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Early estimation of crop sown area by integrating multi-source data

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Abstract: Satellite based remote sensing (RS) data at different spatial and temporal scales can provide crop sown area estimates needed by decision makers. Due to conflict of spatial resolution versus temporal frequency of data collection, getting early and accurate crop sown area at large scale is very difficult. This paper presents a methodology of early estimation of crop sown area at large scale by making use of high temporal coarse spatial resolution data and low temporal fine spatial resolution data. It also uses previous years' data for extracting a-priori knowledge of crop sowing area. Early crop area estimate was made for Gujarat state (India) for 2011-12 rabi season. Multi-date MODIS (MODerate resolution Imaging Spectroradiometer) data and two-date Resourcesat-2 AWiFS (Advance Wide Field Sensor) data upto mid-December were used for crop sown area early estimates. Multi-date MODIS data for previous five years provided a-priori information on crop presence / absence over the previous five crop seasons. While ISODATA was used for classifying multi-date MODIS and AWiFS data; hierarchical decision tree approach was used for integrating multi-source information. Incorporating two date AWiFS data and a-priori information with multi-date MODIS data increased crop sown area early estimates accuracy significantly.

Keywords: Crop sown area, MODIS, AWiFS, ISODATA, Decision tree

1. Introduction

Traditionally, the crop sown area is estimated from the sample data collected by different government institutes/departments or survey agencies. These methods are time consuming and labour intensive. Human subjectivity and biases increase in-accuracy levels of these estimates. Satellite based remote sensing (RS) data is one of the few sources for deriving frequent and reliable estimates of the crop sown area at different spatial scales. A number of research studies and projects have demonstrated the usefulness of RS data in making crop inventory over different parts of the world (Mc-Donald and Hall, 1980; Sharman, 1993; De Roover et al., 1993; Navalgund et al., 1991; Oza et al., 1996; Dadhwal et al., 2002; Parihar and Oza, 2006; Xiangming et al., 2006; Wardlow et al., 2007; Nigam et al., 2009; Nigam et al., 2012; Vyas et al., 2013; Ray et al., 2014; Sharma et al., 2014; Parihar, 2016; Karam et al., 2016; Rajak and Jain, 2016). Large Area Crop Inventory Experiment (LACIE, 1974-1977), covering USA, USSR, Brazil, Argentina, India etc. was one such study (Mc-Donald and Hall, 1980). Europe-wide crop production estimation was carried out by European Union under Monitoring Agriculture with Remote Sensing (MARS) project (Sharman, 1993; De Roover et al., 1993). In India, Crop Acreage and Production Estimation (CAPE) project demonstrated the potential of remotely sensed data for crop inventory (Navalgund et al., 1991). Dadhwal et al. (2002) have reviewed Indian experience of crop inventory using RS data. A multiple crops acreage estimation and production forecasting program based on multiple inputs was developed under FASAL (Forecasting Agricultural output using Space, Agro-meteorological and Land based observations) in India. Parihar and Oza (2006) have described the concept and program details. While Xiangming et al. (2006) have used multi-date MODIS (MODerate resolution Imaging Spectroradiometer) data for mapping paddy rice in South and South-East Asia. Wardlow et al. (2007) have used MODIS NDVI time series data for crop classification in U. S. Central Great Plains.

Nigam et al. (2009, 2011) used atmospherically corrected surface reflectance values in Red and NIR bands of INSAT 3A CCD to compute NDVI at continental scale and these NDVI values were further validated with global product to judge its spatio-temporal profiles and its range over different natural targets. Vyas et al. (2013) demonstrated that the spatially distributed crop sowing dates derived using INSAT 3A CCD data at 1 km×1 km resolution could be captured at regional scale in India. Ray et al. (2014) have summarized an operational methodology of multiple forecasting of multiple crops in India. Sharma et al. (2014) concluded that multi-year multi-date MODIS data could be used for monitoring gross annual changes of major rabi crops at regional scale.

