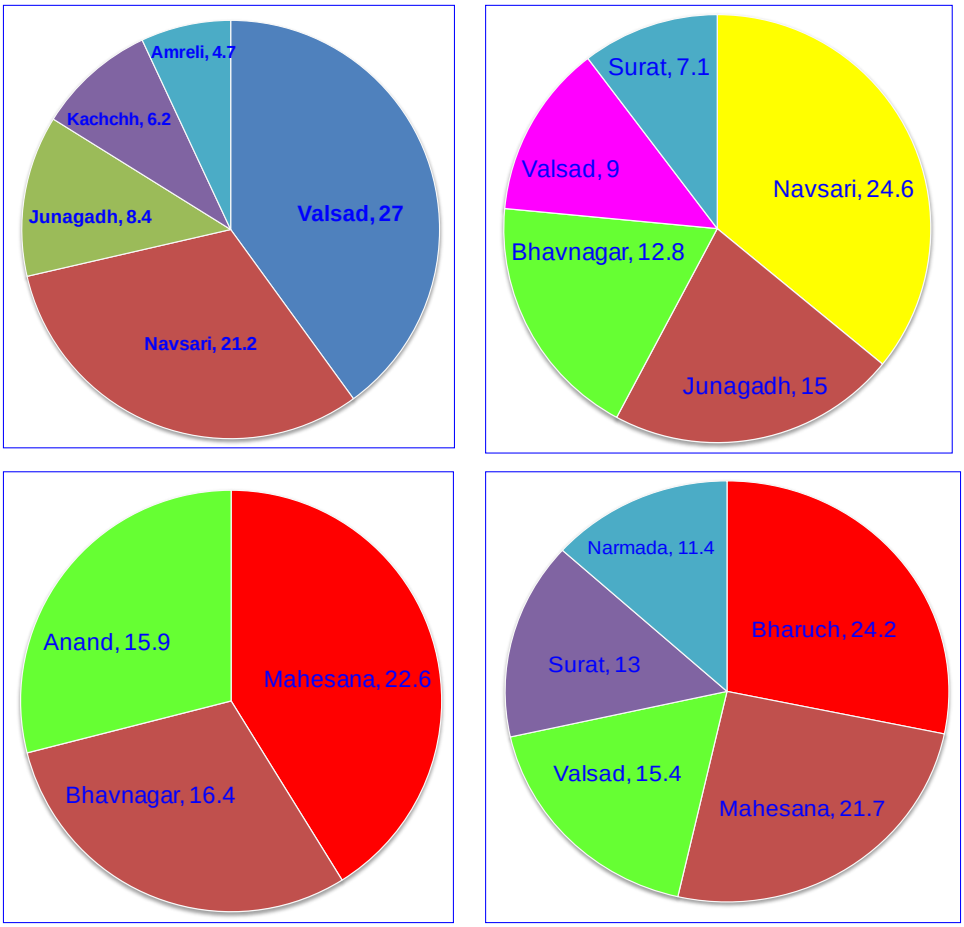

Figure 6: *Fruit crop-wise districts with major share of production (%) in Gujarat state (2012-13)*

A study for identification and mapping of apple and almond plantations was conducted in the Kumarsain tehsil of Shimla district using Indian remote sensing satellite (IRS-IB) LISS-II data. False Colour Composites (FCC) of October 27, March 30 and April 20, 1992 were visually analysed for mapping apple and almond plantations. The results indicated that IRS LISS-II data of month of April on 1:50,000 scale was found very useful for identification and mapping of apple and almond plantations in this region (Kimothi et al., 1997). Recognising importance of horticulture in promoting livelihood and employment opportunity and bringing prosperity to the state, the Govt. of India has extended National Horticulture Technology Mission Programme to Himachal Pradesh. The objective of Mission is to develop horticulture based farming system that is economically viable and ecologically sustainable using all the modern tools and techniques available. The space technology including remote sensing, Global Positioning System (GPS) and Geographical Information System (GIS) are the advanced tools that aid in gathering and updating information and develop scientific management plans. Updated and accurate database is pre-requisite for systematic planning of horticulture sector be it area expansion, increase in productivity or creating post-harvest handling facilities. With this aim, a study was carried out to generate block wise database on apple plantation in Shimla which is the largest apple growing district of Himachal Pradesh. Remote sensing data from the Indian Remote Sensing satellites like IRSP6 has been used along with other international sensors to generate apple orchard maps, orchard conditions in term of density, terrain parameters like elevation, slope, aspect etc. The GIS tools have been used to characterize the orchard distribution pattern in relation to terrain parameters (Sharma and Panigrahi, 2007).

