MULTI-TEMPORAL SATELLITE IMAGE PROCESSING AND CHANGE DETECTION IN GREEN COVER OF NATIONAL CAPITAL REGION

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Contents

1.INTRODUCTION

Trees give us essentials like oxygen to sustain life on planet earth. Trees are required to maintain ecosystem and a perfect balance. With the rising of urban settlements, the forest land covers are depleting. This is a warning sign for all of us. We need to move towards urbanisation, but paying such a big cost is not at all reasonable. We need to plan urban cities with keeping prospects of greenery in mind. Maintaining green cover while scaling up cities was always a need and will remain so.

Green cover at urban areas are an important virtue of the city, as they give consolation in pressurised urban environment (Elmqvist et al., 2013). As the density of urban areas are increasing, the scarcely existing green areas have become an important point of asylum of metropolitan biodiversity (Goddard, Andrew, Dougill, & Benton, 2010). Green cover at a metropolitan gives various ecological benefits for example, purification of air, checking of water pollution, aqua filtration, noise regulation, micro-climate changes, and reduction of carbon emission levels (Kong, Yin, & Nakagoshi, 2007). Green cover at urban areas also play a social role by providing space for people to meet and connect. They act as a place for environmental education, and have a major role in leisure, psychic, therapeutic and social lives of city inhabitants (Bolund & Hunhammar, 1999). Green areas also help in increasing urban feasibility, and helps in overall human wellbeing (Arnberger, 2006; Bennett, Peterson, & Gordon, 2009; Bolund & Hunhammar, 1999).

Even after giving us so much, urban green areas are now on an increased peril and are narrowing in area and encountering fragmentation and lack of affinity because of increasing requirement for urban scaling and the increase in strength of the urban footprint in the cities (Seto, Güneralp, & Hutyra, 2012). The distribution of green covers is spatially uneven and driven by is based on various factors such as economic, biophysical and social forces (Pickett et al., 2001). We need to know the exact reasons that are bringing in these changes in the existence, position and dispension of green spaces. It is important as this will help city planners and lawmakers, make even better strategies to conserve these important green covers of urban areas. Images taken by satellites works as a magnificent source of data for the purpose of precise and substantial supervising of green cover, as they provide continuous reportage at high spatial resolution (Jim & Chen, 2003; Kendal, Williams, & Williams, 2012; Nagendra, Nagendran, Paul, & Pareeth, 2012). Moreover, the feature of remotely sensed data to get nonchalantly united into a geographic information system (GIS) with data from other sources, so as to perform spatial analysis has highly impressed and helped the field of urban and metropolitan studies (Wentz et al., 2014). Supervision of green areas in cities is most important mainly for Asia, as Asia is the home of most of the fastest scaling and densest cities in the world. It is believed that cities of Asia will be the reason for more than 50 percent of the projected total increase in urban area in next 20 years, which will put green areas at a higher risk (Seto et al., 2012). India will have the largest share in this change, as Indian urban areas are projected to provide shelter to more than 400 million people by 2050 (United Nations, 2014).

National Capital Region(NCR), has gone through a drastic, planned and unplanned increase in urban areas at the opportunity of green cover. This made a huge impact on NCR's biodiversity and ecosystem. In this project, we work on satellite images from 1997, 2007 and 2017 to find out changes in use of land as urban land and green cover, we will look at the green area fragmentation, and will find out the key reasons for change in green space in NCR apart from fast paced urbanization. For the context of this report, green covers will be those land patches which are partially or fully covered with greenery.

In this project, we work on three main aspects. The first objective is that the recent studies (Nagendra et al., 2012) shows that the trends of urbanisation in the subcontinent of India differs hugely from that of urban cities of Europe and North America. This could be seen, as the land rates in the city center are too high and even affording a small patch of land in city centers in expensive so, developers prefer peripheral land areas for bringing out new development projects. By this reasoning, the green covers of city area remains protected and depletion happens hugely in peripheral areas. We need to learn these differences while planning for urban centers in India. An American model can not answer the calls. The second focus of the project is on the fact that India hugely lack a planned urban development policy like other south asian countries(United Nations, 2014). Delhi is not a new city. It has been there since mughal era. It came in its present shape during British time. So the urban structure of Delhi is highly dependent on its colonial history. British developed many operational buildings to run administration of British India in Delhi. Even today, The city center of Delhi has big buildings and large area patches which are under aegis of government and are handled by various government authorities. We need to have a thorough understanding of these areas occupied by public institutes as they play a major role in safeguarding greenery in the midst of Delhi (Nagendra et al., 2012). These are the areas, where vegetation can be preserved in the best possible ways. The third objective of the report is to identify the relationship between construction of roads and vanishing of green covers in the periphery region of national capital territory (NCT). This is evident from group reports that the civilization tends to settle around the roads. So once the roads are made, the area near them becomes most vulnerable to get converted from green area to urban area.

Moreover, NCR is not just about urbanisation, later we will see that NCR is quite a big area and a big portion of it still counts as Rural area. So Studying NCR, will also help in

understanding conversion of Rural areas into Urban areas and the impacts on green cover. At the last, we will plot the depleting green cover with the increase in pollution levels to show the relation between the two and to conclude why we need to save green cover in order to safeguard the atmosphere and keep the air clean. We will also plot it with mean ground water level of NCR region to so the relevance of green cover in maintaining ground, which gives us another reason to save our beloved all time friends - the trees.
Concluding from all this, we find out the importance of the three factors mentioned up in bringing changes in green areas and fragmentation, plus the effect of urban development in guiding the variability in scale and fragmentation of green cover into the city center, intermediate and peripheral regions and the importance of public held institutes in keeping green areas safe and checking over fragmentation. The project helps us in understanding the relationship between the urbanisation and how it impacts the land cover usage. Now in the upcoming section, we will give introduction of basic terms and techniques that will be used in this project.