Sud et al. (2015) presented a critical review of the literature related to concepts in crop area estimation and crop yield assessment. In addition, country-experiences were also reported while bringing out several issues and problems with regard to crop area and crop yield estimation. Karam et al. (2016) proposed a management tool for annual inventory and monitoring of cultivated lands using RapidEye and Landsat ETM+ imagery over a test area in Bekaa Valley, Lebanon. The study concluded that satellite imagery was essential for the definition of the existing cropping patterns in the pilot area and it helped in better estimation of seasonal irrigation needs at the scheme level. Parihar (2016) detailed the sequential developments in the use of single and multi-date optical and microwave remote sensing data for crop production forecasting in India. A methodology was developed by Nigam et al. (2015) using high temporal vegetation index data at 1km spatial resolution available from Indian geostationary satellite (INSAT 3A) to monitor progress of rabi crop area at country scale. The rabi crop area estimates obtained at the end of crop season at country level showed mean deviation of −18.1% with respect to reported DAC statistics during rabi season 2011–2012. At national scale, the INSAT- estimated rabi crop area showed 16.36% deviation from AWiFS derived rabi area at 2 km × 2 km grid, but no attempt was made to estimate crop sown area at state level. Sharma et al. (2014) estimated rabi sown area for Gujarat state using full season multi-date MODIS data but no attempt was made to arrive at an early estimation of the crop sown area. Rajak and Jain (2016) have emphasized the importance of two-source data i.e. AWiFS (Advance Wide Field Sensor) and LISS-III (Linear Imaging Self-scanning Sensor - 3) to improve crop acreage estimation at district scale.

There is no doubt that multi-source data analysis will become increasingly widespread in the future, due to increasing ease and lower cost of data collection, storage and manipulation. Availability of multi-source data of the same object at different times provides information on time varying characteristics of the object, if proper tools are available to analyse the multi-source data. In case of satellite based multi-source data, there are a number of commercial image processing software that may be used for storage, archival, and visualization of multi-source data. Extraction of the required information from such a multi-source dataset has remained a challenging task for long. Integration of information available from the previous years' data with current year's multi-source RS data has not been explored adequately for early estimation of crop sown area.

In this study, a methodology developed for early estimation of crop sown area over Gujarat state (India) using current year's multi-sensor data along with the information extracted from previous 5 years' RS data is presented. The methodology uses multi-source information i.e. multi-date satellite data from MODIS, two date satellite data from AWiFS, and a-priori crop history derived from multi-year multi-date MODIS data.

2. Study area and data used

This study was conducted over Gujarat, a western state of India with geographic area of 19.6 Million ha. Gujarat is an agriculturally rich state with a large number of crops grown in mainly rabi and kharif crop seasons. The major crops sown in kharif season (crops associated with the monsoon, mostly sown in June-July and harvested by September-October) include paddy (rice), cotton, groundnut, castor, jowar, bajra, tobacco, arhar, maize, sugarcane etc. Cotton, castor, tobacco, and sugarcane are the crops which continue beyond kharif season and usually available in the field during November – December period. Wheat, rapeseed & mustard, cumin, potato etc. are the major crops grown during rabi season (crops sown during winter and harvested before summer) in the state.

The satellite data used in this study include multi-date MODIS reflectance data over Gujarat for 2006-2007 to 2011-2012 rabi seasons and multi-date AWiFS data of full 2011-12 season (full season data was used for obtaining the classified image that was used as reference classified image). MODIS is a sensor aboard the NASA's Terra and Aqua satellites. The sensor views the entire Earth's surface every 1 to 2 days, acquiring data in 36 spectral bands at different spatial resolutions. Terra MODIS surface reflectance 8-day L3 global 250m (MOD09Q1) data were downloaded from the website: https://lpdaac.usgs.gov. The data used in the present study were from Julian day 281 (9th October) to Julian day 89 (30th March) in subsequent year for six rabi seasons. Thus, for 2010-11 rabi season, the time series contained 23 NDVI composite images, prepared from surface reflectance data. Overall, 115 MODIS images (23 images x 5 seasons) were processed and analysed over 5 years (2006-07 to 2010-11) for getting multi-year crop a-priori information. MODIS derived 9-dates NDVI time series upto mid-December was used for 2011-12 crop sown area early estimation. Two sets of Resourcesat-2 AWiFS data (Path/Row 92/56) for 2011-12 season were prepared. Set 1 having AWiFS data limited to mid-December and Set 2 having full rabi season data from October to March were analysed separately. While Set 1 comprised of November 17 and December 11, 2011 data, there were 7 dates of cloud-free data in Set 2. The sensor characteristics of AWiFS are given in Table 1.