The Haryana state has a rich diversity of horticultural crops due to the presence of diverse agro-climatic zones ranging from sub-tropical and semi-arid to sub-humid. A study was carried out in Adampur and Hisar-IInd development blocks of Hisar district using satellite data of World View-2 (March to Dec., 2011) and IRS-P6-LISS-III (Feb., 2011). The results of this study indicated that, total area under horticultural crops was 7, 865 hectares during 1966-67, which had increased to 45, 910 hectares by the end of 2010-11 of whole Haryana state. Citrus is the major crop of the study area followed by Guava, kinnu and anola. According to this investigation the total area under the horticulture fruit crops was 506.23 ha in Adampur block and 445.88 ha in Hisar-II block (Veena, 2014).

2. Objectives

The project on mapping of horticultural fruit crops in Gujarat State was carried out jointly by the Directorate of Agriculture, Govt of Gujarat and Bhaskaracharya Institute for Space Applications and Geo-informatics (BISAG), Govt of Gujarat. The major objectives of this were as follows:

i) Mapping of Horticultural fruit crops using high resolution Indian Remote Sensing Satellite (IRS) LISS-IV and CAROTSAT-1 digital data covering major fruit crops growing districts in Gujarat State;
ii) Mapping of fruit crops grown at plot-by-plot in each survey number on the cadastral maps;
iii) Preparation of village-level Horticultural Atlas of Gujarat State;
iv) District and Taluka-level area estimation under fruit crops.

3. Methodology

Remotely sensed images are a quick and inexpensive means to differentiate fruit trees or orchards from other land-uses. Geographic Information Systems (GIS) can also help in delineation of fruit crop orchard boundary, ground truth data collection, and preparation of other spatial data from the geo-referenced cadastral maps (Panda and Hoogenboom, 2009). Identification and discrimination of various vegetation types /land cover classes requires use of subtle differences in their spectral data and hence rely mostly on digital image processing techniques. As fruit crops have similar spectral characteristics to forested vegetation, supervised classification is not the best procedure to distinguish these crops even using high resolution Remote Sensing data. Therefore, in the present study geo-

referenced cadastral boundaries with survey numbers were superimposed on the high resolution IRS LISS-IV and CARTOSAT-1 digital data. The fruit crop plantations were delineated in each survey number based on planting pattern with canopy density observed on the CARTOSAT-1 digital data.

3.1. Horticultural Plantations Mapping Procedure

Mapping of horticultural plantations especially fruit crops in different districts using Indian Remote Sensing Satellite (IRS-P6) LISS-IV and CARTOSAT-1 digital data consisted of following procedural steps:

i) IRS LISS-IV and CARTOSAT data preparation and geo-referencing;
ii) Administrative (district/block/village) boundary superimposition;
iii) Geo-referencing of Cadastral maps with IRS LISS-IV and CARTOSAT-1 data;
iv) Superimposing GPS locations of various fruit crop sites collected during field visits on the geo-referenced Satellite and cadastral maps;
v) Identification & delineation of various fruit crops on the survey numbers of each cadastral map superimposed on CARTOSAT digital data;
vi) Generation of spatial information in GIS environment at the taluka and district-level;
vii) Generation of thematic maps showing fruit crops extent in each district;
viii) Quality checks and accuracy assessment based on Field data.