Study Area

The National Capital Region(NCR) is located between 27°03' N and $29^0$29'N latitude and 76°07' E and $78^0$29'E longitude covering a total area 58332 km^2. The entire National Capital Territory of Delhi and some districts of Haryana, Uttar Pradesh and Rajasthan forms the NCR.The NCR and the associated planning board was setup in 1985 to make policy for land-use control and to plan for the development of NCR. The urbanisation level of NCR is 62.6 % with a total population of 4,60,69,000.

The 1985 act defined the NCR as being the whole NCTD , the Uttar Pradesh districts of Bulandshahr, Meerut and Ghaziabad, and the Haryana districts of Gurgaon, Faridabad, Rohtak and also Alwar of Rajasthan. In 2013, Bhiwani and Mahendragarh of Haryana and Bharatpur of Rajasthan were also included in NCR. In 2015, Government approved inclusion of Jind and Karnal of Haryana and Muzaffarnagar of U.P. in NCR. The Government of U.P. has formally proposed to include Aligarh, Bijnor, Hathras and Mathura this year. A total of 24 districts of neighbouring states Haryana , Rajasthan and Uttar pradesh constitute the NCR.The NCR is characterised by the Yamuna passing North-South forming the boundary between Uttar Pradesh and Haryana, the Ganga forming the eastern boundary , and the low hills of the Aravalli ridge.

As per the Indian Forest Report 2013, the Haryana sub-region has total forest cover of 461km^2 falling in NCR region. Forest resources play a vital role in climatic pattern in an area and they also act as a safeguard against the flood. The total forest cover in UP state is 14349 km^2 and out of which 286 km^2 falls in NCR. This region has dry deciduous forests and the trees mostly found are Sal, Sheesham and Teak. Rajasthan sub-regions contributes 1203 km^2 of forest region to NCR. The forest are found in patches in Northern and Southern slopes of Aravalli Range.The NCTD has forest cover of 179.81 km^2 and vegetation found in the region is tropical thorn forest type.

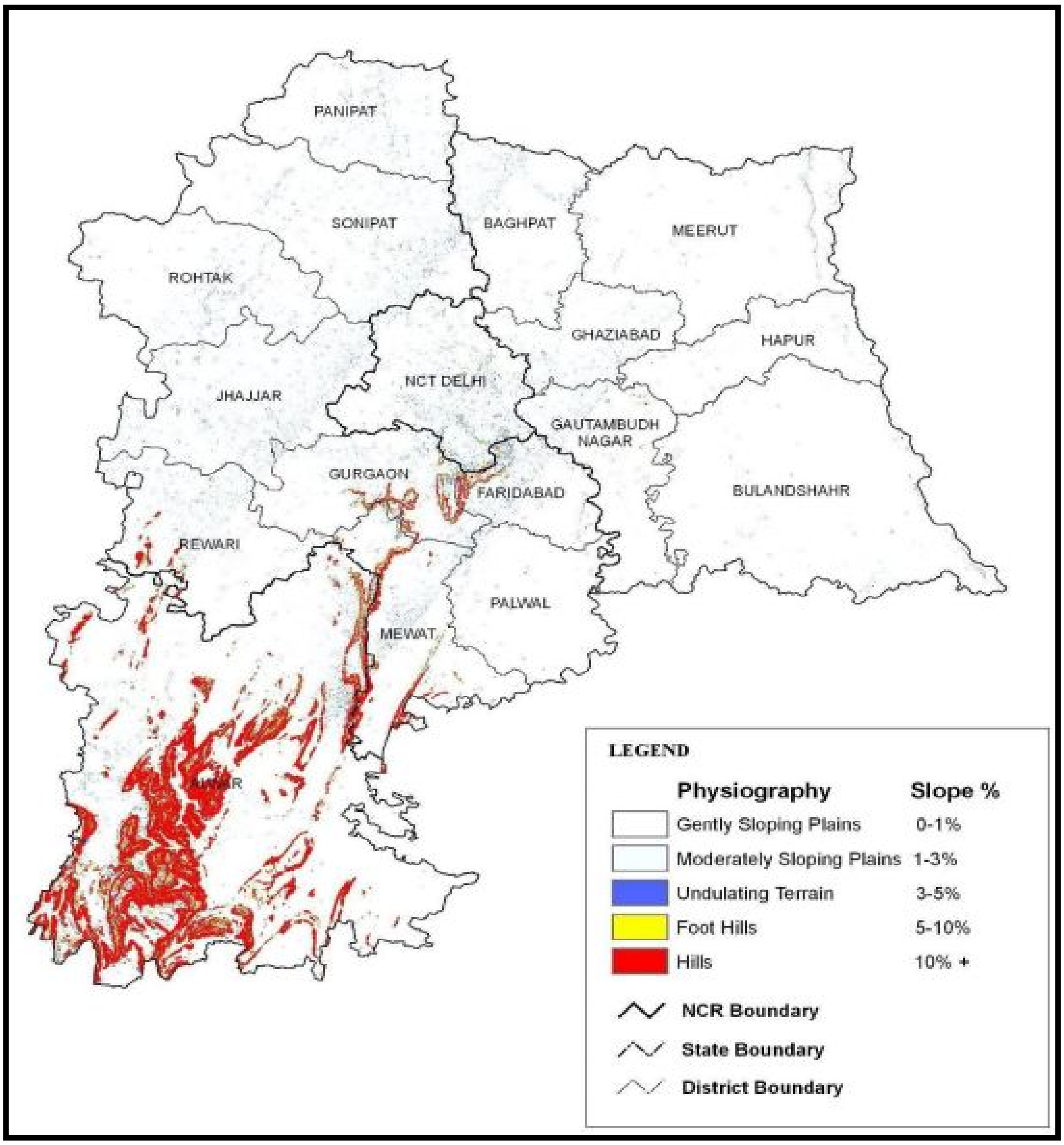


Fig. NCR physiography
[source: NCR planning board]

