Chapter 4

Estimation of Early Crop Sown Area at District Level (Sub-study-A)

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Success of agriculture depends on the timeliness of the information it needs for its proper management. Information is worthless if it is not available in time. Hence, timeliness of information related to various aspects of agriculture is a critical issue that should be dealt with full importance. Early estimation of crop area together with monitoring of crop development and its growth are some important agriculture applications where satellite based RS data along with other data have immense potential.

With the objective of developing a procedure for early estimation of Rabi crop sown area at a district scale this sub-study was taken up. The sub-study described in detail in this chapter, is a sub-set of the main research undertaken. Mehsana district of Gujarat state in India was selected as study area. The RS data available from Resourcesat-2 LISS-III and AWiFS were primarily used for developing the methodology for this Sub-study. The following sections discuss the details of the study area, data used, methodology flow, implementation of methodology steps, data analysis, and the results obtained.

4.1 Study Area and Data Used

Mehsana (also spelled as Mahesana) district with a geographic area of 439.4 thousand hectares, is one of the 33 districts of Gujarat state in India. It shares its border with Banaskantha district in the north, Gandhinagar and Ahmedabad districts in south, Sabarkantha district in the east, and Patan and Surendranagar districts in the west. The district consists of 9 talukas (Becharaji, Kadi, Kheralu, Mahesana, Vadnagar, Vijapur, Visnagar, Satlasana, and Unjha) and around 600 villages. Figure 4.1 sows the location of Mehsana district with respect to India and Gujarat and its boundary overlaid on an AWiFS image of 17 November 2011.

Except two talukas (Vijapur and Satlasana) all the talukas have more than 80% of the geographic area under cultivation (JIT-NHB, 2012). Pearl millet (Bajara or Bajari), green gram, red gram (Tur), rice, black gram, moth-bean, sorghum (Jowar), wheat, castor, cotton, mustard, sesamum, tobacco, summer Bajara are the main crops of the district. Area sown under some major Rabi crops (and castor and cotton) for 2007-08 (shown as 2008), 2008-09 and 2010-11 are shown in Figure 4.2. It is evident from the figure that there are different types of variations in the crop acreages e.g. wheat and cotton area overall increased but mustard area overall decreased. Fennel, cumin, lime/citrus, and potato are the main horticultural crops in the district. While Bajara, Jowar, cotton, and castor crops are grown during the monsoon season (crops are called the Kharif crops), the major crops which are sown after harvesting of the Kharif season crops include wheat, mustard, fennel, cumin, and potato (the crops are called the Rabi season crops or winter crops). Basically castor (sowing in July-August and harvesting in December-January) and cotton (sowing in June-July and picking in November-January) crops are sown during monsoon but they are harvested during Rabi season, as they are long duration crops.

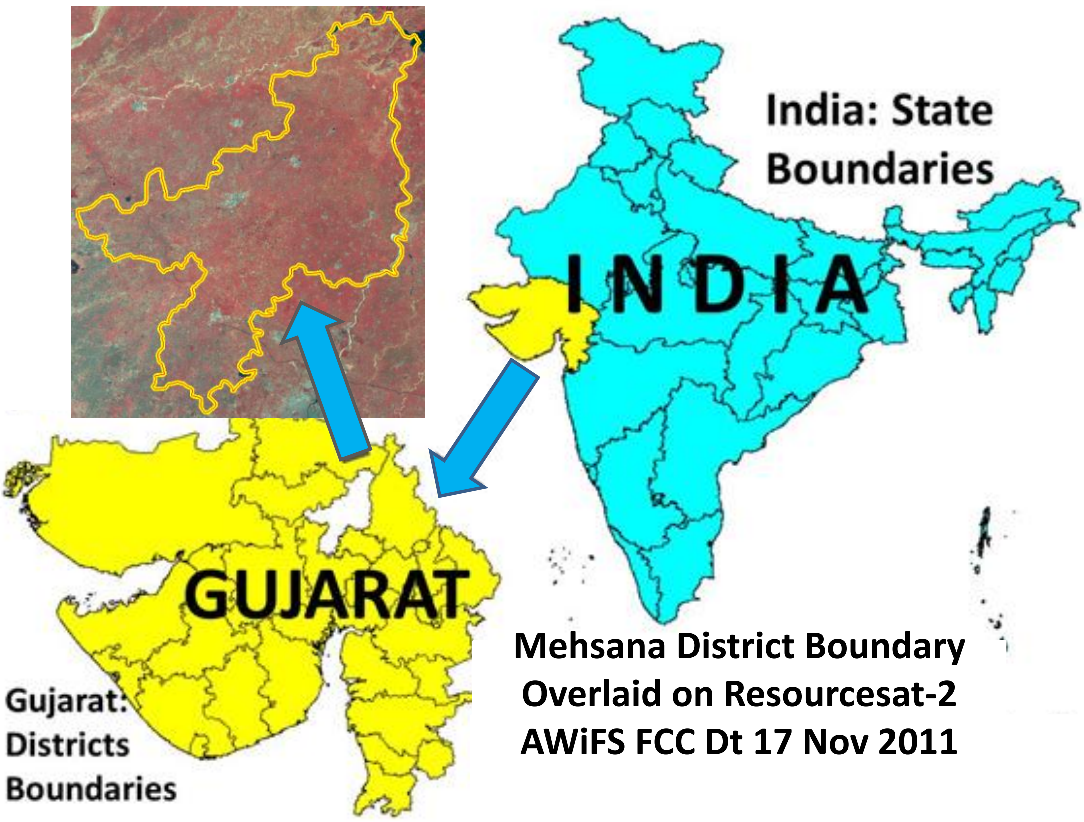


Figure 4.1. Study Area: A FCC of AWiFS over Mehsana District.

Wheat crop is sown in October-November and is harvested by February-March. Mustard crop is sown in October and is harvested in February. During November last week, typical wheat is in early vegetative stage or germination stage while mustard is at flowering stage. Other minor crops include cluster beans (locally known as Guar or Gavar), and red gram (Arhar/Tur) grown from June-July to December-January.