3.2. Study Area

The mapping of major fruit crops in Gujarat State was carried out in those districts where fruit crops are grown on large scale. The major fruit growing districts in Gujarat State consists of Junagadh, Amreli, Bhavanagar, Navsari, Valsad, Mehsana, Vadodara, Bharuch, Surat, Gandhinagar, Ahmedabad, Kheda, Anand district. Various fruit crops like Mango, Sapota (Chiku), Citrus, Banana, Ber, Coconut etc. are cultivated in these districts. The major fruit crop-wise districts and their contribution in total production of Gujarat state for some fruit crops is given in Figure 6.

3.3. Satellite Data Used

The high resolution data from Indian Remote Sensing Satellite (IRS-P6) LISS-IV and CARTOSAT-1 covering major districts in Gujarat State was acquired for mapping fruit crops. The details of IRS LISS-IV satellite data acquired for some of the districts are given in Table 1. The Cartosat-1 data with 2.5 m spatial resolution was also acquired for the all the fruit crops growing districts in Gujarat state.

***Table 1**: Indian Remote Sensing Satellite (IRS-P6) and CARTOSAT data used for village-level fruit crop plantations mapping in different Districts*

Sr. No.	District	Sensor	Path/Row	Date of Pass
1	Kachchh	LISS-IV	202/60	27-Apr-2009
2	Kachchh	LISS-IV	202/62	27-Apr-2009
3	Kachchh	LISS-IV	201/94	08-May-2007
4	Mahesana	LISS-IV	202/88	13-Apr-2009
5	Junagadh	LISS-IV	202/85	15-Mar-2009
6	Junagadh	LISS-IV	202/97	26-May-2009
7	Junagadh	LISS-IV	202/87	02-May-2009
8	Junagadh	LISS-IV	201/103	12-May-2008
9	Bhavnagar	LISS-IV	202/84	18-Apr-2009
10	Bhavnagar	LISS-IV	202/90	07-May-2009
11	Bhavnagar	LISS-IV	202/91	07-May-2009
12	Vadodara	LISS-IV	202/70	06-Mar-2008
13	Vadodara	LISS-IV	202/72	06-Mar-2008

14	Navsari	LISS-IV	202/67	23-Apr-2009
15	Navsari	LISS-IV	202/67	23-Apr-2009
16	Valsad	LISS-IV	202/67	23-Apr-2009
17	Valsad	LISS-IV	202/68	23-Apr-2009
18	Valsad	LISS-IV	202/69	23-Apr-2009

3.4. Collateral data

- Cadastral maps of major villages where fruit crops are grown on large scale were collected and digitized for superposing on the satellite digital data;
- Ground-Truth (GT) data of various fruit crops in selected villages was collected in each survey number where fruit crops are grown using the digitized village maps superposed on satellite digital data.

3.5. Geo-referencing and Transformation of Cadastral Map

Image rectification and geo-referencing involves the removal of random and systematic errors of image and transforming image to UTM coordinate system in WGS84 datum. IRS LISS-IV and CARTOSAT digital data was registered using Ground Control Points (GCPs) identified on image and Global Positioning System (GPS) measurements. For image rectification a large number of well distributed GCPs were identified in the image and their scan line – pixel coordinates were recorded. The GCPs identified on the image were accurately located on the ground and their Latitude-Longitude coordinates were recorded using the GPS. Using these GCPs and GPS measurements, second order polynomials with nearest neighbour (NN) resampling procedure, the georeferenced images were generated. Root Mean Square (RMS) errors of georeferencing were within ±0.5 to 0.75 pixels. The Cadastral maps of villages were superimposed over geo-referenced LISS-IV and CARTOSAT satellite images. The IRS LISS-IV geo-referenced images of two villages along with plot boundaries superposed from the cadastral maps are given in Figure 7 and CARTOSAT-1 image with plot boundaries superposed from the cadastral map is given in Figure 8.

