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Analysis of INSAT 3A CCD NDVI data for crop monitoring in Rabi season

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Abstract: *Over the last 30 years, coarse resolution satellite sensors are being used routinely to monitor crops and other vegetation, to generate various estimates on their areal extent and to detect the impact of moisture stress on vegetation, at regional scales. Satellite derived Vegetation indices have been used extensively for varied geospatial applications in agriculture. Vegetation indices show better sensitivity than individual band reflectance and hence are more preferred for crop vigor assessment, crop discrimination, crop monitoring etc. Vegetation indices also act as proxies to various crop bio-physical parameters. NDVI, the most popular index due to its simplicity in computation and interpretation has been found to be a proven index for crop studies. As a result, several geospatial products of NDVI and its derivatives are available as free downloads from various sensors of moderate to coarse resolutions. But all these datasets are from polar orbiting satellite systems and are limited by inadequate temporal repitivity, leading to the presence of considerable extent of cloud infestation in the composite images. Geostationary satellites with constant viewing direction produce the images of higher geometric fidelity and their very high temporal frequency reduce the residual cloud content in the composite images.*

Application potential of geostationary satellite data for crop monitoring is investigated in the current study. Indian Geostationary satellite INSAT 3A launched in 2003 provides spectral data in red, NIR and SWIR bands at 1km spatial resolution through its CCD sensor. It has a very high temporal receptivity (half an hour) with constant view direction.NDVI generated at multiple times in a day from INSAT provide opportunity to get more cloud free NDVI compared polar orbiting large swath satellites (Fensholtet al., 2006).

Keywords: **NDVI, remotesensing, crop-monitoring, geo-stationary satellites.**

1) Introduction:

India is the second most populous country, seventh largest country by geographical area and the most populous democracy in the world. India is agriculture dependent country. Agriculture is the means of livelihood of almost two thirds of the work force in the country. It has always been India's most important economic sect or. Agriculture resources are among the most important renewable, dynamic natural resources.

After achieving self-sufficiency in food grain production through green revolution, Indian agriculture is in crisis today with an unprecedented challenge of sustainable resource management. Recent research has brought clear-cut evidences that Indian agriculture is tending to stagnate with slowing down productivity, increasing yield gap etc. Alarmingly lower growth rates in the agricultural GDP are a cause of serious concern for the planners in the country and remind the technologists and scientists of the overwhelming challenge of reviving the agriculture sector. The situation calls for innovative ways of planning and execution to revive the moribund agriculture sector and to bring it to the path of sustainable development. Both policy makers and farming community should be knowledge based and tap the full potential of emerging areas like information and communication technologies in addition to implementing the sustainable farming practices. Globalization and technological innovations could also contribute to the acceleration of change in agriculture.

With the population increasing in leaps and bounds, an accurate and timely crop monitoring system is an essential element for strengthening the country's food security. Periodic with-in season estimates of crop hectarage and yield and accurate forecast of most likely range of crop growth conditions help in organising availability of inputs. Pre-harvest estimates of crop production, guides the decision makers in formulating optimal strategies for planning, distribution, price fixation, procurement, transportation and storage of essential agricultural products.

ICT based monitoring of crops during the season and generating customized information on the prospects of crops would help minimize the impacts of various kinds of risks in farming. A sound crop monitoring system with a combination of technologies and research methods is a pragmatic approach that leads to more efficient planning and to assess the crop prospects from time to time. Thus, the near real-time crop information products from sowing-harvesting, has great influence on crop management and policy-making on the price, circulation and storage.

Crop monitoring helps to provide accurate tools in decision-making. It reduces uncertainty by providing real time, accurate and validated information in form of maps. The technology supporting this project is remote sensing. Ultimately in form of accurate, high-resolution maps, this technology will help manage challenges to achieving food security by providing real-time transparent information on wheat growth in developing countries and emerging economies. Conventional methods for wheat monitoring are based on ground-collected statistics, which is time consuming, inaccurate and expensive. Since the 1980s, satellite remote sensing has been considered as an important component in most crop monitoring programs.

Ground surveys estimate the crop acreage and production at the provincial and national level but the limitation is getting timely and accuracy. Some of the limitations of conventional crop monitoring systems include – qualitative measurements, human intensive, subjective judgements, time consuming, expensive etc.

Unlike point observations of ground data, satellite sensors provide direct spatial information. Because of its ability to provide fast, up-to-date information and wide spatial coverage, space borne imagery is being used extensively for monitoring agriculture. Remote sensing (RS) is very promising in monitoring agriculture and water management activities as both the spatial and temporal characteristics of a region can be easily accounted for by satellite imageries. Remote sensing, with varying degree of accuracy, has been able to provide information on land use, irrigated area, crop type, biomass development, crop yield, crop water requirements, crop evapotranspiration, salinity, water logging .Water demand by the crop depends on the phenological stages. It is possible to extract crop phenological stages from satellite image.

2) Objectives of the study:

The present study investigates the potential of INSAT 3A satellite data for crop monitoring

The specific objectives are:

(i) Comparison of INSAT NDVI data sets with other global NDVI data sets AVHRR,MODIS.

(ii) To perform unsupervised classification using multi-temporal NDVI composites for discriminating rabi crop area and wheat area .

3)STUDY AREA

Analysis of data and generation of time composite images was done for all India to study the temporal NDVI changes in different crop growing environments. Detailed analysis of NDVI composites for multiple years was carried-out in Haryana.