Table 1: Characteristics of AWiFS onboard Resourcesat-2

Sr No	Characteristic	Value
1	Spectral band: Green (B2)	0.52 – 0.59 μm
2	Spectral band: Red (B3)	0.62 – 0.68 μm
3	Spectral band: NIR (B4)	0.77 – 0.86 μm
4	Spectral band: SWIR (B5)	1.55 – 1.70 μm
5	Spatial Resolution	56 m
6	Swath	740 km
7	Revisit period	5 days
8	Quantisation	12 bit

(Source: Bhuvan, 2012)

Crop and other land use / land cover details collected in field during crop season 2011-12 were used for training signature generation and validation in image classification. A sample of major crop parameters collected during the field visit is shown in Table 2.

Table 2: A sample of major crop parameters collected during the field visit in 2011-12

Field ID	**20111213-02**	**-**	**20111212-07**	-	**20111213-05**
Date	13 Dec 2011	-	12 Dec 2011	**-**	13 Dec 2011
Lat. (N)	23.872	-	23.685	**-**	23.774
Long. (E)	71.990	-	72.238	**-**	71.989
Crop Type	Wheat	-	Mustard	**-**	Castor
Crop Stage	CRI	-	Flowering	**-**	Capsule Formation
Field Size (m)	100x100	-	100 x 100	**-**	200x200
Synthetic Field Size (m)	200x200	-	200 x 200	**-**	-
Crop Fraction (%)	50	-	50	**-**	70
Date of Sowing	November III	-	Oct III week	**-**	N/A (Kharif)
-	**-**	**-**	**-**	**-**	**-**

3. Methodology

This study has three major data analysis components, namely analysis of multi-date and multi-year MODIS data, analysis of multi-date AWiFS data and integration of multi-source parameters for early crop sown area estimation.

3.1 Processing of MODIS and AWiFS data

MODIS MOD09Q1 data were converted from HDF-EOS format to ERDAS raster image format for further image processing through ERDAS IMAGINE software. MODIS surface reflectance values at pixel level were obtained by multiplying 16-bit unsigned data values with a factor of 0.0001 (Vermote et al., 2011).

In case of AWiFS data the Digital Numbers (DN) stored in the original data were converted to spectral radiance by using saturation radiance value available in data header file.

Accurate co-registration: Spatial characteristics of any land use / land cover including crops derived from different sources need to have common geo-referencing so that they can be integrated. It requires very accurate geo-referencing of the multi-source data. In this study, the multi-date MODIS data at 250m spatial resolution, which are well co-registered among each other, were co-registered with Resourcesat-2 AWiFS data at 56m spatial resolution. Both the datasets were brought to a common projection system of Albers Conical Equal Area (ACEA) projection and WGS84 datum.

NDVI and scaled NDVI calculation: An index derived from spectral values in Near Infra-Red (NIR) and Red (R) bands of electromagnetic spectrum, called Normalized Difference Vegetation Index (NDVI) is extensively used for studying vegetation using RS data. It responds to changes in the amount of green biomass, chlorophyll content and canopy water stress. NDVI is defined as ratio of the difference of spectral values (NIR-R) to the sum of spectral values (NIR+R). Its theoretical value ranges from -1.0 to +1.0. To avoid working with real/float numbers and to store in integer formats, it is sometimes scaled by multiplying and adding some constant values. In this case, the real values were multiplied by 100 and then 100 was added to get the scaled NDVI values.

Scaled NDVI = 100 + 100 * (NIR-R) / (NIR+R).

So the theoretical range of scaled NDVI became 0 to 200, hence the values were stored in single byte format.