Figure 7: *IRS LISS-IV image of Vanthali village with plot boundaries superimposed from cadastral maps*

3.6. Ground Truth (GT) data collection of fruit crop Plantations

Ground truth/field data collection is an important component in this project and an important source of information for verification and accuracy estimation / validation of thematic details mapped from satellite imagery. Initially a reconnaissance survey was carried out in each district where fruit crops are grown on large scale to identify fruit crops growing areas in each district and base maps were prepared for detailed ground truth data collection. The cadastral survey numbers were also superimposed on theses base maps for detailed and accurate identification of fruit crops. During detailed Ground truth data collection, hard copies of CARTOSAT-1 images with cadastral survey numbers along with Global Positioning System (GPS) were used for accurate marking of fruit crops on the high resolution CARTOSAT-1 data. This detailed Ground Truth (GT) information was used to prepare interpretation key for identification and delineation fruit crops in survey numbers of each village. The field photographs of various fruit crops grown in various villages along with GPS measurements were recorded to help in accurate mapping of fruit crops in various villages using CARTOSAT satellite images. Some of the field photographs of various fruit crops grown in different districts are given in Figure 9.

Figure 8: *CARTOSAT-1 image with plot boundaries superimposed from geo-referenced cadastral map*

4. Results and Discussion

4.1. Delineation and Mapping of Fruit Crop Plantations

In this study, the major trust was on identification and delineation of fruit crop plantations based visual interpretation rather than digital classification. The fruit crops in different districts of Gujarat State were identified on the high resolution IRS LISS-IV and CARTOSAT-1 data based on the planting pattern and tree-crown density. In this study an alternate method of mapping fruit crop plantations using high resolution, single-band CARTOSAT-1 panchromatic data on cadastral maps with survey numbers gave very good results for preparation village-level horticultural atlas of Gujarat State. Field survey in different villages was also carried out for accuracy assessment of survey numbers mapped as horticultural plantations. These fruit crop plantations were identified on CARTOSAT-1 data superimposed with cadastral map and survey numbers. The fruit crop plantations delineated using

CARTOSAT-1 data superimposed with cadastral map and survey numbers are given in Figures 10 and 11. These figures indicate those survey numbers only which have fruit crop plantations delineated on the CARTOSAT data along with cadastral boundaries.

Figure 9: *Field photos of major fruit crops: mango, banana papaya and coconut grown in different districts of Gujarat state*

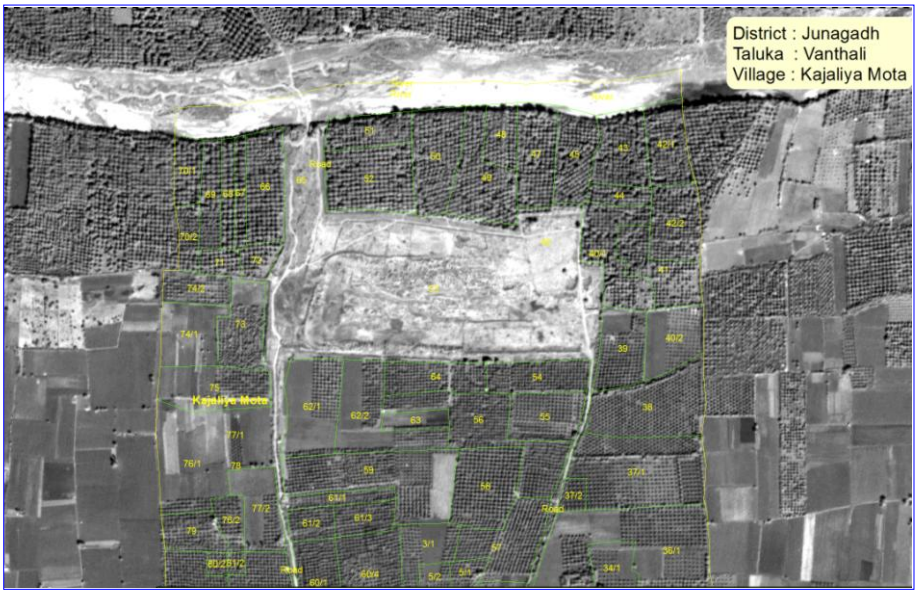

Figure 10: *CARTOSAT-1 image with survey numbers having fruit crop plantations in Vanthali Taluka*