The oilseeds, cumin (Jeera), and psyllium (Isabgul) are the main crops of the district used in major trading.

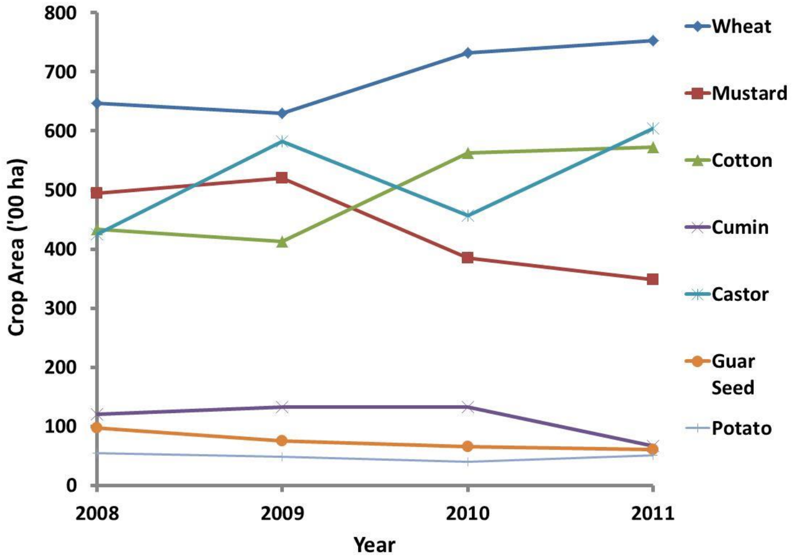


Figure 4.2. Crop Acreage Variations in Mehsana District During 2007-08 to 2010-11 (Source: DA-Guj 2011 and DA-Guj 2012**).**

Mehsana is a part of NARP (National Agricultural Research Project) defined North Gujarat Zone i.e. GJ-4 Agro-climatic Zone. The district has a net sown area of 365.3 thousand hectares. More than 60% of the soil belongs to sandy to sandy loam type (ACPD-M, 2012). The major source of irrigation is the water extracted from groundwater (by tube/bore/dug wells) from a range between 400 to 1000 feet (~123 m –305 m) and the Narmada Canal (GPCB, 2016; Sinha, 2014). The quality of the underground water is poor. The excess irrigation to the crop has badly affected the soil fertility and productivity in the district (KVK-Mehsana, 2014).

Resourcesat-2 AWiFS data of three dates and single date data of Resourcesat-2 LISS-III form the primary RS data used for early estimation exercise; however multi-date AWiFS and multi-date LISS-III data were used for preparing the reference classified image. Further details of the primary RS data are given in Table 4.1 and the major specifications of the data from two sensors i.e. AWiFS and LISS-III on-board Resourcesat-2 are given in Table 4.2.

Table 4.1. Details of the Primary RS Data from Resourcesat-2 Used in the Study.

Sr. No	Sensor	Path	Row	Date of Pass
1	AWiFS	094	056	10 October 2011
2	AWiFS	092	056	24 October 2011
3	AWiFS	092	056	17 November 2011
4	LISS-III	093	055	22 November 2011
5	AWiFS	091	053	06 December 2011
6	AWiFS	092	056	11 December 2011
7	LISS-III	093	055	16 December 2011
8	AWiFS	094	056	21 December 2011
9	AWiFS	092	056	04 January 2012
10	LISS-III	093	055	09 January 2012
11	AWiFS	094	056	14 January 2012
12	AWiFS	090	053	18 January 2012
13	AWiFS	092	056	28 January 2012
14	AWiFS	093	056	26 February 2012

Table 4.2. Major Characteristics of AWiFS and LISS-III Data. (Source: ISRO, 2011)

Specifications	AWiFS	LISS-III
Spectral Bands (µm):	(4) 0.52 – 0.59, 0.62 – 0.68, 0.77 – 0.86, 1.55 – 1.70	
Spatial Resolution (m)	56	23.5
Swath (km)	740	140
Revisit (days)	5	24
Quantisation (bits)	12	10
Pixel Size in m (square)	56	24
Spatial Resolution (m)	56	23.5

The ground truth data collected through field surveys in parts of Mehsana district during 2011-12 Rabi crop season was used as a-priori information as well as reference data for verifying the image classifications. A sample of major parameters noted during the field visits is shown in Table 4.3.

Table 4.3. A Sample of Ground Truth Parameters: 2011-12 Rabi Season.

Field ID (yyyymmdd-nn)	Lat. (N)	Long. (E)	Crop in field	Field size (m)	Crop Growth Stage	Crop Cover
20111212-03	23.349	72.305	castor	100 x 100	capsule formation	41-60%
20111214-04	23.711	72.492	castor	100 x 100	capsule formation	>80%
20111214-05	23.834	72.624	castor	100 x 100	capsule formation	>80%
20110929-10	23.675	72.580	cotton	150 x 150	ball formation	61-80
20110929-11	23.663	72.597	cotton	200 x 200	ball formation	61-80
20111212-08	23.686	72.232	cotton	100 x 100	picking	61-80%
20111214-12	23.703	72.778	cotton	100 x 100	picking	61-80%
20120111-06	23.836	72.749	fennel	-	seed formation	61-80%
20111212-06	23.604	72.277	mustard	100 x 100	flowering	61-80%
20111212-07	23.685	72.238	mustard	100 x 100	flowering + pod	41-60%
20111214-09	23.855	72.678	mustard	150 x 100	flowering	61-80%
20120111-04	23.583	72.747	potato	500 x 300	-	41-60%
20111214-03	23.706	72.449	tobacco	100 x 200	Vegetative	-
20111214-11	23.712	72.781	tobacco	100 x 100	sowing	-
20111214-13	23.595	72.743	tomato	100 x 100	vegetative	21-40%
20111214-08	23.855	72.673	wheat	100 x 100	CRI	-
20120111-07	23.826	72.579	wheat	> 100 x 100	booting	>80%
20120111-09	23.601	72.505	wheat	> 100 x 100	booting	>80%
20120111-10	23.517	72.293	wheat	> 100 x 100	tillering (late)	61-80%

GIS layer of GT was prepared from the information collected during in-season surveys. These layers were then used for the data analysis. Geo-referenced master image over Mehsana district available from FASAL project at Space Applications Centre, Ahmedabad was used for geo-referencing of the primary RS data. District boundary vector available from FASAL project was used for sub-setting of the RS data.