The climate of NCR is humid with extreme summer and winter. During summer, the temperature is high ranging between 30-45^{0}C while the winter is cold with temperature variation from 3-20^{0}C. The cold wave from Himalayan range makes it more chilly during winters. The sub-regions of Haryana comprises of old alluvial soils of Aravalli hills. The U.P.

sub-regions has mainly sandy and clayey soil. The soil close to river Yamuna and Ganga are sandy while those in Meerut and Ghaziabad are old alluvium. The sub-regions of Rajasthan have Loamy , sandy and clay soil. Delhi is mainly composed of alluvial soil.

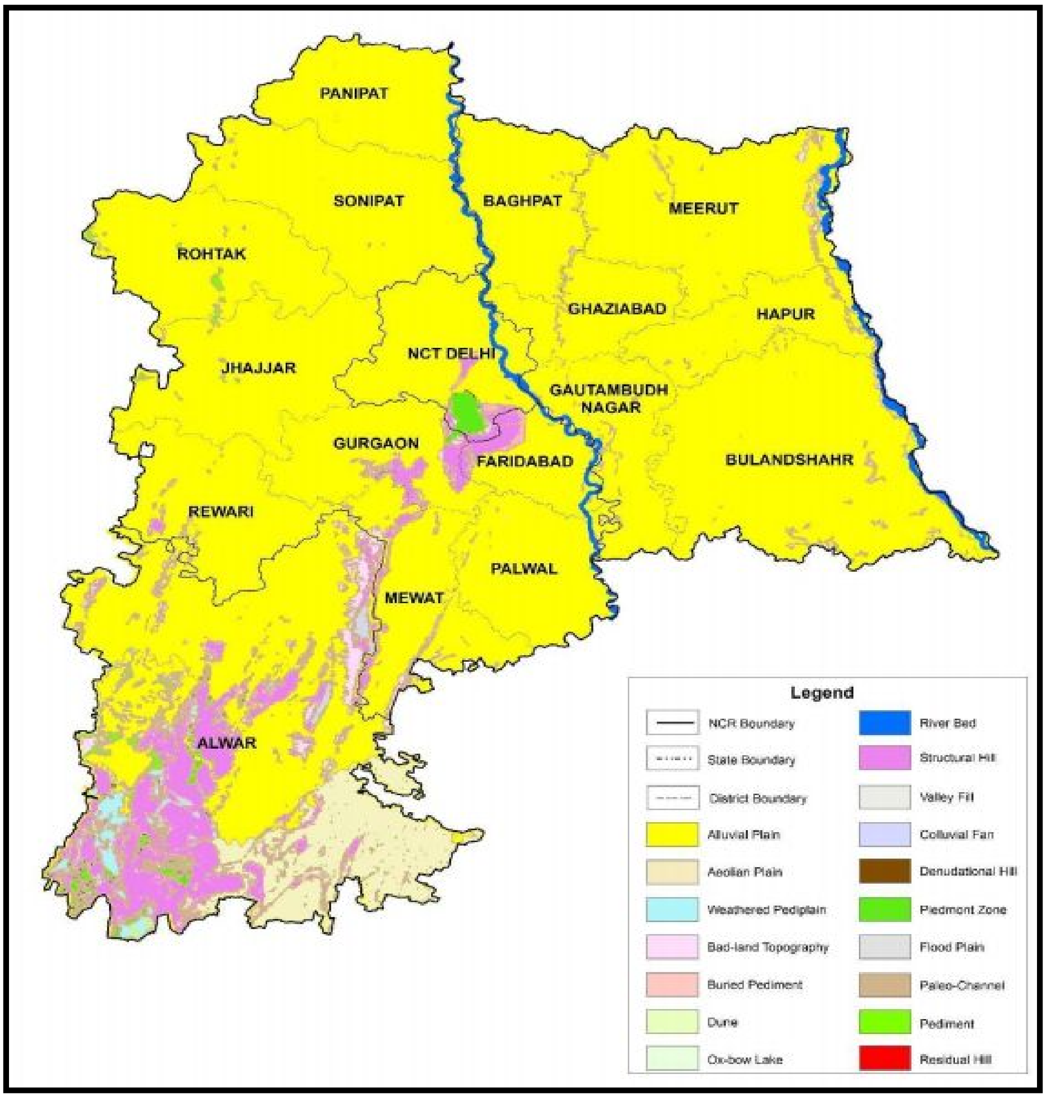


Fig. NCR geomorphic units
[source: NCR planning board]

Haryana sub-region is quite rich in mineral field. It possess kaolin , Dolomite, Lime Kankar, Silica sand in sufficient quantity. The minerals in UP sub-region is very limited. The only mineral available in the region is kankar which is clay product used only for construction purpose. Rajasthan sub-region produces many minerals like barite, feldspar, quartz, dolomite,etc. The hills of the south are rich in minerals such as copper,iron and lead. The NCTD does not possess minerals of economic importance but the road construction material and china clay deposits.