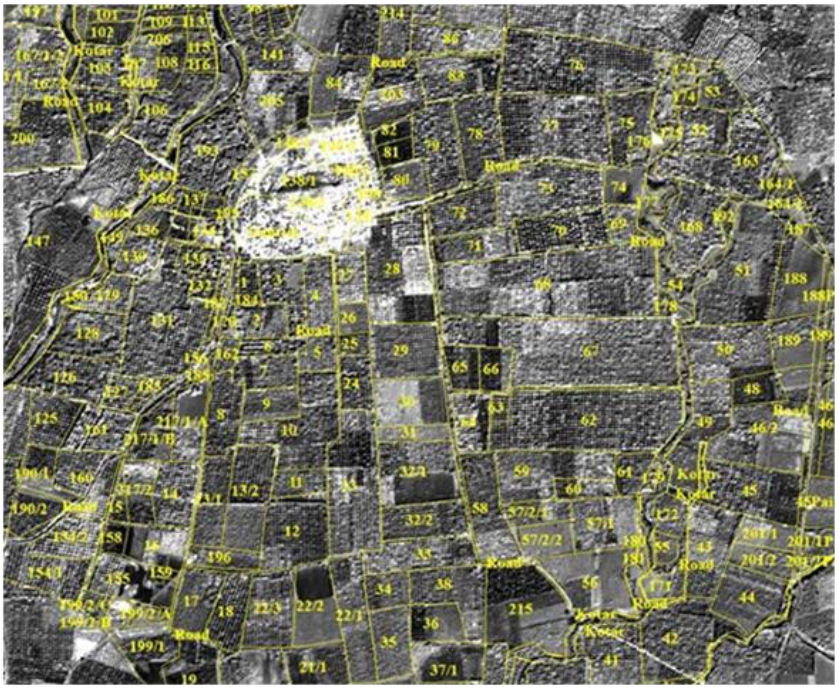

Figure 11: *CARTOSAT-1 image with survey numbers having fruit crop plantations in Talala Taluka*

4.2. Preparation of Taluka-level Horticultural Plantation Maps

The IRS-P6 LISS-IV and CARTSAT-1 satellite images covering different villages in each taluka having fruit crop plantations were analyzed for identification and delineation of fruit crop plantations. The cadastral maps were geo-referenced and superimposed on the satellite data along with survey numbers in each village. The survey numbers having fruit crop plantations were delineated on the CARTOSAT data. The fruit crop plantation maps of each village were complies at taluka level. The taluka-level fruit crop plantation maps showing the extent of fruit crop plantations along with village boundaries for Vanthali, Talala, Dhari and Pardi Talukas are given in Figures 12, 13, 14 and 15, respectively.

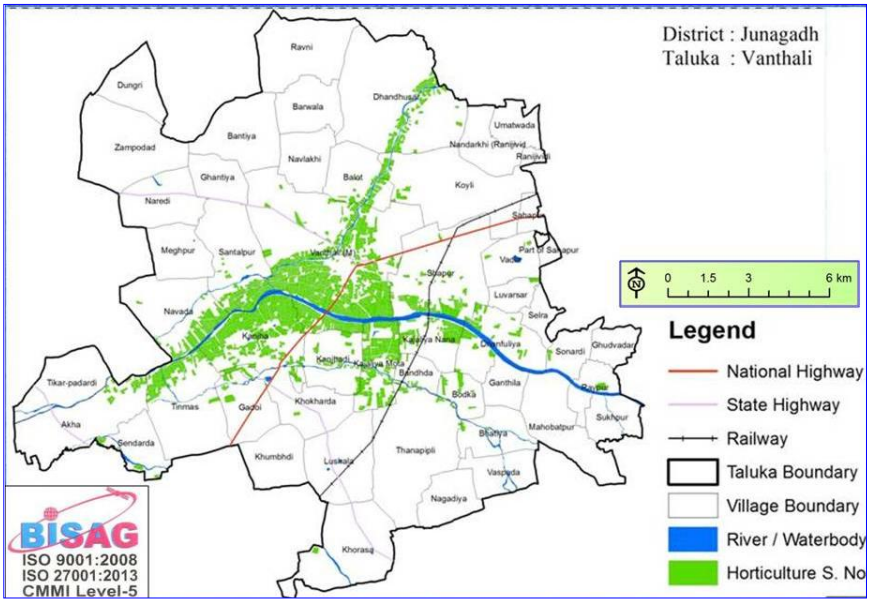

Figure 12: *Fruit crop plantations map of Vanthali Taluka, Junagadh district with village boundaries*