4.2 Data Analysis Flow and Multi-Sensor Dataset Preparation

The RS data analysis of the study may be described in two parts i.e. (i) RS data analysis for classifying single date LISS-III data (November 22, 2011) and 3 dates AWiFS data (October 10, October 24 and November 17), and (ii) RS data analysis for classifying integrated full dataset (see Table 4.1) incorporating 3 dates of LISS-III data and 11 dates of AWiFS data. While part (i) produced the classified image for early crop sown area estimation, part (ii) provided classified image that was used as the reference image for accuracy assessment of part (i) classified image.

The major components of the part (i) data analysis include:

(i) Importing of multi-date and multi-sensor data separately in the working environment and common format,

(ii) Sub-setting of the data to approximate extent of the study area (an extra margin is kept in all the four directions),

(iii) Radiometric normalisation of the first order by converting DN images to spectral radiance images,

(iv) Geo-referencing of LISS-III data with the reference master data,

(v) Co-registration of multi-date AWiFS data with LISS-III geo-referenced data,

(vi) NDVI images preparation from LISS-III and AWiFS data in a common framework,

(vii) Ground truth GIS vector layer preparation from field data,

(viii) Marking of GT locations on LISS-III data & spectral signature extraction,

(ix) Classification of LISS-III data (Maximum Likelihood and ISODATA),

(x) Stacking of multi-sensor NDVI images and multi-date normalisation,

(xii) Temporal NDVI pattern from GT data,

(xiii) Classification of multi-sensor data (integration), and

(xv) Estimation of the early crop sown area and accuracy assessment.

While part (ii) data analysis for reference classified image generation is explained in brief under Section 4.4, data analysis flow for part (i) in terms of the major inputs, intermediate outputs and final output of early Rabi crop area are shown in Figure 4.3 and the major processing steps are summarised below:

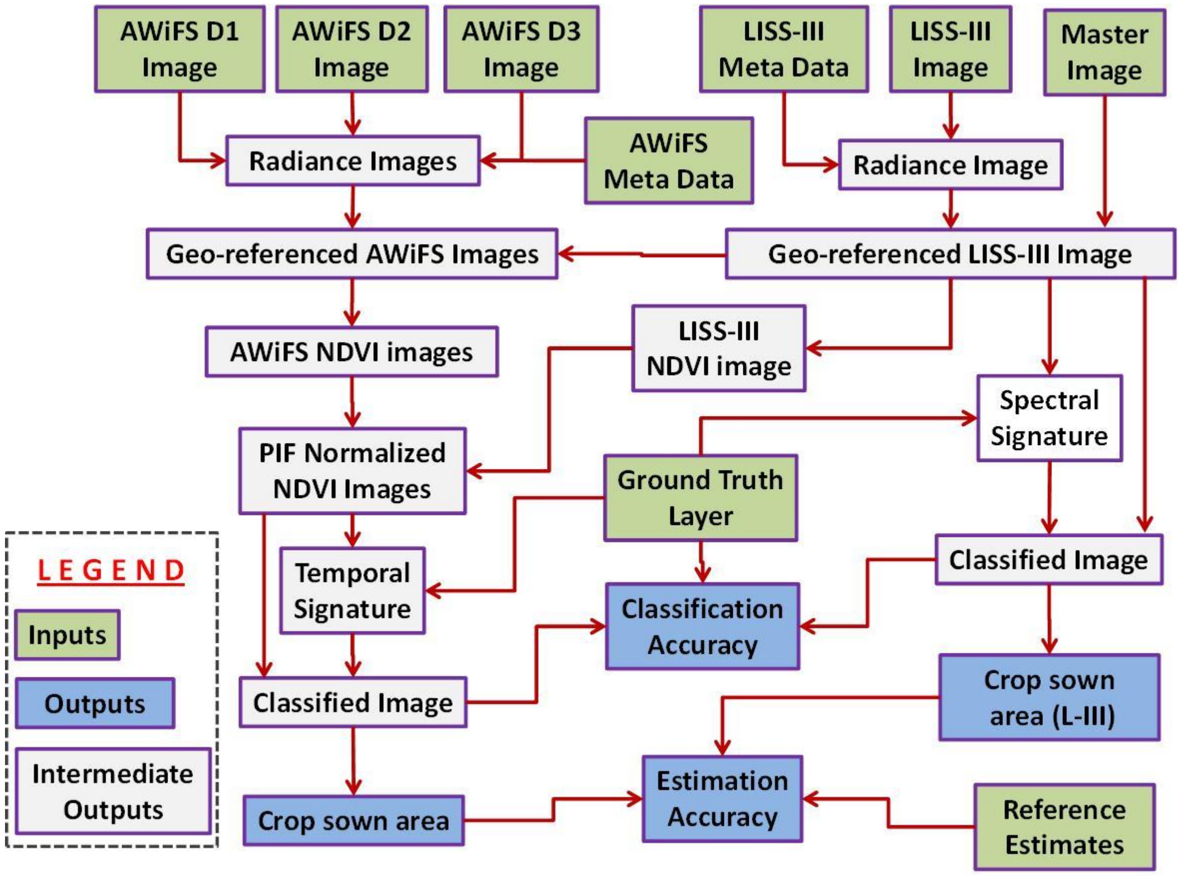


Figure 4.3. Implementation Flow of Data Analysis Part (I).