Haryana State - Salient Features

The total geographical area of the state is 44,212 km^2. Average annual rainfall is 573mm (Range from 325 mm in the south-west to 988 mm in the north-east) . The net cropped area is 3.64 million hectares. About 86% of the area is arable, and of that 96% is cultivated. About 75% of the area is irrigated, through tubewells and an extensive system of canals. The main crops of Haryana are wheat, rice, sugarcane, cotton, oilseeds, pulses, barley, maize, millet etc. There are two main types of crops in Haryana: Rabi and Kharif. The major Kharif crops of Haryana are rice, jowar, bajra, maize, cotton, jute,
sugarcane, sesame and groundnut. The crops are ready for harvesting by the beginning of November. The major Rabicrops are wheat, tobacco, pulses, linseed, rapeseed and mustard. The ground is prepared by the end of October or the beginning of November and the crops are harvested by March.

4) SATELLITE DATA USED:

INSAT-3A SATELLITE DATA:

INDIAN NATIONAL SATELLITE SYSTEM IS A MULTI PURPOSE GEO-STATIONARY SATELLITE.

Meteorological payload of INSAT-3A:

- Very High Resolution Radiometer (VHRR) with 2 km resolution in visible band and 8 km resolution in Infrared and Watervapour band.

- Charged Coupled Device (CCD) camera operating in Visible(0.4-0.7micrometer), Near Infrared(0.75-1.4micrometer) (NIR)and Shortwave Infrared band(1.4-3micrometer)(SWIR) with 1km resolution

- Data Relay Transponders (DRT) .

NOAA-AVHRR SATELLITE DATA:

- It is a space-borne sensor embarked on the National Oceanic and Atmospheric Administration (NOAA) family of polar orbiting platforms (POES).
- It has a cross track scanning system with five spectral bands having a **resolution of 1.1 km** and a frequency of earth scans twice per day (0230 and 1430 local solar time).
- The **5 spectral bands** of AVHRR are **Red (0.6 micrometres)** and **NIR(0.9 micrometres)regions**, the **third one** is located around **3.5 micrometres**, and the **last two sample the thermal radiation** emitted by the planet, around **11 &12 micrometres.**

MODIS(TERRA) SATELLITE DATA:

Terra's orbit around the Earth is timed so that it passes from north to south across the equator in the morning, while Aqua passes south to north over the equator in the afternoon.

Terra MODIS and Aqua MODIS are viewing the entire Earth's surface every 1 to 2 days, acquiring data in 36 spectral bands, or groups of wavelengths

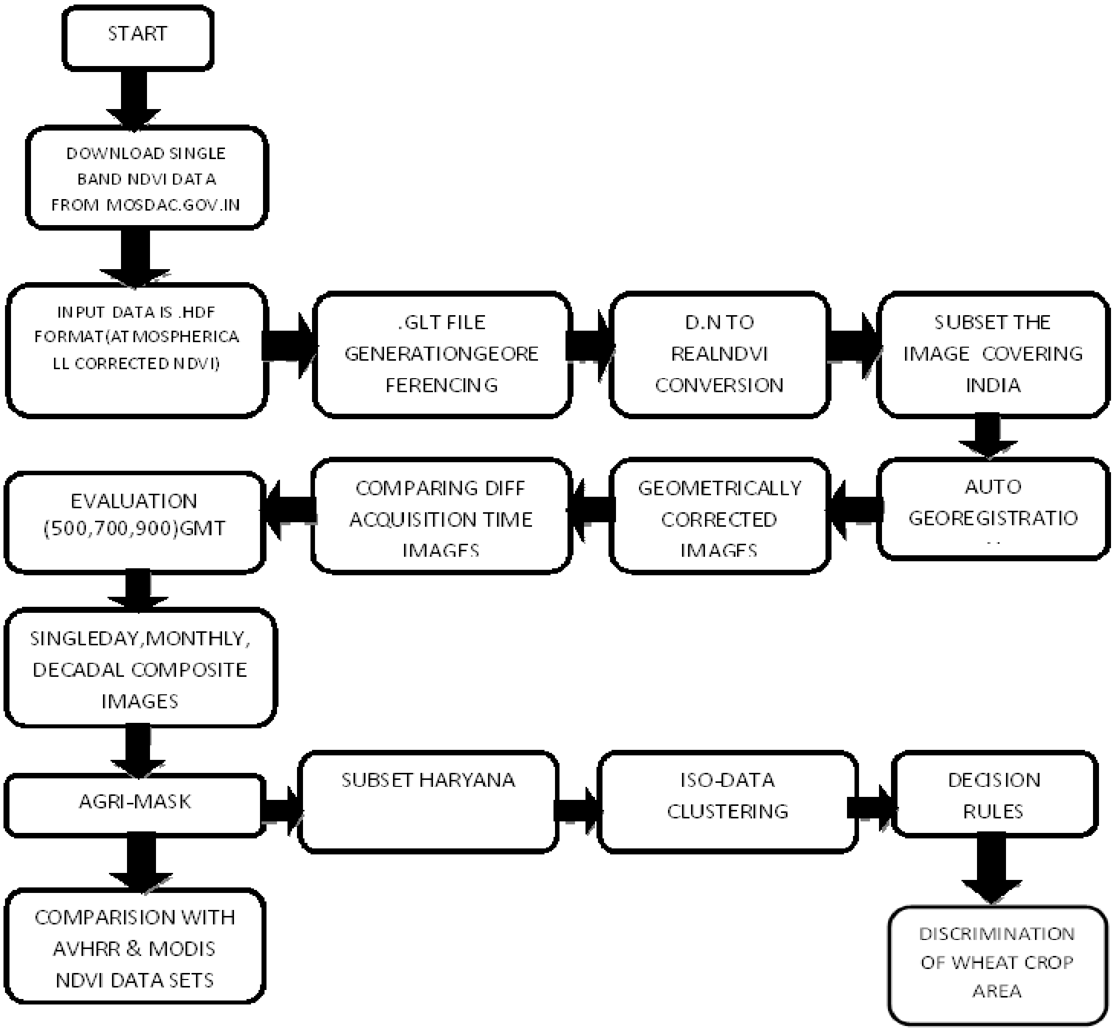
For comparison Terra MODIS 500m resolution(bands 3-7) ndvi data is used.Whose band widths are