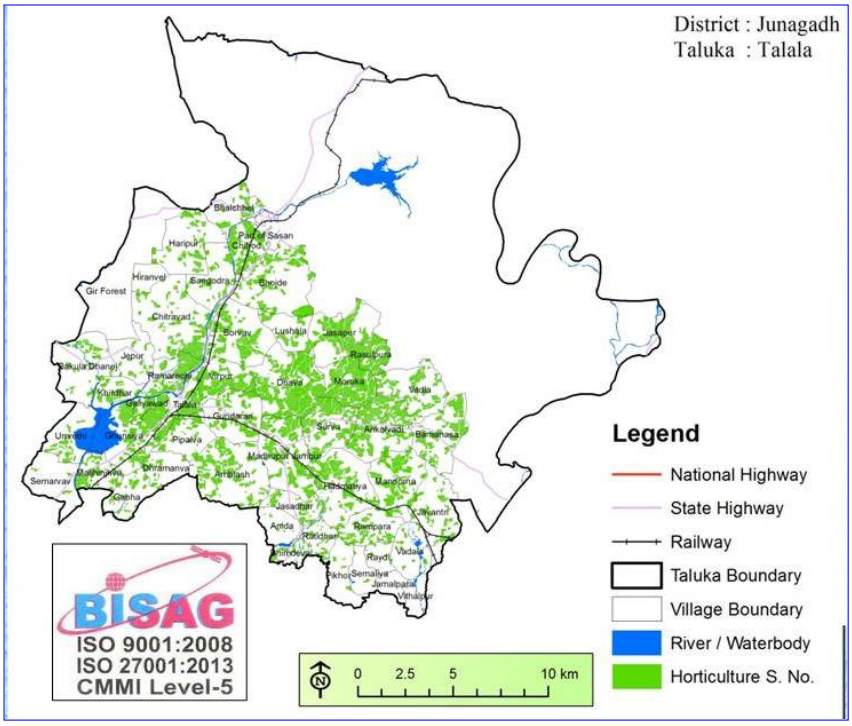

Figure 13: *Fruit crop plantations map of Talala Taluka, Junagadh district with village boundaries*