The raw LISS-III data was available in GeoTiff format and AWiFS data was available in LGSOWG (Landsat Ground Station Operators Working Group) or Super Structure Format. Both the data were imported in the Erdas Imagine working environment format. Although the quantisation labels of the two data are different (Table 4.2) they are stored in 16-bit unsigned. After sub-setting the data to study area (with sufficient margin in all the four directions) the DN values were converted into radiance values for each band (L) by using saturation radiance of sensor by the formula:

Radiance for a given DN (L) = (DNvalue/ DNmax) x (Lmax - Lmin) + Lmin

Where Lmin = Minimum radiance; Lmax = Saturation radiance/maximum radiance. DNmax= 1023 for 10 bit LISS-III data and DNmax = 4095 for 12 bit AWiFS data. The values of Lmax and Lmin are available in the metadata. Saturation radiance values (L_max) for Resourcesat-2 LISS-III and AWiFS (mw/cm^2/sr/µm) are: B2: 52.0, B3: 47.0, B4: 31.5, and B5: 07.5. In the case of these two sensors the values are same.

4.2.1 Geo-referencing of LISS-III and AWiFS Data

While working with two spatial resolutions RS data, integrating the two is a challenging task. Moreover, the primary geo-referencing available with the raw data is not good enough to overlay one data over the other accurately. In this study, firstly the LISS-III data was accurately geo-referenced with the master data available from FASAL project. The common projection system adopted was Albers Conical Equal Area (ACEA) projection with WGS84 datum (Rajak et al., 2002). Then multi-date AWiFS data was co-registered with the LISS-III data. During registering two images with different spatial resolutions selection of common GCPs, locating exact location of the GCP, and spatial distribution of GCPs become critical things which determine the accuracy of relative registration accuracy. The detailed procedure of registering multi-resolution data has already been described in Chapter 3. Well distributed over the study area, 30 to 40 GCPs were identified, located and linked to generate 2nd order polynomials to register all AWiFS data with November 22 LISS-III data. The root mean square error of registration was within 12m i.e. half of the LISS-III pixel size, in all image to image registration cases.

4.2.2 NDVI Preparation and Multi-date Normalization

Once multi-source data is available at a common reference framework with respect to its geometry, spatial resolution, spectral bands and radiometry, it is ready to be integrated. NDVI derived from the spectral values in Red and Near Infrared bands of optical RS data is very important parameter for detection and discrimination of vegetation/crops against non-vegetation land classes.

NDVI = (NIR-Red)/(NIR+Red) and

Scaled NDVI = 100 + 100 * NDVI

The range of NDVI value is -1.0 to +1.0 and the range of scaled NDVI is 0 to 200.

Multi-date data need an extra normalisation of radiometry to take into account temporal variations in the atmosphere. PIF based multi-date NDVI normalisation technique was applied to normalized NDVI values ($NDVI_{10Oct}$, $NDVI_{24Oct}$ and $NDVI_{22Nov}$) obtained from 2-dates of AWiFS and 1-date of LISS-III data, respectively. NDVI values of 17 November images ($NDVI_{17Nov}$) were treated as the master values. Deep water bodies, dense built-up and dry barren lands were taken as the PIF and regression based normalisation equations were derived. Following three equations were obtained for 3 combinations:

- $NDVI_{17Nov} = NDVI_{10Oct} \times 1.107 - 12.85$
- $NDVI_{17Nov} = NDVI_{24Oct} \times 1.039 - 6.681$
- $NDVI_{17Nov} = NDVI_{22Nov} \times 0.987 + 0.391$

Hence, 4-dates NDVI dataset was prepared by integrating and stacking these NDVI images in temporal sequence. The same technique of NDVI normalisation was employed for normalising multi-date AWiFS and multi-date LISS-III based dataset used for preparing the reference classified image.

4.2.3 Reference Spectral Signatures and Temporal Patterns Generation

The field locations visited during in-season field surveys (see Table 4.3) were overlaid and marked on LISS-III data and saved for further use. Reference spectral signatures for major land cover classes were generated and saved to be used for training Maximum Likelihood Classifier. The saved field locations were overlaid on integrated stacked NDVI dataset and temporal patterns for 4-dates were generated. These temporal patterns were used as reference patterns for labelling the ISODATA clusters. The spectral signatures, temporal patterns and their usefulness for class discrimination are discussed in the next sections.

4.3 Classification of LISS-III and AWiFS Data

Two classifications were attempted for classifying LISS-III November 22, 2011 image, an unsupervised (ISODATA) and a supervised (Maximum Likelihood). Firstly, it was classified using ISODATA (Iterative Self Organizing Data Analysis Technique) clustering algorithm (Rajak et al., 2011). In ISODATA clustering, the spectral values in Green, Red, NIR and SWIR bands were used as input for the classification. Initially 40 to 50 clusters were formed and then these clusters were assigned to crop, plantations/Kharif crops/other vegetation, and mask classes. Later on plantations/Kharif crops/other vegetation were merged with mask and the classified image was prepared. The LISS-III 4-bands data was also classified by Maximum Likelihood Classifier using the spectral signatures for training it. The ISODATA and Maximum Likelihood Classification techniques, already explained in Chapter-3 are not again detailed here to avoid unnecessary repetition. The classified images were subjected to classification accuracy assessment as discussed in succeeding sections.

In the second set of RS data classification, ISODATA was applied on 4-dates NDVI stacked dataset. In this case too, initially 40 to 50 clusters were formed, they were assigned to crop, plantations/Kharif crops/other vegetation, and mask classes. The final classified image was prepared by merging plantations/Kharif crops/other vegetation with mask class.

The two sets of classified images were tested for crop classification with respect to the field data collected by ground surveys. It was found that there were some clusters in first set of classifications in which there was mixing of plantations/Kharif crops and crop pixels. Hence some plantations/Kharif crops got classified as crop and some crop pixels got classified as plantations/Kharif crops. Spectral analysis of these mixing clusters was carried out with respect to 4-bands LISS-III data and 4-dates NDVI integrated data. It was observed that the crops and plantations/Kharif crops classes which were not separable in single date classified images could be discriminated using multi-date NDVI based classification. The detailed discussion on class separability due to temporal spectral patterns is presented in Section 4.5.

The classified images obtained through the two different classification schemes are shown in Figure 4.4. The crop area is shown in green colour.