BAND	BANDWIDTH(in micrometres)
3	0.459-0.479
4	0.545-0.565
5	1.230-1.250
6	1.628-1.652
7	2.105-2.155

Table 1: Satellites/Sensors widely used for Agriculture Monitoring

S. No	Satellite/sensor	Spectral resolution (μm)	Spatial resolution (m)	Radiometric resolution (bits)	Temporal resolution
1.	NOAA-AVHRR	0.58-0.68 0.725-1.00 3.55-3.93 10.3-11.3 11.5-12.5	1100	10	Twice a day
2.	Terra/Aqua-MODIS	36 bands	250 500 1000	12	Every day
3.	IRS 1C/1D - WiFS	0.62-0.68 0.77-0.86	188	7	5 days
4.	IRS P6-AWiFS (RESOURCESAT-I)	0.53-0.59 0.62-.068 0.77-0.86 1.55-1.70	56	10	5 days
5.	IRS P6-LISS-III (RESOURCESAT-I)	0.52-0.59 0.62-0.68 0.77-0.86 1.55-1.70	23.5	7	22 days

5) METHODOLOGY:



6) Preparation of INSAT datasets

INSAT data preparation requires following steps

1. Downloading NDVI data (single channel).
2. Conversion of .HDF format to .IMG
3. Conversion of D.N values to real NDVI values
4. Co-registration
5. Subset the image and masking non agriculture areas.
6. Generation of decadal and monthly time composite images

6.1 Downloading NDVI data(Single Channel image).

INSAT 3A CCD NDVI data can be downloaded directly from WWW.MOSDAC.GOV.IN. This is the data centre archives Meteorological and Oceanographic data products from ISRO science missions, which is free of cost. For this study 700 GMT data was used which is 12:30 pm pass (IST=5(1/2)hours+GMT) and for analysis of change in NDVI acquired within a day images of 900GMT,700GMT,500GMT were also analysed. Downloaded data is in .HDF file format which is Hierarchical Data format.It is the name of set of file formats and libraries designed to store and organize large amounts of numerical data. HDF is supported by many software platforms including Java, MATLAB/Scilab, Octave, IDL, Python.The freely available HDF distribution consists of the library, command-line utilities, test suite source, Java interface, and the Java-based HDF Viewer (HDFView).The downloaded data is single band NDVI data which is atmospherically corrected but not georeferenced.

The NDVI is calculated from these individual measurements as follows:

$$\mathrm{NDVI} = \frac{(\mathrm{NIR} - \mathrm{VIS})}{(\mathrm{NIR} + \mathrm{VIS})}$$

where VIS and NIR stand for the spectral reflectance measurements acquired in the visible (red) and near-infrared regions, respectively .NDVI values for vegetation generally range from 0.1 to 0.7, the higher index values being associated with greater green leaf area and biomass (Tucker, 1979). Lowering of vegetation index values reflects moisture stress in vegetation, resulting from prolonged rainfall deficiency. Such a decrease in vegetation index could also be caused by other stresses such as pest / disease attack, nutrient deficiency or geochemical effects. The seasonal vegetation index profile is thus reflective of vegetation dynamics and condition. Comparison of vegetation index profile of the reporting year and a previous normal agricultural year provides assessment of drought impact in the scale of previous agricultural scenario. According to McVicar and Jupp (1999), NDVI associated with drought decreases while the Land Surface Temperature (LST) increases slightly earlier than plant cover decreases.

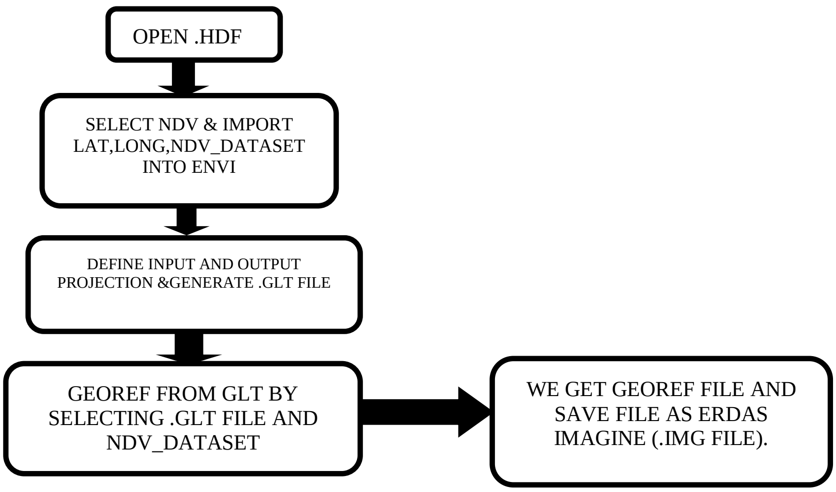
NDVI gives the information on vegetation cover defined as the ratio of difference in red and near infrared reflectance to their sum. Index values can range, theoretically from -1.0 to 1.0, but vegetation values typically range between 0.1 and 0.7. Higher index values are associated with higher levels of healthy vegetation cover, whereas clouds and snow will cause index values near zero, making it appear that the vegetation is less green (Tucker, 1979).