2. METHODOLOGY

We have used three satellite images for our project. The images are from a gap of 10 years each. First is from 1999, second from 2009 and the last one from 2017. This gives us change detection in last two decades. The images from 1999 and 2009 are from Global Land Survey (GLS). The GLS dataset was developed by National Aeronautics and Space Agency (NASA) of United States in collaboration with United State Geological Survey (USGS) department. The resolution of Data is 30 meter and it passes the standards of cloud clearance. The data was collected by using LandSat sensors. For 1999 data. LandSat 4-5 Thematic Mapper (TM) sensors were used. The image was taken on 14th september 1999. For 2009, a combination of thematic mapper and enhanced thematic mapper plus (ETM+) sensors were used. The image was taken on 15th september 2009. The format of data is in geoTIFF. The data is already corrected and resampled using cubic convolution. The data is projected in Universal Transverse Mercator (UTM).

TM is an a highly advanced sensor for multispectral image sensing. It's design serves the purpose of attaining a high level of image resolution and sharper level of separation in spectrums. It also enhance geometric fidelity plus achieve a greater radiometric preciseness. Its resolution beats that of MSS sensors. The data through TM gets sensed in seven spectral bands all together. Its the Band number 6 which senses the infrared.

The Enhanced Thematic Mapper Plus (ETM+) sensor is a constant “whisk-broom”sensor with eight-band. This multispectral scanner and radiometer have power of getting information about surface of earth with high resolutions. It can sense radiations that are spectrally filtered in visible and near infrared (VNIR), short-wavelength infrared (SWIR), Long wavelength infrared (LWIR) and panchromatic bands from the radiations retaliated by Earth. It has a swath as wide as 183 km when it orbits earth on an altitude of 705 km. A panchromatic band that has spatial resolution of 15, a solar calibrator with full aperture on-board and four times improvement in TM's spatial resolution, are new features of Landsat 7.

The third image for year 2017 was taken from Landsat 7 ETM+ Level 1. The image was taken on 24th september 2017. All three images were downloaded from USGS earth-explorer server (https://earthexplorer.usgs.gov). (The stepwise process of data acquisition is mentioned in appendix 1) It was noted that the maximum trees planted in NCR region are evergreen in nature. There are some deciduous trees too. The deciduous trees have leaf fallout during the months of January to March. After that the weather starts getting cloudy. So the best images to be used are from the late September to end of December.

All images projects data in UTM coordinate system. UTM is a two dimensional coordinate system to point out locations on earth. It is different from longitude and latitude approach. The earth is fragmented into 60 horizontal zones for in UTM. and then each zone is mapped separately. The credits of this system goes to United State Army Corps of Engineers. It was developed in 1940s.

After getting the images, preprocessing step was done. There are two components of preprocessing, The first is, Layer Stacking and Mosaicking and the second is Registration and resampling.

Layer stacking is the process of combining different images of different bands to a single image. As discussed earlier, TM sensors take image in 7 different bands. The first band is 0.45-.52 micrometer, and the last band is of 2.08-2.35 micrometer. These seven different images are combined into one image. This could be understood as follow. Suppose, we have to click picture of a person from a camera. But instead of one camera, we have 7 cameras and each camera captures a different band of wavelengths reflected by that person. So one camera just clicks the red part, another just the green part and so on. Now to get one single clear picture, we need to superimpose all these seven pictures. The same happens when satellites take pictures. They take pictures using different sensors which captures electromagnetic waves of different wavelength. But for the use, we need to stack these different images into one. So all the 7 images of 1999 from TM sensors (Shown in appendix 2) were stacked into one layer. The images from 2009 and 2017 were from ETM+ sensors. They take 8 different images from 8 different bands of wavelength. So all these 8 images were stacked into one. The stacking process was done using 'Layer Stacking' tool of ArcMap. (The steps of layer stacking are mentioned in appendix 2). Mosaicking is done with the layer stacking only. We don't require mosaicking though as we do not have to merge datasets. Mosaicking and stacking are two different things as mosaicking is merger of two images while layer stacking is merger of different aspects of one image only. Mosaicking can be done using ArcGIS 10.5. (The steps involved in mosaicking are mentioned in appendix 3). After layer stacking and mosaicking, next thing to be done is image registration and resampling.

The first thing that has to be done is the image registration. Image registration can be simply defined as the act of georeferencing one set of data with the other set that is already georeferenced. A known coordinate system works as the the referenced dataset. So the image acquired is fit on a known coordinate system and that's how it gets it georeferencing. Image registration is the main function for aligning more than two satellite images spatially so that comparison of the changes amongst them or finding of relative information from these satellite images can be done. We can do registration using a GIS framework. The framework we used is ArcGIS 10.5. The georeferencing toolbar of ArcGIS is used for the purpose. (Steps for registration are mentioned in appendix 4) The 2017 image was registered to a map of NCR that was already created by us by integrating all districts of NCR region in one map. The dataset from which this map was created is GADM (www.gadm.org) database. GADM stands for database of global administrative areas. It is a free database with better spatial resolution than most of the free databases. The images of 2009 and 1999 were registered to the already registered image of 2017.