4.4 Preparation of Reference Classified Image and Accuracy Assessment

To compare the results obtained from the above mentioned exercise, a reference crop classified image was prepared using 9 dates of AWiFS data and 3 dates of LISS-III data. The procedure explained in above mentioned exercise was followed and 12-dates NDVI stack layer prepared and normalised by PIF method. Temporal profiles of NDVI for three of the major Rabi crops (wheat, mustard and potato) of the district are shown in Figure 4.5.

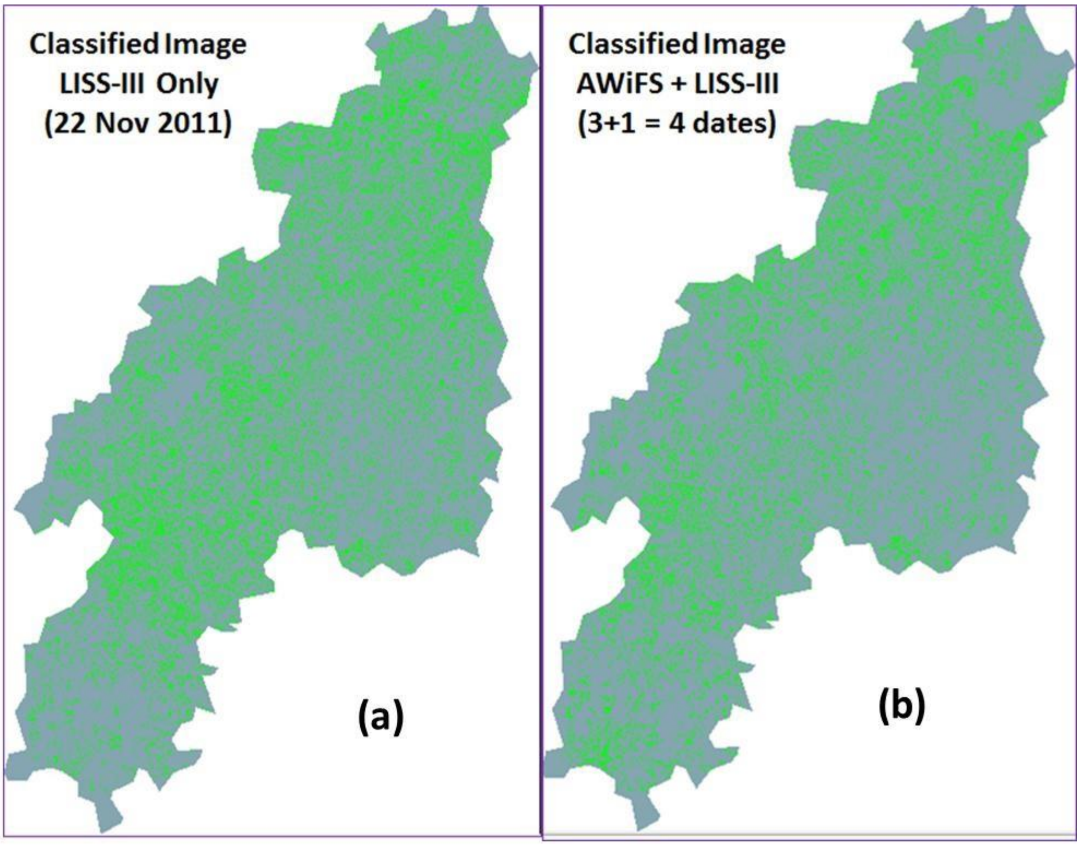


Figure 4.4. Classified images showing Rabi crop in green colour (i) single date LISS-III, and (ii) integrated dataset.

ISODATA clustering was employed for classification and the classification accuracy of this classified image was assessed with respect to the GT collected during field visits. Total Rabi crop sown area was estimated.

To assess the classification accuracy error matrices were prepared for all the three classified images with respect to the data collected during in-season field visits. Error matrix for classified image prepared using integrated dataset is shown in Table 4.4.

The overall accuracy of classification improved from 79.3 and 83.4 (single date ISODATA and Maximum Likelihood classifications, respectively) to 96.5 (integrated dataset classification) percent.