6.2 Conversion of .HDF format to .IMG

To perform analysis we require NDVI image. So to get image we need to convert .HDF format to .IMG file. For conversion we use ENVI software. ENVI (an acronym for "ENvironment for Visualizing Images") is a software application used to process and analyze geospatial imagery. It is commonly used by remote sensing professionals and image analysts.

The process of conversion from .HDF to .IMG is shown in following flow chart.

Fig 1:Steps for conversion of .HDF to .IMG

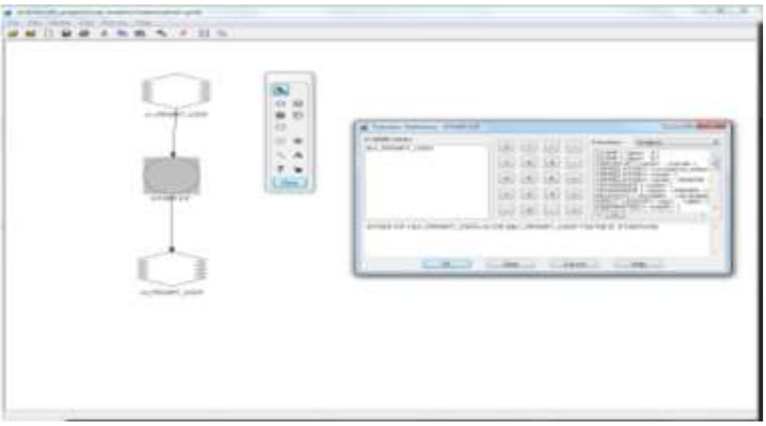


In the above steps we define input and output projection as Geographic Lat/Long and generate .GLT file which is Geographic Look-up Table file which is not georeferenced so we georeference .GLT file by selecting NDV_DATASET and save the resultant file as Erdas Imagine which is .IMG file.

6.3 Conversion of D.N values to Real NDVI values.

After conversion of .HDF format to .IMG file the resultant .IMG file contains pixel values in Digital Numbers(D.N) values. Which are ranging from 0 to 255 depending on spectral reflectance of features on earths surface. For analysis we require Real NDVI values which are ranging from 0 to 1. We use modelmaker for conversion of D.N values to Real NDVI values in ERDAS IMAGINE software. The model for conversion is shown in figure.

Fig 2: Model for conversion of D.N values to Real NDVI

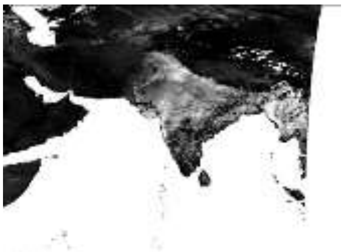


In the above model Input image contains pixel values in Digital Numbers ranging from 0 to 255 and the output image contains pixel values in Real NDVI ranging from 0 to 1.The conversion logic used in this model is as follows.

EITHER 0 IF ($n1_PROMPT_USER==0) OR (($n1_PROMPT_USER-110)/100.0) OTHERWISE

The resultant sample image is as follows.

Fig 3:INSAT 3A CCD NDVI IMAGE 700GMT22OCT2012



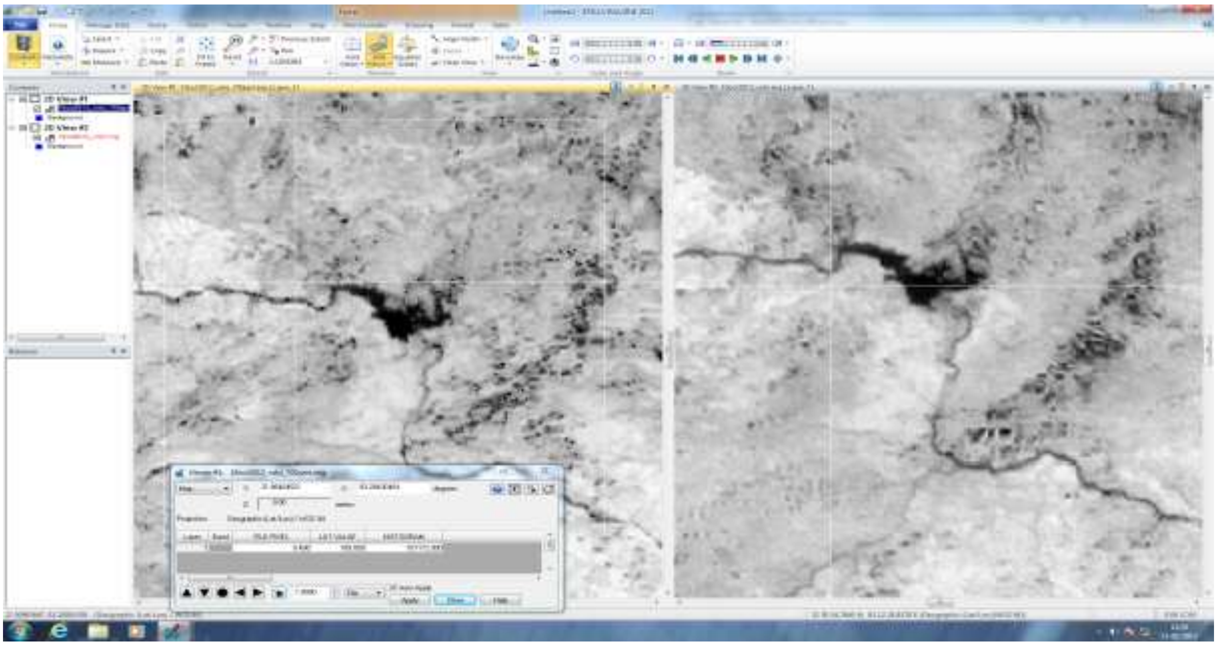
We can see that INSAT 3A satellite covers INDIA and also other surrounding countries.