Screening & smoothening of MODIS time series data: An algorithm, named Harmonic ANalysis of Time Series (HANTS) was employed for detecting the cloud contaminated pixels in MODIS data and for temporally interpolating the remaining non-contaminated data to construct gapless images at a prescribed interval of 8 days. The HANTS algorithm was devised and developed at NLR (Nationaal Lucht- en Ruimtevaartlaboratorium), in collaboration with KNMI (Koninklijk Nederlands Meteorologisch Instituut) and Alterra (Menenti et al., 1993; Verhoef et al., 1996; Roerink et al., 2000) the Netherlands. Its applications have been successfully demonstrated for vegetation monitoring, land surface temperature studies and generating cloud-free weather images (Wen et al., 2004; Xu and Shen, 2013; Sharma et al., 2014). The HANTS software can be downloaded free from the Naval Research Laboratory (NRL) website http://www.nlr.org/space/earth-observation/ or http://gdsc.nlr.nl/gdsc/en/tools/hants.. It can be implemented through MATLAB also (Abouali, 2012).

The HANTS algorithm can provide a much better smoothing of time series than most other methods can offer. Further details on HANTS can be found elsewhere (see Roerink et al., 2000; Wen et al., 2004; Verhoef et al., 2005). The basic mechanism is to calculate a Fourier series to the data, identify and remove outliers and replace them with the value produced by the Fourier series. This process is controlled by five parameters, which have to be set at the beginning of each HANTS run. The HANTS control parameters used are shown in Table 3.

Examples of thin cloudy data normalisation and thick cloudy data interpolation using HANTS technique are shown in Fig. 1.

3.2 Extracting data specific crop patterns

Data specific pattern analysis is an important element of multisource data mining. The idea is to mine each data type separately to get data patterns using appropriate mining techniques instead of combining all the data into one huge dataset before mining. Then assemble the data specific attributes (information) derived from all the data types separately and perform integrated analysis on them. This approach promotes data specific knowledge discovery at each data source independently to maximize utility of data specific information. In this study, based on the field knowledge, rabi crop locations were identified on the images and crop specific temporal NDVI patterns were derived from multi-date MODIS (2006-07 to 2010-11) as well as multi-date AWiFS data (2011-12, reference dataset).

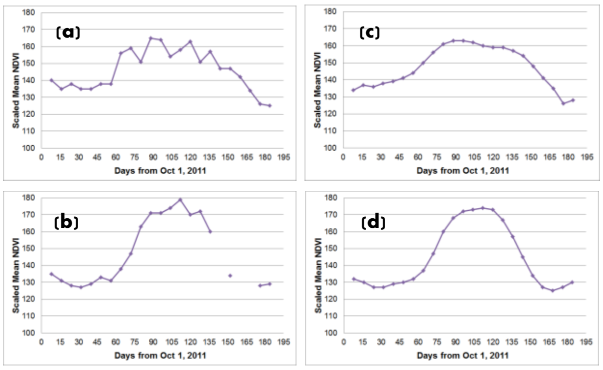

Figure 1: Examples of Harmonic ANalysis of Time Series (HANTS) applications: (a) scaled NDVI profile of a rabi crop with thin cloudy atmosphere, (b) scaled NDVI profile of another rabi crop with missing data due to thick cloudy atmosphere; (c) after applying HANTS over profiles in (a); and (d) after applying HANTS over profiles shown in (b)

3.3 ISODATA Classification

The Iterative Self-Organizing Data Analysis Technique (ISODATA) was used as an unsupervised classifier by recognizing multi-temporal patterns in the dataset (Ball and Hall, 1965). It is an iterative and heuristic procedure which assigns first an arbitrary initial cluster vector based on user's input. In the second step, it classifies each pixel of the data to the closest cluster in spectral domain. Merging and splitting of clusters is done, if conditions are met. Clusters are merged if either the number of pixels in a cluster is less than a certain threshold or if the centres of two clusters are closer than a certain threshold. Similarly, clusters are split into two different clusters if the cluster standard deviation exceeds a predefined/user defined value and the number of pixels is twice the threshold for the minimum number of pixels in a cluster. In the third step the new cluster mean vectors are calculated based on all the pixels in that cluster. The second and third steps are repeated until the "change" between two consecutive iterations is small. ISODATA has been found very effective at identifying spectral clusters in data. It is especially very useful while analysing a new data as we don't need to know much about the data beforehand. Care has to be taken that the data is structured well otherwise ISODATA may take long time if data is largely unstructured. Conceptual flow of the procedure followed in ISODATA clustering and spectral matching is shown in Fig. 2.