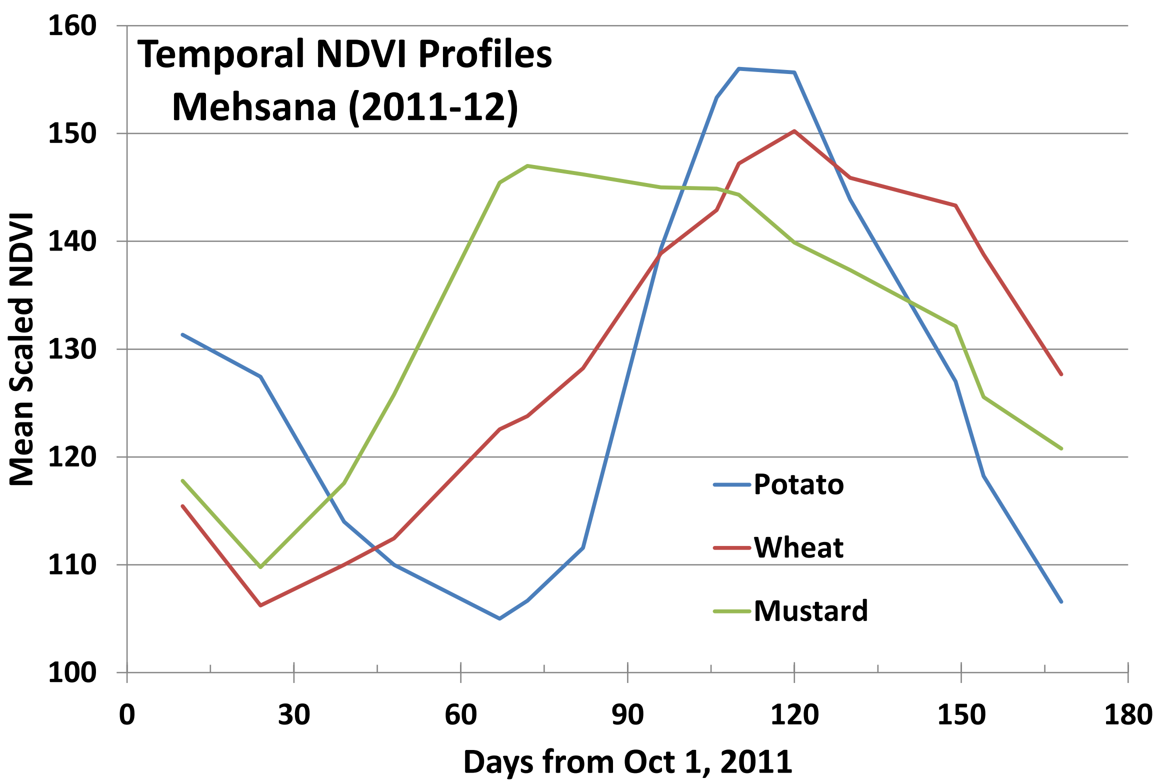


Figure 4.5. Temporal NDVI Profiles of 3 Crops in Mehsana District for 2011-12.

The User's and Producer's accuracies of crop and forest/plantation classes steeply increased to more than 95% in integrated data classification from less than 80% in single date classifications. The Kappa coefficient (as defined in Chapter 3, Section 3.7) for the error matrix shown in Table 4.4 is 0.954.

Table 4.4. Error Matrix for Classified Image Prepared from the Integrated Dataset (30m Pixel Size) in Terms of Pixels.

		Actual (GT)				Row Sum	User's Accuracy
	Classes	Built-up	Water	Crop	Forest/ Plntn		
Classified	Built-up	507	21	0	0	528	96.0
	Water	18	612	0	0	630	97.1
	Crop	0	0	611	26	637	95.9
	Forest/ Plntn	0	0	17	554	571	97.0
Column Sum		525	633	628	580	2366	
Producer's Accuracy (%)		96.6	96.7	97.3	95.5		Overall Accu.=96.5

4.5 Discussion: Temporal NDVI Patterns and Class Separability

The basic concept of distinguishability of vegetation classes in temporal and spectral domains is compared in Figure 4.6 and Figure 4.7. Two of the major vegetation classes that usually get mixed in single date LISS-III data are ‘crop’ (here Rabi crops) and ‘plantation/Kharif crops’. Analysis of spectral variations through Green, Red, Near Infrared (NIR), and Sort Wave Infrared (SWIR) for mixing ‘crop’ and ‘plantation/Kharif crops’ classes (named Class1 to Class4) was carried out. While the four classes are well separable in NDVI profiles derived from 3-dates AWiFS and 1 date LISS-III data (Figure 4.6) they are not well distinguishable in Spectral profiles derived from single date LISS-III data (Figure 4.7). The spectral radiance values are almost same in all the four bands i.e. Green, Red, NIR, and SWIR which is depicted in Figure 4.6.

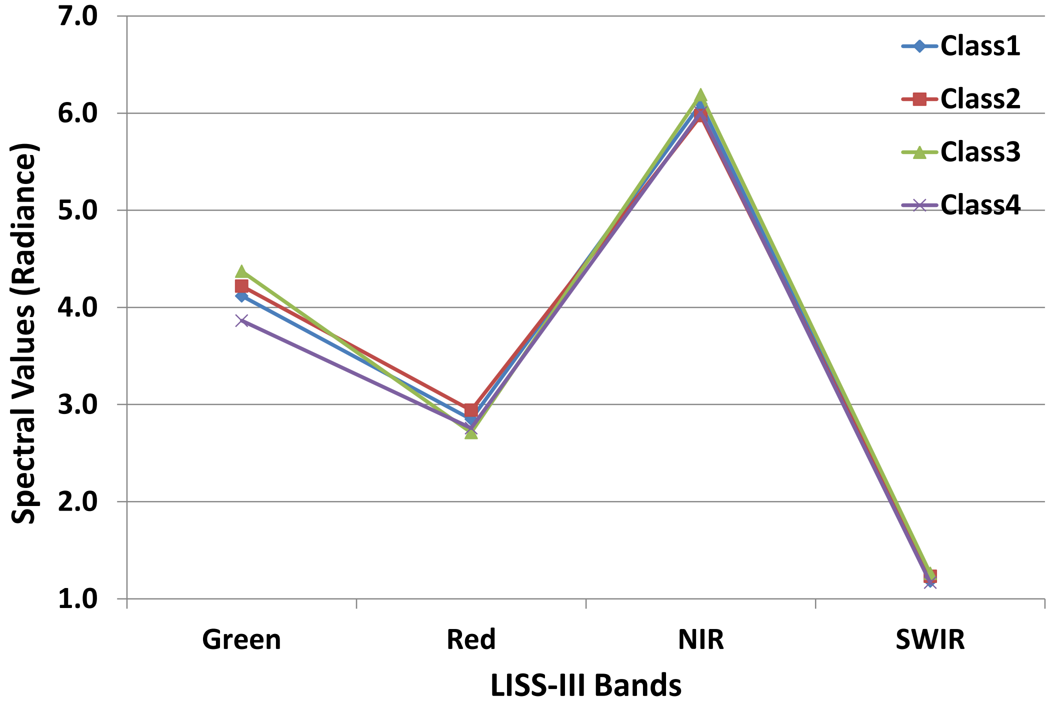


Figure 4.6. Temporal NDVI Patterns of Four Classes (Class1 to Class4) Showing Different Temporal Trends.