6.4 Co-registration

The resultant images are co-registered and contains Real NDVI values. But due to shift in acquisition path we need co-registration. The Geometric mismatch is shown in following figures. Although the INSAT images are georeferenced there is a significant geometric mismatch between two images.

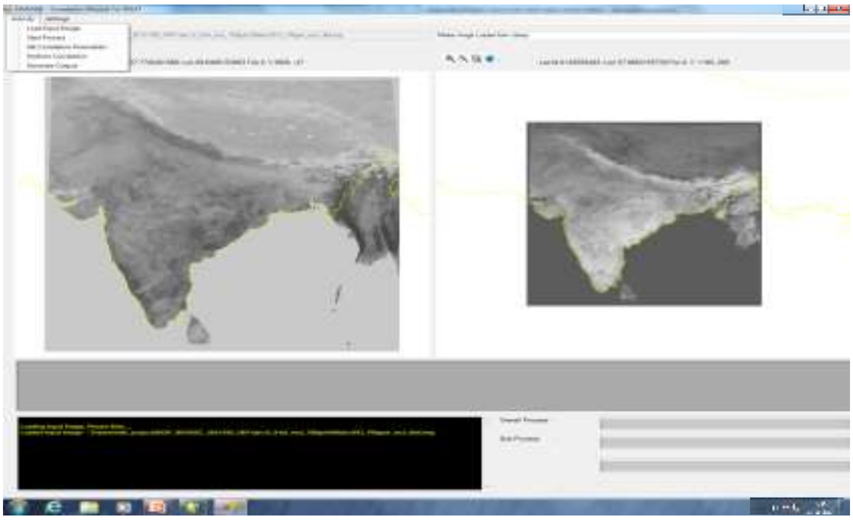
Fig 4: Geometric Fidelity of satellite images

INSAT 3A CCD NDVI OF 18OCT2012 700GMT **INSAT 3A CCD NDVI OF 18OCT2012 900GMT**



We can observe from above images that there is a shift. We cannot use these images for further analysis and we cannot generate Time Composite images. So we need to Co-register all the images with respect to one image which should be a clear day image. After observing all the images a clear day image dated 12JAN2013 700GMT is considered for geo-registration. For co-registering two images manually it takes more time. We can co-register 3 or 4 images per day. To overcome this problem a automatic co-registration tool developed at NRSC and we can use this tool for co-registration. With the help of this tool we can georegister 30 images per day. This automatic registration tool was developed using Visual Studio.net with MapWinGIS ActiveX controller for image viewing. The uniqueness of this tool was that it contains GDAL library in the core for image processing routines. The registration method depends on multi level correlation technique supported by OSSIM registration module. This automatic registration tool was customized at NRSC. The Auto co-registration tool is shown in following figure.