Before classifying 9-dates MODIS NDVI time-series data of 2011-12, temporal patterns of reference crops were obtained from 9-dates NDVI values at the crop locations collected during the in-season field surveys. Stacked 9-dates NDVI data was subjected to ISODATA and clusters were obtained for 2011-12 season. The temporal NDVI patterns of the ISODATA clusters were then matched with the reference patterns and classified into different classes based on their temporal profiles.

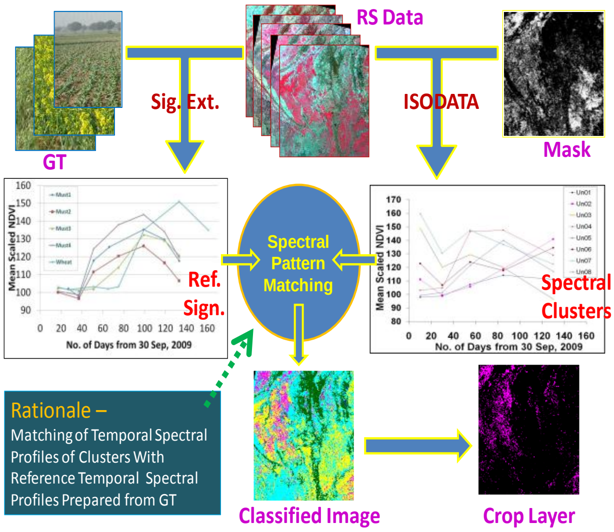

Figure 2: Conceptual flow of ISODATA clustering and spectral pattern matching showing major data analysis components

Multi-date full-season MODIS NDVI time series data from 2006-07 to 2010-11 were subjected to data screening and extrapolation before classification. The HANTS corrected data were then classified using ISODATA clustering. The temporal spectral profiles of ISODATA clusters were matched with the reference temporal spectral profiles and the clusters were labelled to rabi-crop and other than rabi classes. Thus classified images were obtained for 5 rabi seasons i.e. 2006-07 to 2010-11.

Two sets of multi-date AWiFS data, as described earlier, were processed to prepare classified images. Set 1 was classified by subjecting 7 dates of NDVI stack to ISODATA clustering and then labelling of clusters to rabi-crop and other classes. In case of Set 2, firstly December 11 AWiFS data was classified by ISODATA in vegetation (crops, forest, shrubs, plantations etc.) and other classes and ΔNDVI (i.e. $NDVI_{Dec11} - NDVI_{Nov11}$) image was used for classifying vegetation class in 4 sub-classes based on NDVI gradient.

3.4 Integration by decision tree approach

Decision tree approach is a commonly used method of information extraction in data mining. The objective is to create a model that estimates the value of a target variable based on several input variables available from single or multiple data sources. A decision tree is a flow-chart-like structure, where each internal (non-leaf) node denotes a test on an attribute, each branch represents the outcome of a test, and each leaf (or terminal) node holds a class label. The topmost node in a tree is the root node (Quinlan, 1993).

In this study three input images namely (i) a-priori crop history image from 5-years multi-date MODIS data, (ii) 9-dates MODIS derived classified image, (iii) 2-dates

AWiFS derived classified images were integrated to yield an output image.

The a-priori rabi crop history image was prepared by integrating 5 classified images of 2006-07 to 2010-11 seasons and the crop pixels were grouped in following 5 classes:

- Apr1: pixels with crop all the 5 years.
- Apr2: pixels with crop in 2010-11 and any 3 seasons.
- Apr3: pixels with crop in 2010-11 and any 2 seasons.
- Apr4: pixels with crop in 2010-11 and any 1 season.
- Apr5: pixels with crop in 2010-11 only.

Decreasing weightages were given to these classes, highest to Apr1 and lowest to Apr5, while this image was integrated for final classification of crop sown area for 2011-12 rabi season.