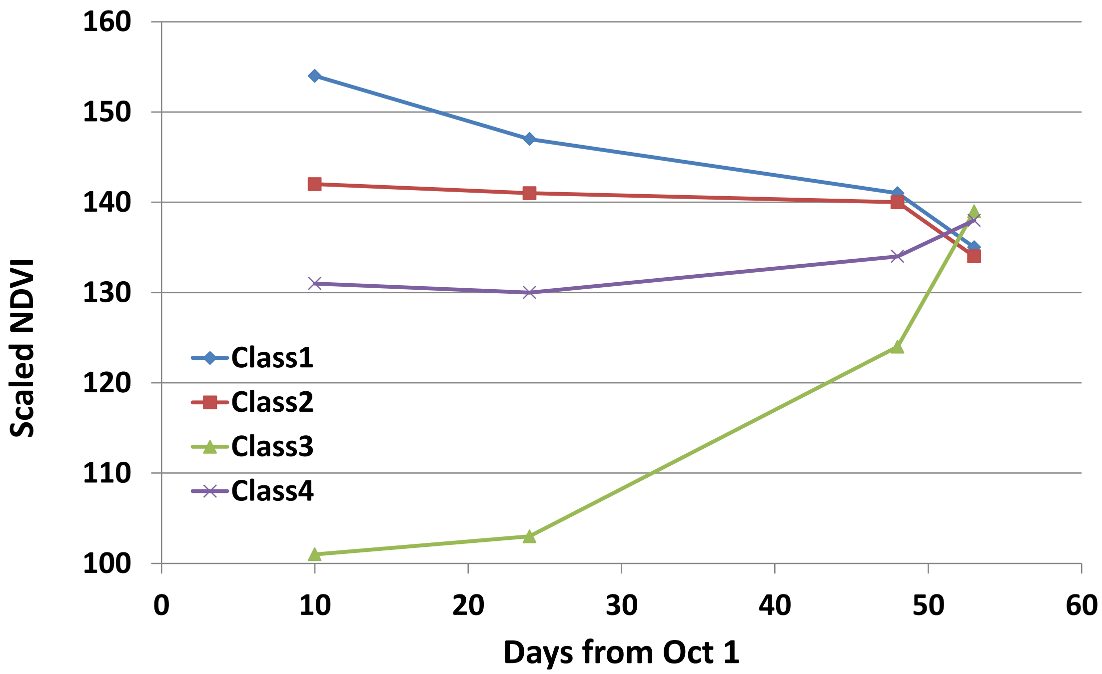


Figure 4.7. Spectral Profiles of Four Classes (Class1 to Class4) Showing Clustering of the Classes.

The LISS-III derived scaled NDVI values lie between 134 and 139 (Absolute values 0.34 to 0.39) for all the four classes. It is clear from Figure 4.6 that Class1 has high decreasing NDVI temporal trend while Class2 has moderately decreasing NDVI temporal trend. These two classes belong to Plantations. Similarly Class3 and Class4 show moderately and high increasing NDVI temporal trends, respectively. These two classes belong to Crop. Hence, the four classes which were mixing together in LISS-III data were well separated into Crop and Plantations/Kharif crop using integrated data i.e. 3-dates AWiFS data and 1-date LISS-III data

The advantage of using AWIFS data with LISS-III data for correcting the LISS-III misclassification has been shown in Figure 4.8. An example of two classes (Class-X and Class_Y) misclassified by LISS-III data has been illustrated. Class_X, classified as non-crop in LISS-III data has been shown in Figure 4.8A (LISS-III image, November 22, 2011). Similarly, Class_Y, classified as crop in LISS-III data has been shown in Figure 4.8B.

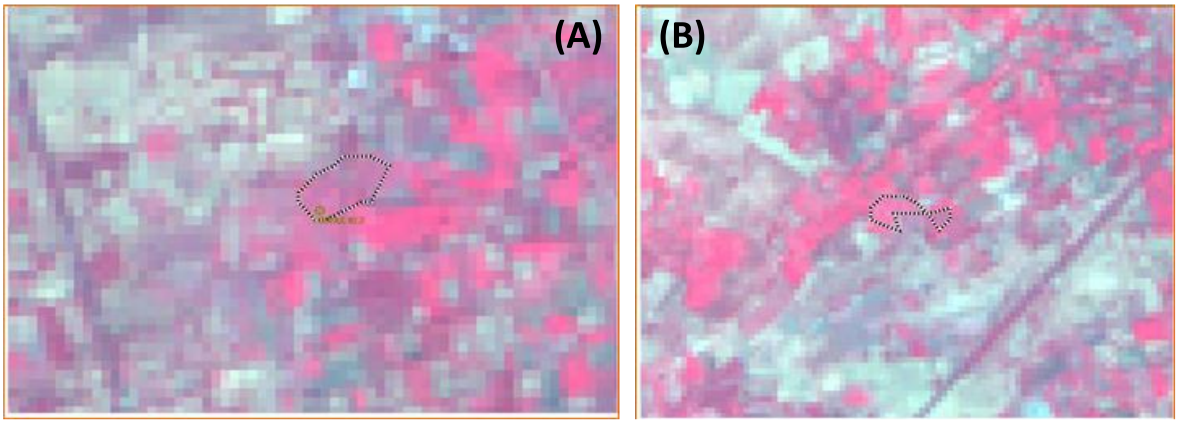
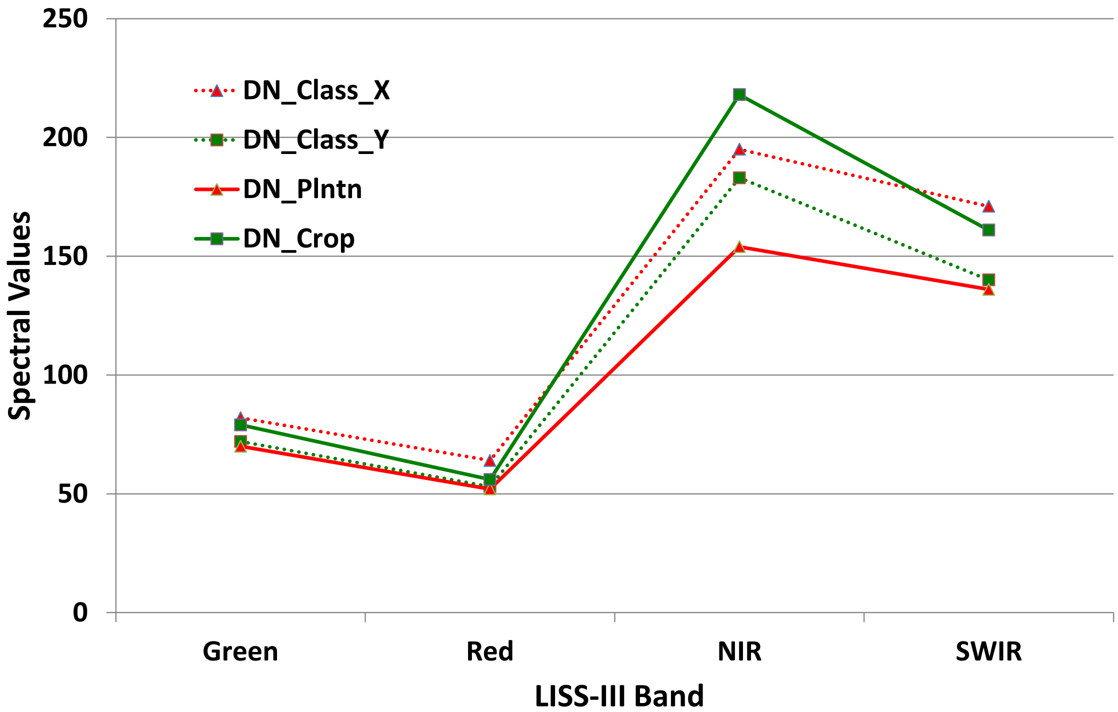