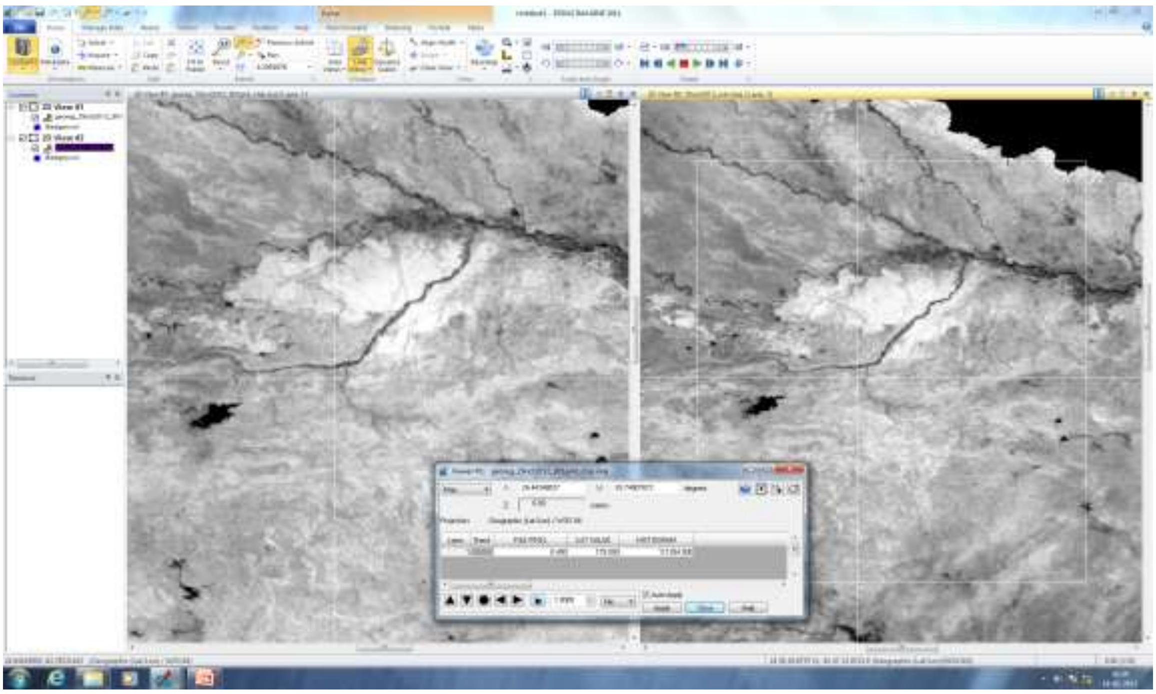
Fig 5:Co-registration



In the above image the reference image is 12JAN2013 700GMT and the input is NDVI image which is georeferenced but not georegistered. We have to load input image and click on start process. This tool contains predefined control points more than 1800 covering all over India. When we click on start process then it checks for matching control points and Georegisters automatically .The resultant output is saved in .TIFF format.

Fig 6: Resultant image after Co-registration

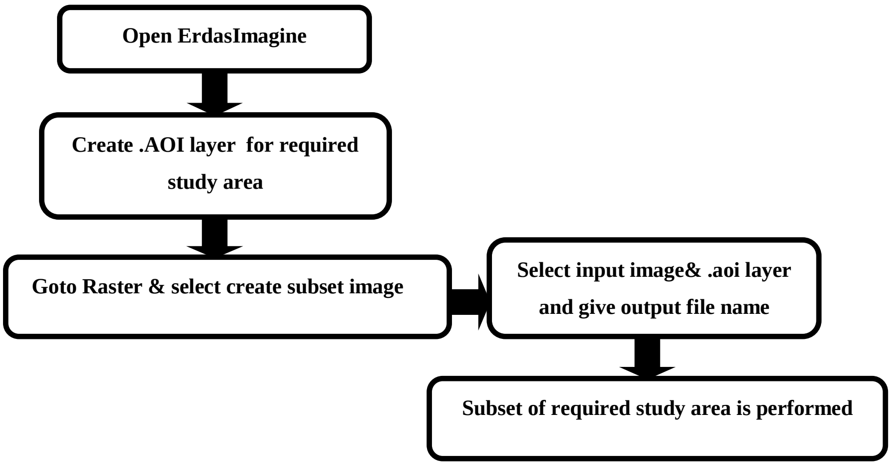
INSAT 3A CCD NDVI OF 29OCT2012 901GMT **INSAT 3A CCD NDVI OF 30OCT2012 900GMT**



6.5 Subset the image covering required study area and generate Agri-mask images.

After Auto-georegistering all the images of different years (2010-11,2011-12,2012-13) Rabi data(oct-april) subsetting of required study area is performed. INDIA subset is performed first and the required study area Haryana is subsetted from INDIA subset image. To perform subset of image we use Erdas Imagine for this we require .AOI layer which covers the required study area.

Fig 7: Steps for subsetting require study area



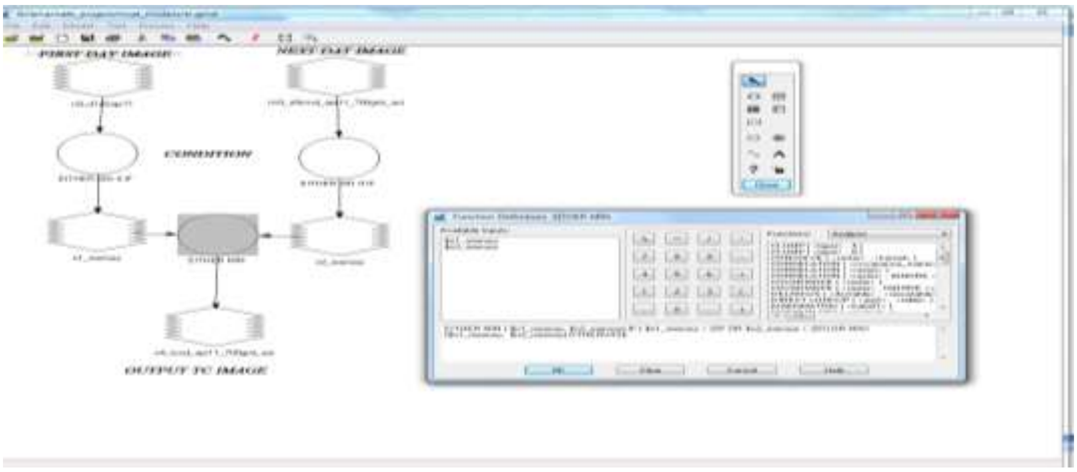
6.6 Generating decadal and monthly Time composite Images

Daily NDVI images of 0700 GMT were composited over decadal (10 days) period, using maximum value compositing (MVC) approach. MVC is widely recommended technique for time composition . Maximum Value Composites (MVC) technique retains the highest NDVI value for each pixel during a 10-day period producing images that are spatially continuous and relatively cloud-free, with temporal resolution sufficient for evaluating vegetation dynamics (Holben,1986).