This concludes the pre-processing phase. After preprocessing, the image processing step was done. There were two processes involved in image processing. The first one being, supervised classification followed by Assessment of accuracy. The classification of all three images were done separately. Each image was classified into three categories. The categories are, vegetation, built-up area and other areas. The vegetation area comprises, all the vegetation covers like ridge area, gardens, trees on roadsides, protected areas, vegetations in monuments and universities and all the green covers at other areas. The Built-up area consists of buildings, roads and other concrete structures. The other category consist of all the left out areas like water bodies, non-urban developments, dumping grounds, wastelands, open grounds and all the left out things. The classification is done on the basis of colour of pixels of the image. A different kind of surface, reflect back a different set of electromagnetic waves and thus have a different pixel information in the image taken. Green covers and built-up areas can be classified by studying properties of different land surfaces and their behaviour with regarding reflection of electromagnetic spectrum. However, this requires a thorough learning of remote sensing techniques and knowledge of land covers. The alternate approach is of supervised learning. For this we require two datasets. One for training and the other one for testing. The datasets were taken from survey of India topsheets. This training data was used to make our classification model learn. We can understand its working in the following manner. Every pixel has a location in map and its RGB value. Now the training dataset is a map in which each pixel in it is classified as vegetation, built-up area and other area. Our aim is to develop a model, which can take RGB values as input and can give one of those classes that we have discussed above as output. There are millions of pixels in every image so it won't be feasible to classify each pixel. So instead of classifying each pixel, we will create clusters using clustering tool of arcGIS 10.5. Now we create training set for our image using arcGIS 10.5. The training set is developed by selecting polygons from image with accuracy whose classification is known to us. We come to know these classifications using google earth photos of respective years. Once the training set is completed, it is saved as signature file. The signature file is then used to classify the image. This process is repeated for all three images. All the three classified images and the process of creating signature file and doing supervised classification is mentioned in appendix 5. We do classification of each image using different techniques that are available with arcGIS that are, maximum likelihood, class probability, iso clusters and principal components. All these classification techniques are mentioned in detail in appendix 5. First of all, classification of image from 2017 is done using all these 4 techniques and then Accuracy assessment is done. The result of accuracy assessment is mentioned in analysis section. We find that maximum likelihood comes out to be most accurate. Accuracy assessment is done using a testing dataset that was created by careful observations from google earth. The testing dataset and results shown by all four methods are summarised in appendix 6. After this, all three images were classified using maximum likelihood algorithm.

Now we have three images and every image has clusters which are either classified as vegetation, built-up or others. Now the next thing that we have to do is change detection. We would do change detection with two images at a time. We will do change detection in images of 1999 and 2009, then in images on 2009 and 2017 and finally directly in the images of 1999 and 2017 to see the change in two decades. The change detection is done using arcGIS 10.5 tool called difference. This tool is the part of image processing framework of arcGIS. The formula used for mapping change is given in the table blow -

Land use in time 1	Land use in Time 2	Change
Vegetation	Vegetation	Stable Vegetation
Vegetation	Built-up	Decreased Vegetation
Vegetation	Other	Decreased Vegetation
Built-up	Vegetation	Increased Vegetation
Built-up	Built-up	Stable Non-vegetation
Built-up	Other	Stable Non-vegetation
Other	Vegetation	Increased Vegetation
Other	Built-up	Stable non-Vegetation
Other	Other	Stable non-vegetation

TABLE 2.1 CHANGE DETECTION ASSESS

So this classify the map into four parts. Now we will calculate the area of these four parts separately for all three change detection images using area tool of arcGIS.

Now we identify the areas with increased vegetation and stable vegetation and support the fact that in urbanisation of Delhi, the city centre area falls in mostly vegetation and stable vegetation category. The boundaries for division of NCR region into city centre, periphery and intermediate are taken from (Nagendra and Paul, 2015).

Now the last part of the project is finding relation of roads with depletion of green cover. For this, we superimpose map of roads that we took from GADM database. The roadmap is first clipped for NCR region and then superimposed with the change detection images. The areas adjacent to roads in 10 meter proximity is calculated using area tool of arcGIS. The area so calculated is looked at and percentage is calculated for all four type of changes. It is shown that the largest percent share in area is of decreased vegetation category. The detailed results are shown in next section.

ANALYSIS

The first part of analysis as mentioned in methodology is to make a raster map of NCR region so that it can be used for clipping later. The map was created out of administrative shapefile of India from GADM database.