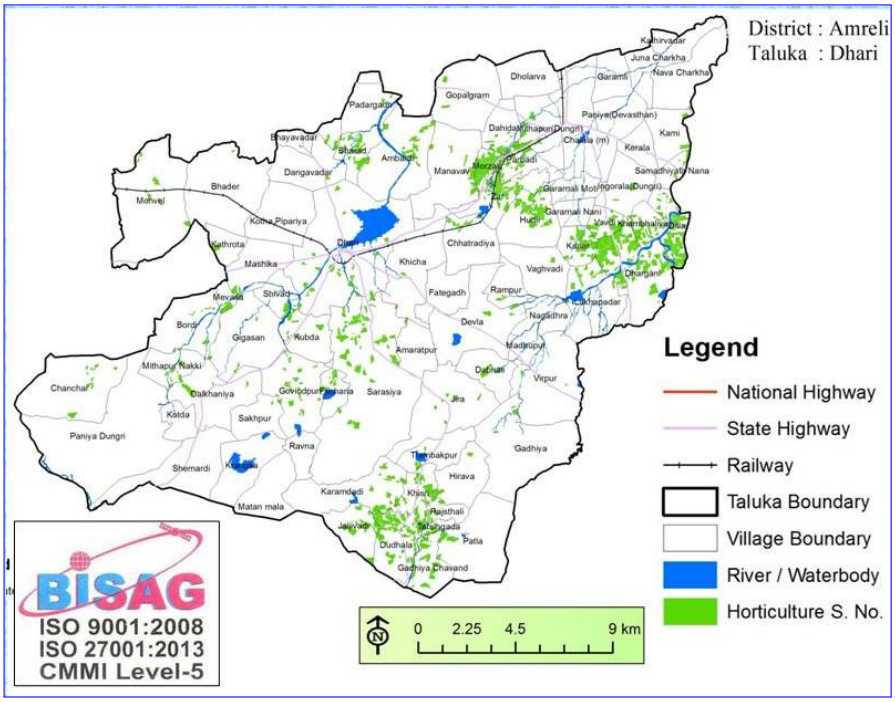

Figure 14: *Fruit crop plantations map of Dhari Taluka, Amreli district with village boundaries*

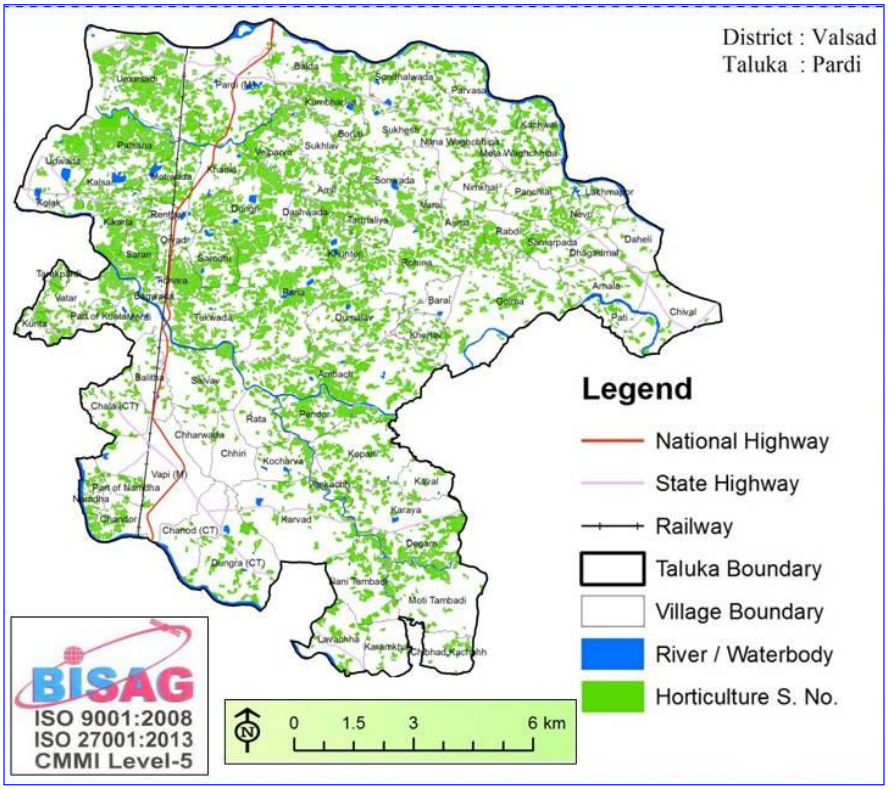

Figure 15: *Fruit crop plantations map of Pardi Taluka, Valsadi district with village boundaries*

4.3. Fruit Crops Plantations area compilation at taluka and district-level

The results of analysis of IRS-P6 LISS-IV and CARTSAT-1 satellite images covering different villages in each taluka having fruit crop plantations were compiled at village and taluka level. The results compiled at taluka-level were again compiled at district-level. The fruit crop plantations area estimates in Gujarat State are given in Table 2. This table indicates that, total area under fruit crops based on analysis of Indian Remote Sensing Satellite data is 177.74 thousand ha in Gujarat State. The major fruit crops growing top ten districts are: i) Valsad, ii) Junagadh, iii) Navasari, iv) Mahesana, v) Bhavnagar, vi) Amreli, vii) Kachchha, viii) Gandhinagar, ix) Vadodara and x) Anand (Figure 16).