4. Results and Discussion

The MODIS / Terra MOD09Q1 and Resourcesat-2 AWiFS image sub-sets for Gujarat state were extracted from the original data from October to mid-December 2011. While MODIS two bands i.e. red (620 – 670 nm) and near infrared (841 – 871 nm) data were used, all the four bands data from AWiFS (Green: 0.52-0.59µm, Red: 0.62-0.68µm, NIR: 0.77-0.86µm, and SWIR:1.55-1.70µm) data were used in this study.

The MODIS reflectance images were used to derive scaled NDVI for all the nine 8-day interval dates (8, 16, 24 October, 1, 9, 17, 25 November, 3 and 11 December, 2011) of 2011-12 rabi season. Scaled NDVI images obtained from MODIS reflectance data are shown in Fig.3. The temporal variations of forest cover NDVI are clearly visible from October to December images. The spectral contrast between forest regions (for example Gir Forest and Dangs Forest) and their surroundings has continuously decreased from October to December. It is because of decrease in Forest NDVI and increase in crop NDVI during this time period.

In case of Resourcesat-2 AWiFS Set 1 data, cloud free images were available for 2 dates (November 17 and December 11) over the selected study period of October to mid-December. Colour Composite prepared from 2 dates data (Red: ΔNDVI, Green: red band of Dec 11, Blue: NIR band of Dec 11) is shown in Fig. 4. In case of AWiFS Set 2 data, similar methodology was followed and the NDVI time series was classified to rabi crop classified image using ISODATA clustering. As this dataset contained full rabi season data, the crop temporal spectral patterns of major crops were well discriminated from each other and this image was considered as reference classified image. Typical temporal NDVI patterns of three major rabi crops of Gujarat are shown in Fig. 5.

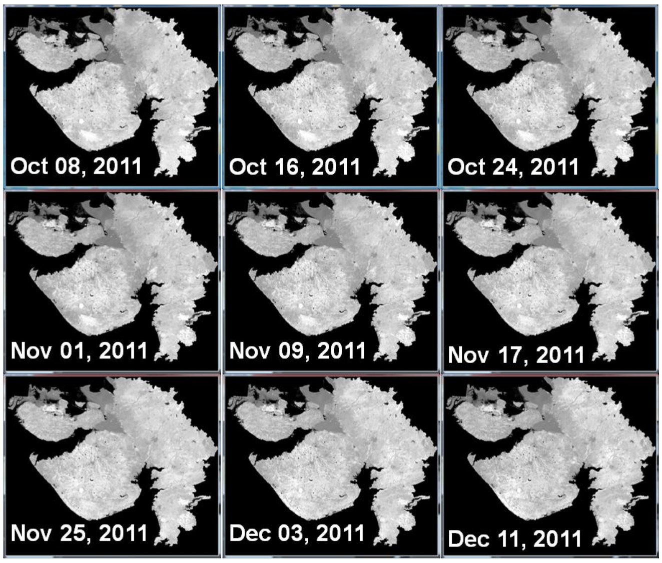

Figure 3: Scaled NDVI images obtained from MODIS reflectance data over Gujarat from October 8, 2011 to December 11, 2011 (2011-12 rabi season)

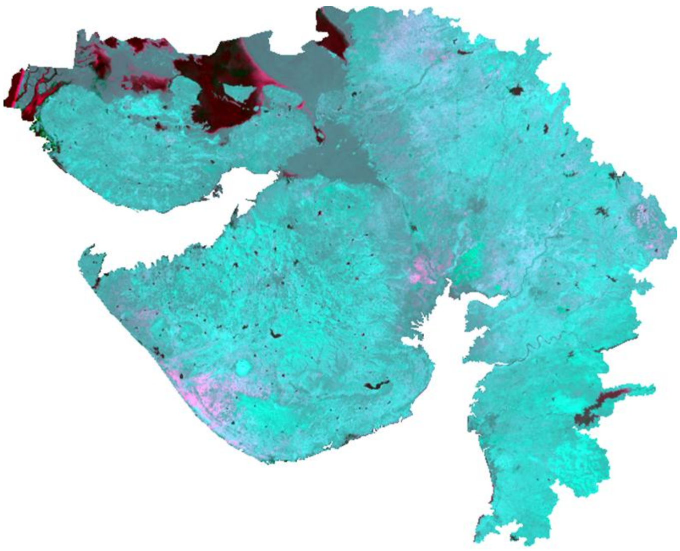

Figure 4: Colour Composite prepared from 2 dates AWiFS data (Red: ΔNDVI, Green: red band of Dec 11, Blue: NIR band of Dec 11). The regions with high ΔNDVI are red and pink in the image. The rabi crop area are visible in pink colour