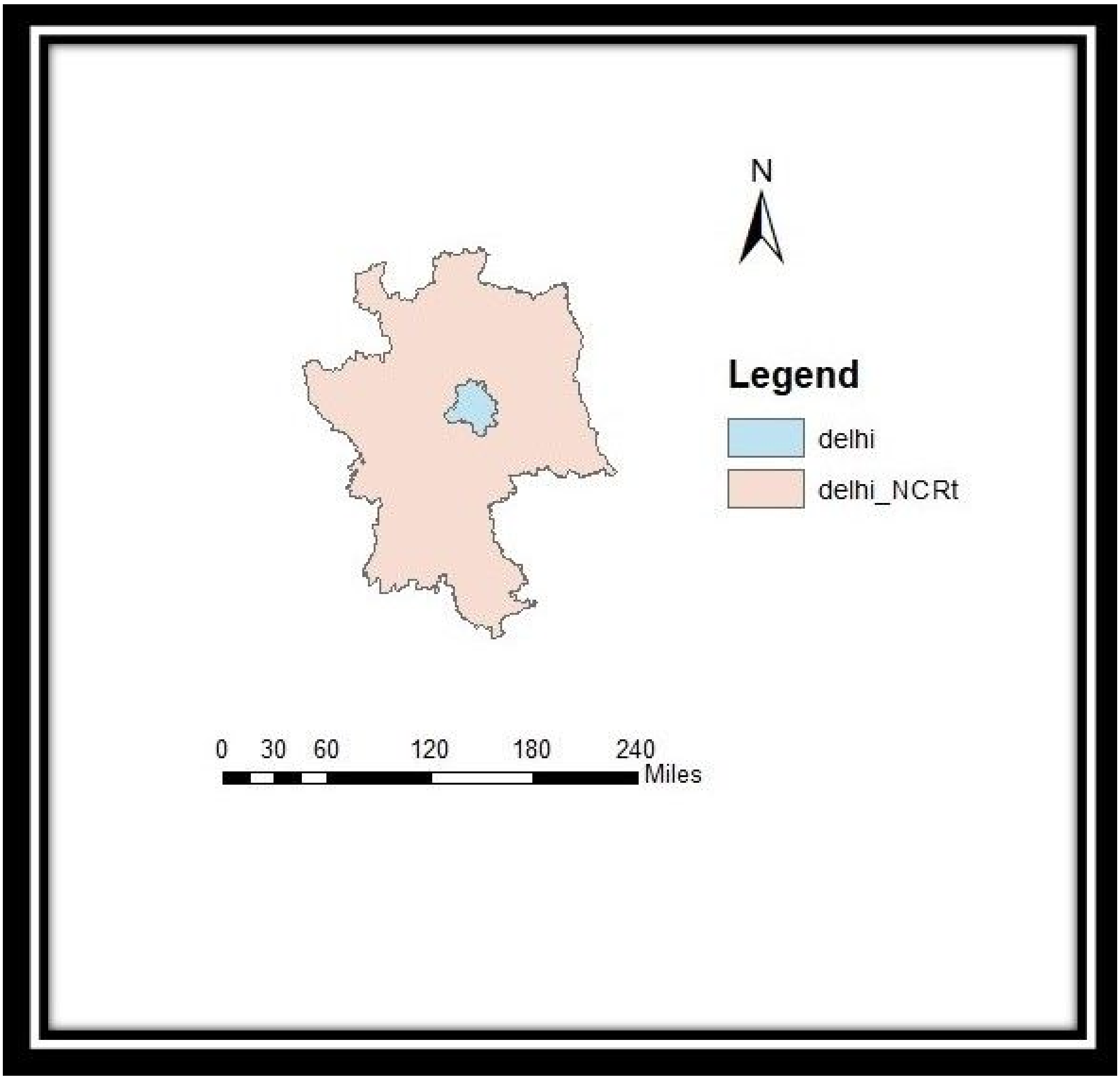


Image 4.1 - shapefile of NCR

After that satellite images were downloaded from earth explorer server. The layer stacking and mosaicking was done for all three years. The process is explained in detail in appendix 1, 2 and 3. The bands selected for all three images were 1,4 and 7. As this combination is best while location green cover. Final images after this process were as follow-