Since the images are available on daily images and that these images are relatively cloud free due to post-monsoon season, the period of time composition is taken as 10 days which is sufficient to capture the changes in agricultural areas. SPOT NDVI images are generated with 10-day composite and MODIS images are produced as 8-day period. Decadal composite images from Decade 1 (D1) of Oct 2012 to Decade 3 (D3) of April 2013 over India

Time composite images are required for crop area estimation, crop monitoring and crop growth analysis. The model for generating Time composite NDVI was described here under.

Fig 8:Model for Time composite image generation



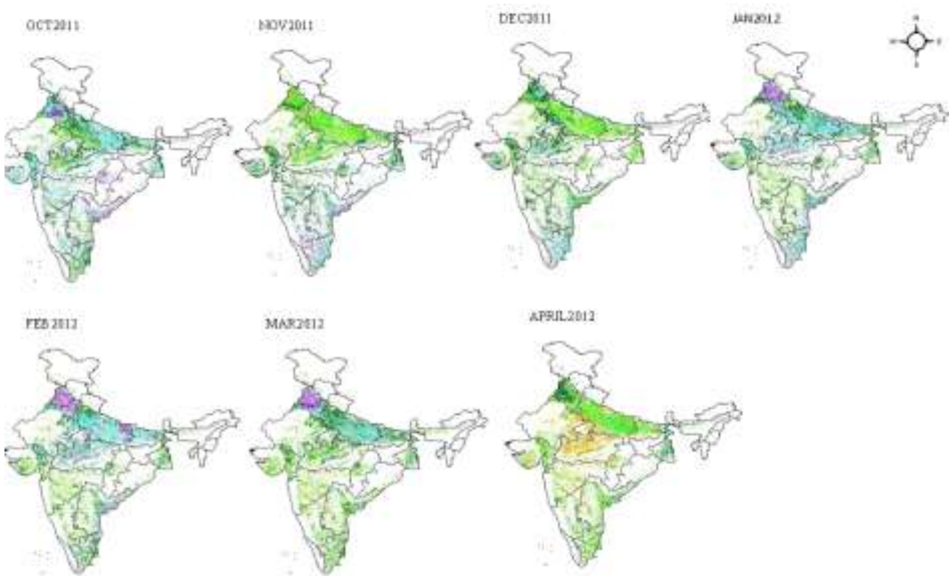
In the above model input images are first day image and next day image this is for generating dekadal time composite images. To generate monthly time composite images inputs are First dekade and Next dekade image. The logic used in this model is as follows

EITHER MIN($n1_memory,$n2_memory)IF($n1_memory<201 OR $n2_memory<201) OR MAX($n1_memory,$n2_memory) OTHERWISE.

The resultant output image is time composite image of First and Second input images. To generate decadal time composite images again first input is time composite image of first two days and second input is next day image. This process is carried out for ten days to get decadal time composite image. Similarly the same process is carried out to generate monthly time composite images. Thus by using this model we can generate Decadal and Monthly time composite images of required study area.

To improve the interpretation of NDVI images, agricultural area mask of rabi season was applied and agricultural area NDVI images were extracted for each composite period. Monthly NDVI composites over rabi areas from October to April months covering the rabi seasons of 2010-11, 2011-12, 2012-13 were generated.Sample composite image is show in fig.These monthly composites also reflect the seasonality in temporal progression

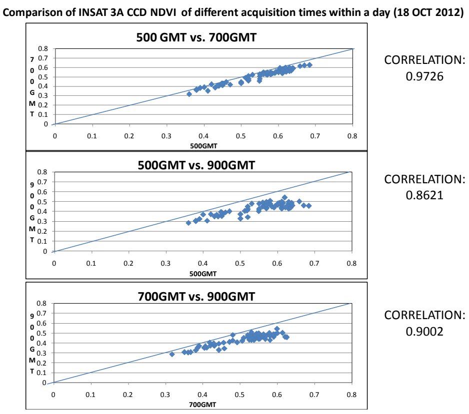
Fig 9:Monthly composites of agricultural area NDVI, rabi season, 2011-12