A subset of the MODIS / Terra MOD09Q1 8-day reflectance data for Red and NIR bands was created for all the 5 seasons (2006-07 to 2010-11). Multi-date NDVI images were prepared from the reflectance images. The HANTS corrected NDVI stacked images were subjected to ISODATA clustering for each crop season. Based on the temporal spectral profiles shape matching with the reference profiles, unknown clusters were classified to different classes. Classes were merged to form rabi crop and other-than-rabi-crop theme images. The visual profile matching was carried out based on the overall NDVI pattern, peak value, time of peak, duration of peak value, growth gradient, decay gradient etc.

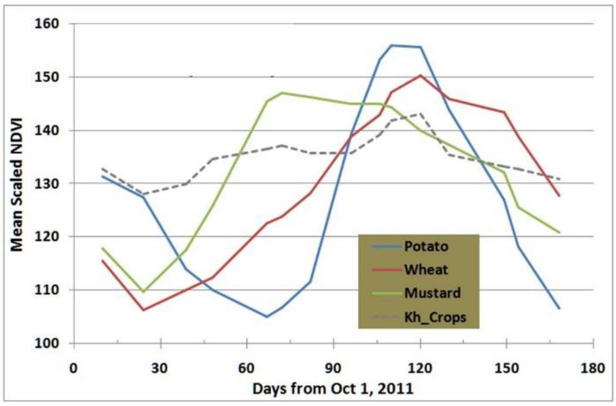

Figure 5: Typical temporal NDVI patterns of three major rabi crops and a kharif crop of Gujarat derived from multi-date AWiFS data

These five classified images for 2006-07 to 2010-11 seasons were used to create a-priori rabi crop history image for 2011-12 season. The a-priori rabi crop image is shown in Fig. 6.

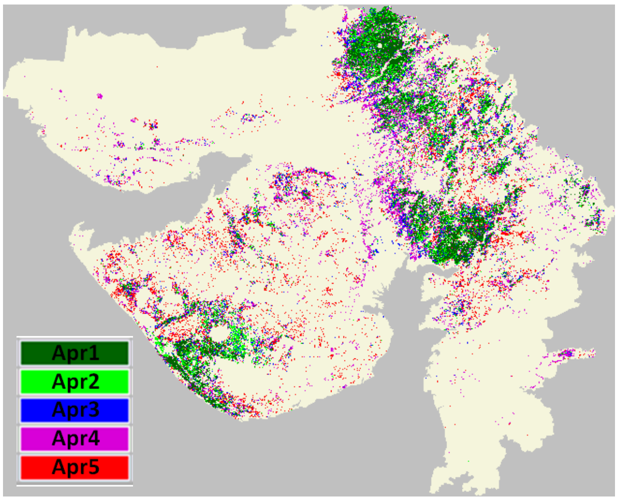

Figure 6: The a-priori rabi crop image prepared from 5-year multi-date MODIS data. While Apr1 represent the pixels with rabi crop for all the 5 years, Apr5 represents rabi crop during the previous season i.e. 2010-11

The crop sown area image for 2011-12 was obtained by integrating information extracted from 9-dates of MODIS images, 2-dates of AWiFS images and the a-priori rabi crop history image prepared from 5-years of multi-date MODIS images. The hierarchical decision rules were applied for obtaining this classified image and are given in Table 4. The pixels belonging to the fields where crop was grown during all the 5 rabi seasons were assigned a-priori category Apr1. Similarly, Apr2 to Apr5 categories were assigned as defined in Section 3.4. While forming decision rules for integration, Apr1 and Apr2 (crop at least 4 years) were given the highest weightage. The pixels belonging to Apr1 & Apr2 were classified to rabi crop class although ΔNDVI (AWiFS) was just greater than 0.0 with ΔNDVI (MODIS) was just greater than 0.05 (see Level 5, Table 4). However, Apr5 was given the least weightage as the pixels belonging to it were classified to rabi crop only with higher gradient values of both the ΔNDVIs (see Level 2, Table 4).