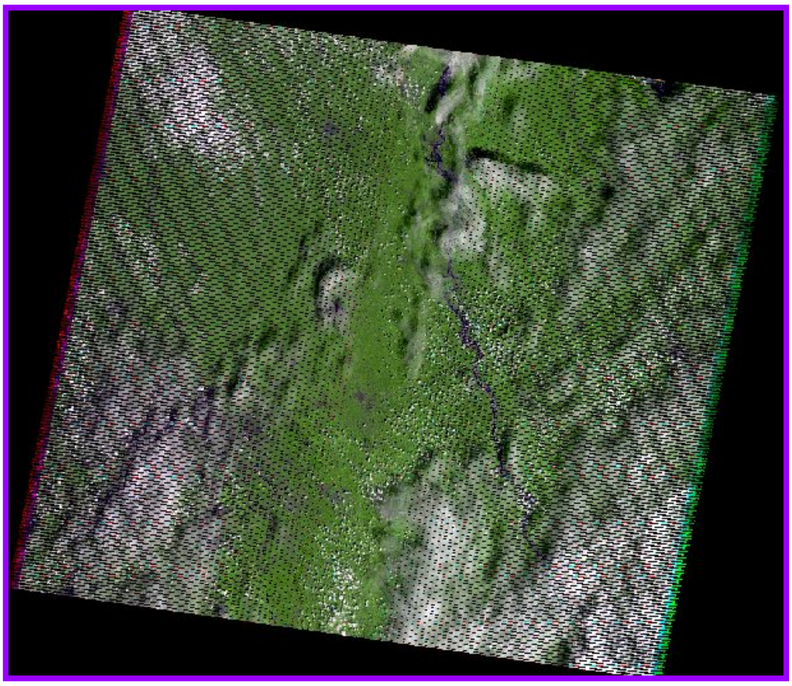


FIG 4.2: STACKED IMAGE OF 14th September 1999 with band 1,4,7 selected

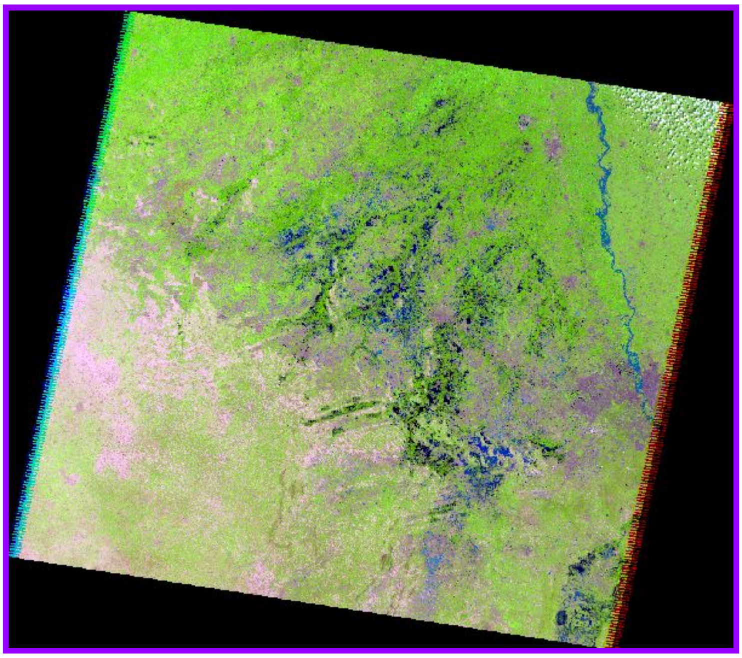


FIG 4.3: STACKED IMAGE OF 15th September 2009 with band 1,4,7 selected

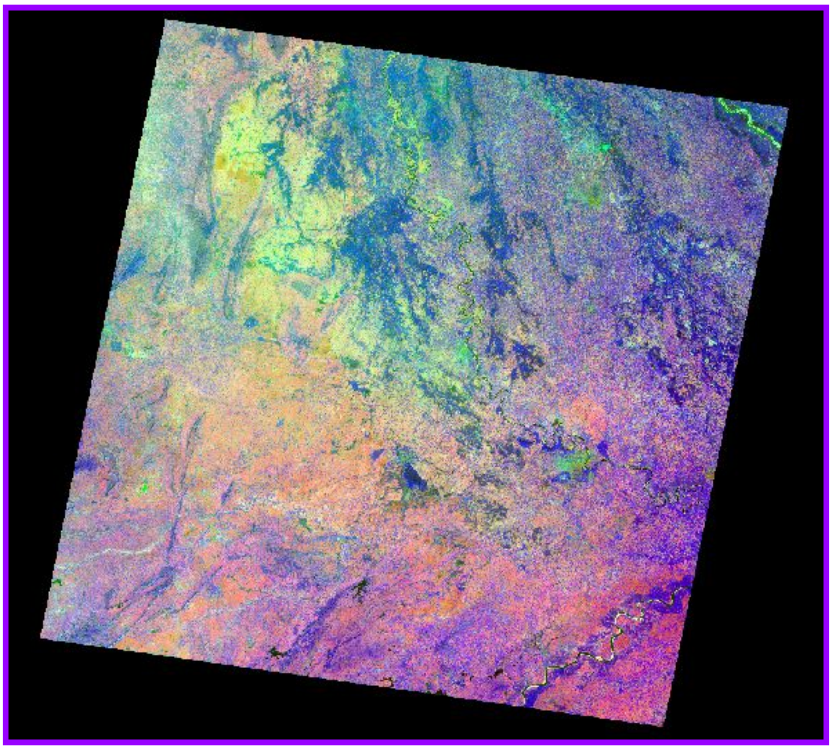


FIG 4.3: STACKED IMAGE OF 15th September 2009 with band 1,4,7 selected

After all these processes the next pre-processing was registration. The details of registration are explained in appendix IV. Registration of 2007 image was done with respect to GADM dataset of India. The image after registration got fit to the place where it belonged.

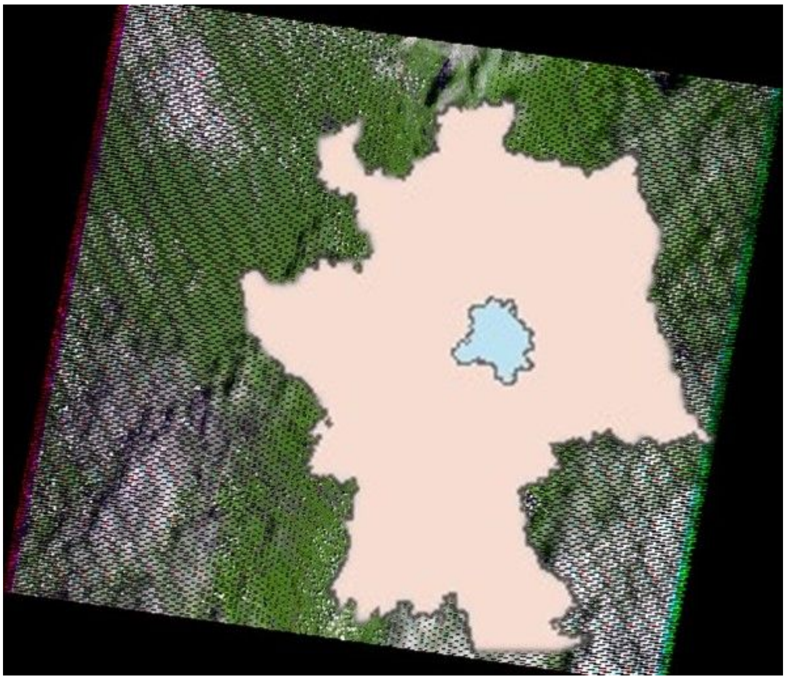


FIG 4.4 1999 Image after registration

The same process was repeated for images from all three years. The result is not relevant here so the other two images are not shown.

The next analysis step that follows is classification of image. Classification can be done using three supervised classification techniques using arcGIS. We need training dataset for classification. The areas with sure green covers can be used as training patches. In our case, we chose, patches from kamla nehru ridge and bharatpur wildlife sanctuary (Rajasthan) as our training data. This whole process was done using arcGIS classification tool. Once the training dataset was selected, We tried all the three algorithms principal component, maximum likelihood and class probability. After classification from all three algorithms, We got three maps. Now we chose 10 points in map whose informations we got from google maps. Those 10 points are mentioned in appendix VI. We checked what results our three algorithms gave for these 10 point clusters. These point clusters were different from the training data we used. We found that maximum likelihood did correct predictions for 9 out of those 10 clusters. So we used the maximum likelihood for classifying all three images.