Figure 4.8. A Part of LISS-III Image Showing Locations of Class_X and Class_Y.

The spectral patterns of Class_X (shown as DN_Class_X) and Class_Y (shown as DN_Class_Y) are compared with that of Crop (shown as DN_Crop) and Plantation (shown as DN_Plntn) classes (well classified by LISS-III data) in Figure 4.9. It shows that the NIR values of the two classes, Class_X and Class_Y are closer to the Crop and Plantations classes, respectively. The values of Red spectral bands are also not distinct. That is the reason that the two classes are classified as Crop and Plantations, respectively with respect to NDVI profiles of Crop (NDVI_Crop) and Plantations (NDVI_Plntn).

Temporal profiles of these four classes (Class_X, Class_Y, Plntn, and Crop as shown in Figure 4.9) are presented in Figure 4.10. Class_X has the decreasing NDVI trend very similar to Class_Plntn, being classified in to the Plantations class. The temporal variation of Class_Y is showing increasing pattern similar to that of Class_Crop. Hence, Class_Y is classified as Plantation. Although, the last date NDVI values of Class_X and Class_Y are very close, they are classified in two different classes due to their temporal trends derived from integrated dataset. These classifications were compared with the limited field data collected in ground



surveys during 2011-12 crop season.

Figure 4.9. Temporal Patterns of Spectral Values for Class_X and Class_Y Compared with that of Rabi Crop and Plantation.

4.6 Results: Early Estimates of Crop Sown Area for Mehsana

While the crop area estimated through single date LISS-III classified image was found as 72.8 thousand ha, it was updated to 58.9 thousand ha by incorporating 3-date AWiFS data analysis. During third week of November, almost all mustard area was sown and a large area of wheat crop was also sown. A considerable amount of wheat crop sown after first week of November was not expected to be visible to satellite sensors by November 22. Hence, at this stage total crop area comprised of almost complete mustard area and partial wheat area. The analysis of multi-date NDVI profiles of the ISODATA clusters that were classified as Rabi crop in the reference classified image shows that not more than 62 thousand ha of crop area (38 thousand ha of wheat area and 24 thousand ha of mustard area) would be detectible by satellite.

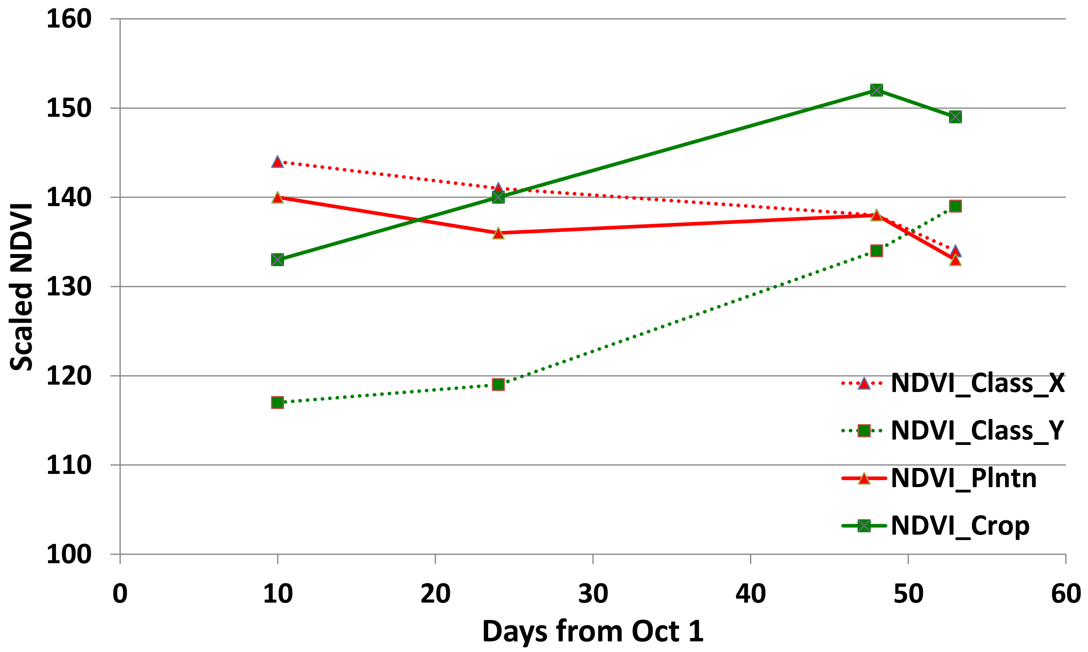


Figure 4.10. LISS-III NDVI Variations for Class_X and Class_Y Compared with NDVI variations of Rabi Crop and Plantation.

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