4.3.1. *Preparation of Horticultural Atlas of Gujarat State*

The fruit crop plantations in different villages of each taluka were identified and delineated using IRS-P6 LISS-IV and CARTSAT satellite images. The cadastral maps were geo-referenced and superimposed on the satellite data along with survey numbers in each village. The survey numbers having fruit crop plantations were delineated on the CARTOSAT data. The fruit crop plantation maps of each village were compiled at taluka level. These village-level maps of each taluka were compiled in the form of Horticultural Atlas of Gujarat state.

Table 2: *District-wise Fruit Crops Area in Gujarat State based on satellite Data*

District-wise Fruit Crops Area: Gujarat State		
Sr.No.	District	Area (000' ha)
1	AHMEDABAD	2.851
2	AMRELI	8.179
3	ANAND	4.464
4	BANASKANTHA	1.461
5	BHARUCH	0.737
6	BHAVNAGAR	14.827
7	DOHAD	0.575
8	GANDHINAGAR	6.823
9	JAMNAGAR	0.496
10	JUNAGADH	35.118
11	KACHCHH	6.972
12	KHEDA	1.978
13	MAHESANA	18.726
14	NARMADA	0.250
15	NAVSARI	21.730
16	PANCHMAHA	0.730
17	PATAN	0.943
18	PORBANDAR	0.549
19	RAJKOT	0.908
20	SABARKANTHA	2.867
21	SABARKANTHA	2.643
22	SURENDRANAGAR	2.756
23	TAPI	0.553
24	VADODARA	5.016
25	VALSAD	35.592
	Total	177.743

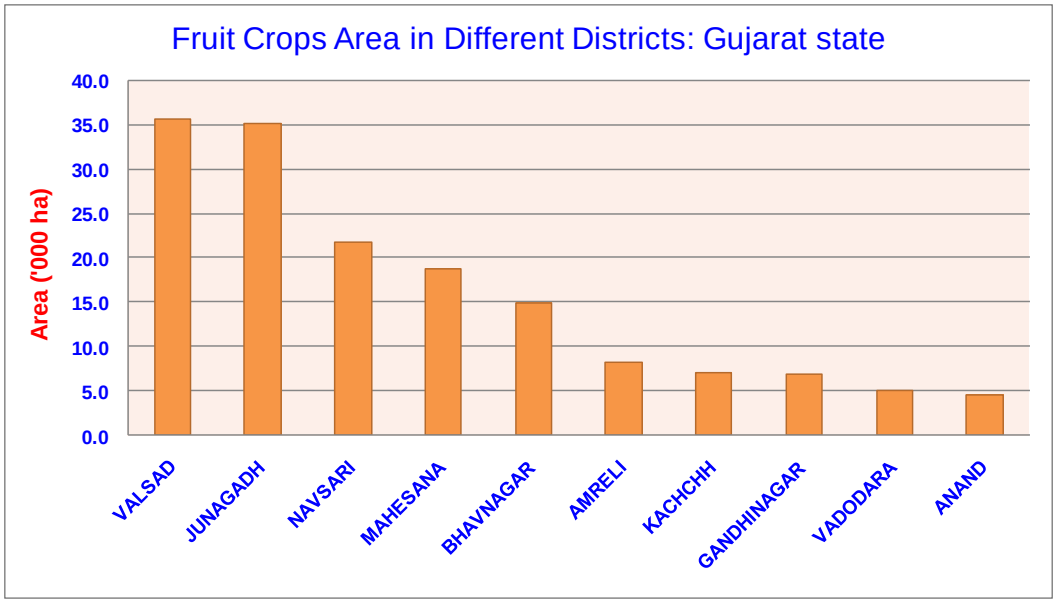

Figure 16: *District-wise fruit crop plantations area in Gujarat State based on IRS satellite data*

Acknowledgements

The authors like to express their sincere thanks to Shri T.P. Singh, Director, Bhaskarcharya Institute for Space Applications and Geo-informatics (BISAG), Department of Science & Technology, Government of Gujarat, Gandhinagar-382007, for fruitful discussions, suggestions and continuous guidance in carrying out this study. We are also thankful to the Department of Horticulture, Govt. of Gujarat for their kind cooperation.

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