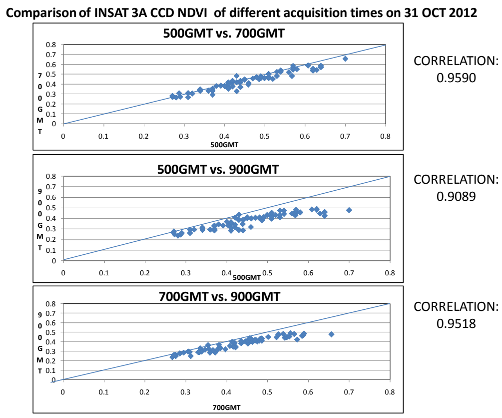


7) <u>RESULTS:</u>

(i) <u>Comparison with other global NDVI data sets AVHRR,MODIS:</u>

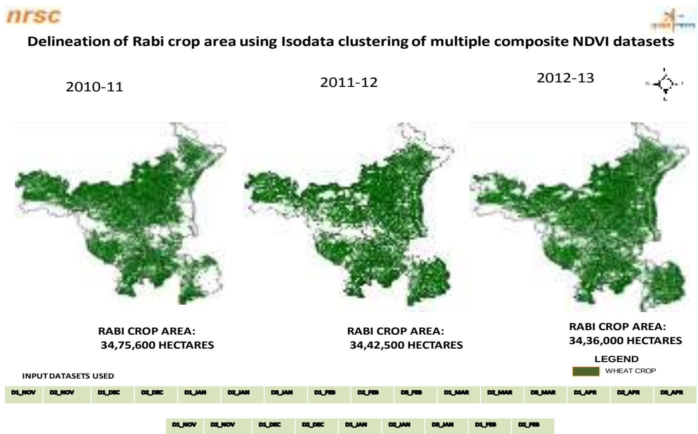
Comparison of INSAT NDVI with other global NDVI data – NOAA AVHRR and Terra MODIS was done by analyzing the composite (same period) as well as single day (concurrent) NDVI of three sensors, over agricultural area. It was found that MODISNDVI values were greater than INSAT NDVI by about 25-30% indifferent ranges of NDVI. Similarly, INSAT NDVI values were found to be on higher side compared to that of AVHRR by about 10-15%. Despite differences in absolute values, there was a significant correlation between the three NDVI data sets. Correlation was 0.97 between INSAT and AVHRR NDVI and 0.85 between INSAT and MODIS NDVI. This observation on the INSAT NDVI makes it an equally potential dataset for use in agricultural applications.





(ii)<u>Performing unsupervised classification using multi-temporal NDVI composites for discriminating rabi crop area and wheat area:</u>

Unsupervised classification technique- Isodata clustering was performed with the dekadal NDVI composites of November to April period of 2012-13, covering Haryana state and wheat clusters could be delineated. Signatures of wheat crop in different parts of the state were analysed. Seasonal NDVI profiles of selected wheat dominant districts - Kaithal, Kurukshetra and Fatehabad - were analysed. Decision rules for wheat classification, using multiple NDVIcomposit images, were developed. Rules were defined based on NDVI progression from November to February to delineate wheat pixels. These decision rules were applied; wheat area was delineated in the three rabi seasons. The estimated wheat area in Haryana state was 25.89 L ha in rabi 2010-11, 24.25 L ha in rabi 2011-12 and 24.13 L ha in rabi 2012-13. The actual wheat crop area in the state was 25.12 L ha in 2010-11 and 25.22 L ha in 2011-12, as per the data of Department of Agriculture, Government of Haryana. Thus, INSAT NDVI datasets can be effectively used for rapid assessment of major crop areas in the country at state/regional level.

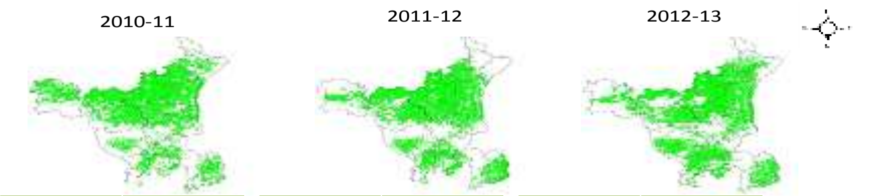


Classification of wheat based on decision rules using multi-temporal NDVI

Decision rules for wheat crop area estimation

	2010-11	2011-12	2012-13
D1_NOV	>0.15	>0.15	>0.15
D1_DEC	>0.20	>0.20	>0.20
D2_JAN	>0.35	>0.35	>0.35
D1_FEB	>0.40	>0.40	>0.40
D3_FEB	>0.55	>0.47	>0.55
WHEAT AREA IN HECTARES	27,55,100	26,87,100	28,36,800

	2010-11		2011-12		2012-13	
	MIN	MAX	MIN	MAX	MIN	MAX
D1_NOV	0.15	0.25	0.13	0.25	0.16	0.25
D1_DEC	0.20	0.32	0.19	0.30	0.25	0.34
D2_JAN	0.38	0.45	0.36	0.47	0.39	0.46
D1_FEB	0.38	0.54	0.36	0.50	0.35	0.56
D3_FEB	0.54	0.63	0.48	0.51	0.56	0.67



ESTIMATED WHEAT CROP AREA(2010-11)	ACTUAL WHEAT CROP AREA(DEPT.OF AGRICLTURE,HARYANA)	ESTIMATED WHEAT CROP AREA(2011-12)	ACTUAL WHEAT CROP AREA(DEPT.OF AGRICLTURE,HARYANA)	ESTIMATED WHEAT CROP AREA(2012-13)	ACTUAL WHEAT CROP AREA(DEPT.OF AGRICLTURE,HARYANA)
27.55 L ha	25.12 L ha	26.87 L ha	25.22 L ha	28.36 L ha	25.05 L ha

8) <u>CONCLUSION:</u>

The current study concludes that INSAT 3A CCD NDVI datasets, available as free down loads on daily basis, with low turn-around-time provide unique opportunity for rapid assessment of area under major crops, progression of total crop area, crop condition and routine monitoring of crop areas in the country. The potential of these datasets needs to be unlocked further by extending the studies to other crops and using the data as inputs for retrieval of different bio-physical parameters.

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