Table 4: The hierarchical decision rules applied for obtaining the classified image by integrating multisource data

Level	MODIS 9-Dates	AWiFS 2-Dates	A-priori (5-years)	Output, if YES
1	Non-rabi-crop class	Non vegetation class or ΔNDVI< 0	-	Non Rabi crop
2	Rabi crop with ΔNDVI>0.10	Veg. class with ΔNDVI> 0.05	Crop at least 1 year	Rabi crop 1
3	Rabi crop with ΔNDVI>0.10	Veg. class with ΔNDVI> 0	Crop at least 2 years	Rabi crop 2
4	Rabi crop with ΔNDVI>0.05	Veg. class with ΔNDVI> 0.05	Crop at least 3 years	Rabi crop 3
5	Rabi crop with ΔNDVI>0.05	Veg. class with ΔNDVI> 0	Crop at least 4 years	Rabi crop 4
6	Rabi crop	Vegetation class	-	Non Rabi crop

Note: In case of MODIS 9-Dates, ΔNDVI = (mean NDVI of 7,8,9 – mean NDVI of 4,5,6) and in case of AWiFS 2-Dates, ΔNDVI = (NDVI Dec 11 – NDVI Nov 17).

While the crop sown area estimated from 9-dates MODIS data was found to be 2.370 million hectares (0.913 Mha with NDVI>0.1 and 1.457 Mha with NDVI>0.05); the integrated dataset yielded rabi crop sown area of 1.125 million hectares. This shows that the classification based on only MODIS data overestimated the rabi sown area; as rabi crop area at the end of crop season was reported to be 2.045 million hectares (DES, 2016). The rabi crop sown area as on mid-December 2011 was reported to be 1.238 million hectares (DES, 2016), indicating that the area estimated by the proposed methodology is almost same as reported. However, it is not expected that the RS data upto mid-December should match the area estimated reported by mid-December. It is expected that the data upto mid-December may pick-up the crop sown at most upto November end. This indicates that the proposed methodology is slightly overestimating the crop sown area. The degree of over estimation could not be quantified as November-end crop sown area estimates are not available from any source. The classified image obtained through the proposed methodology was checked for its accuracy in classifying the rabi crops for 2011-12. It was compared with the reference crop sown area image obtained using full rabi season AWiFS data.

It was found that crop sown area images upto mid-December could pick up almost 57% of full season rabi crop area. Sharma et al. (2014) estimated the rabi sown crop area of 1.798 million hectare using full season MODIS data, but early estimation was not attempted.

Government of India (Department of Agriculture and Farmers' Welfare) estimated that almost 60% of full season rabi crop was sown as on December 16, 2011. The mapping accuracy of rabi sown area was found to be 88.6% with respect to the reference full season AWiFS image based rabi sown area. The full season crop sown area determined from the reference classified image was 1.972 million hectares. While the Government of India (DES, 2016) estimates were 1.238 and 2.045 million hectares as on December 16, 2011 and February 24, 2012, respectively.

5. Conclusion

A technique for early estimating crop sown area over a large region has been developed using multi-source remote sensing data. Crop sown area of Gujarat state (India) for 2011-12 rabi season was estimated by mid-December. The multi-source data used in this study included in-season MODIS 8-day composite, and two dates AWiFS data along with multi-year, multi-date MODIS derived a-priori crop image. Initial crop growth trends in terms of NDVI values were obtained from multi-date MODIS data from October to mid-December 2011. ISODATA clustering algorithm was used to cluster similar trends of temporal NDVI patterns. Spatial distribution of crop and non-crop fields/clusters was obtained from two dates AWiFS data (November 17 and December 11). Integration of the temporal patterns derived from MODIS data, spatial clusters derived from AWiFS data, and a-priori image derived from multi-year MODIS data was carried out using hierarchical decision tree approach. Reference crop sown area was obtained by using full crop season multi-date AWiFS data for 2011-12. It was found that the integration of in-season multi-source data provided the crop sown area estimates closer to the reference estimates.

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