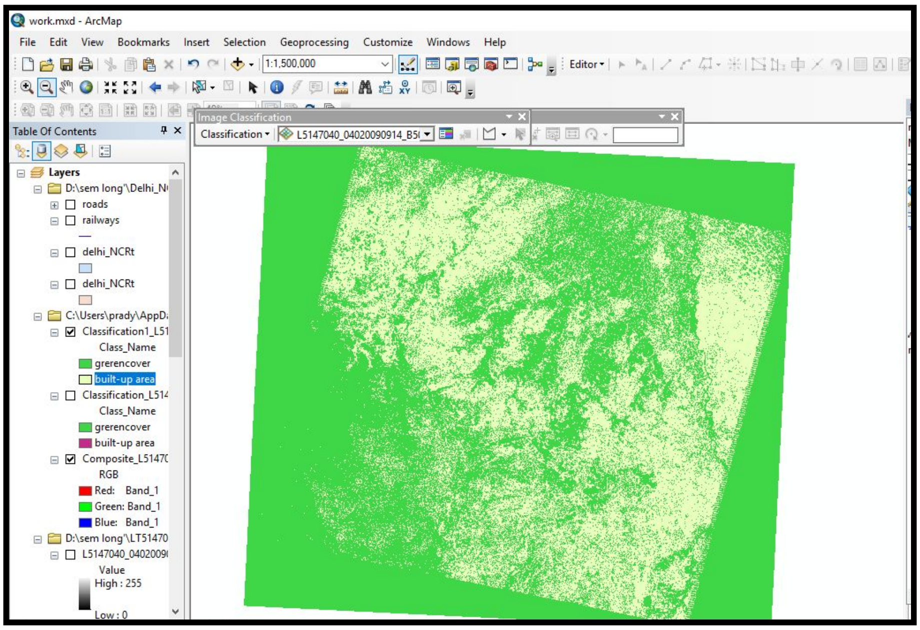


FIG 4.5 Classified satellite image

Just like this, all other images were classified. The classified images were then used for change detection. Change detection was done using arcMap only. Now we make the maps showing changes and every portion falling in one of the category as mentioned in table 1. The interval for stable vegetation was taken to be 5%. That is, if there was a positive or negative change of 5% pixels in a packet, then it was called stable vegetation or built-up area. Else it fell in decreased vegetation of increased vegetation category. The change detection images that we got are

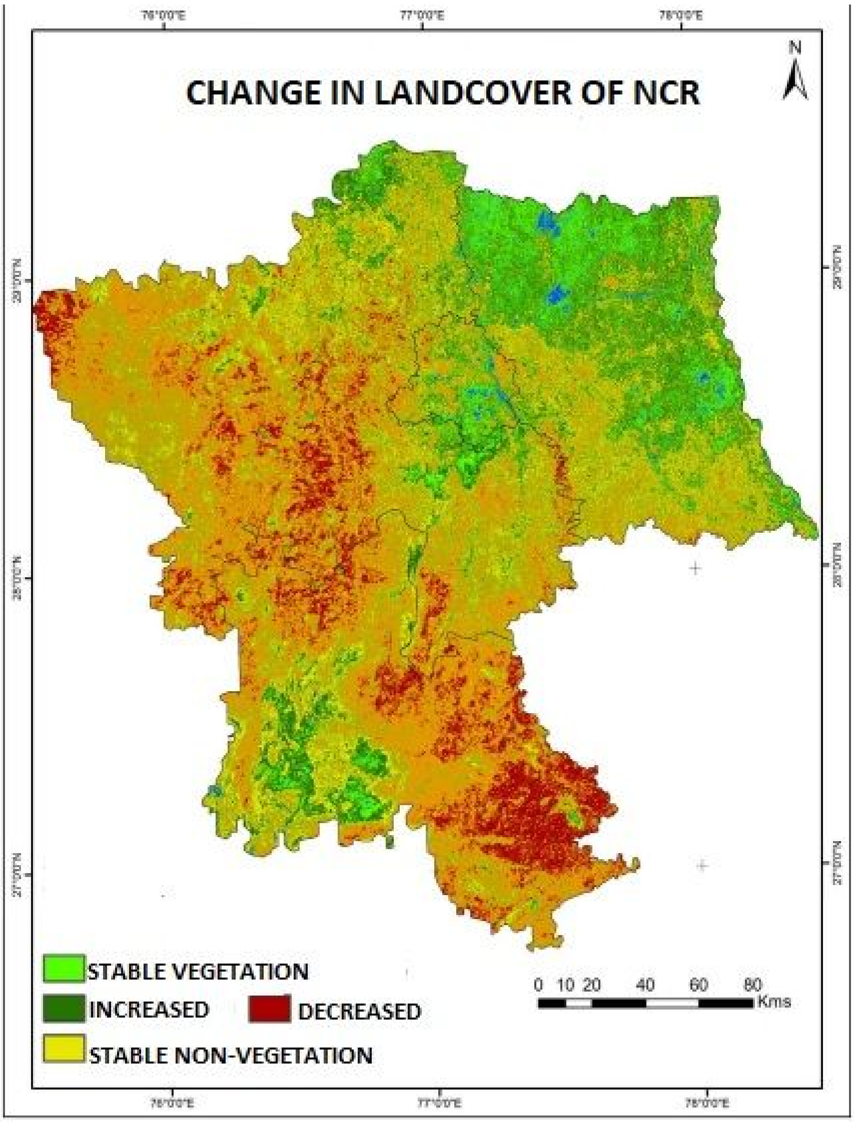


FIG: CHANGE IN LAND COVER FOR 1999-2009

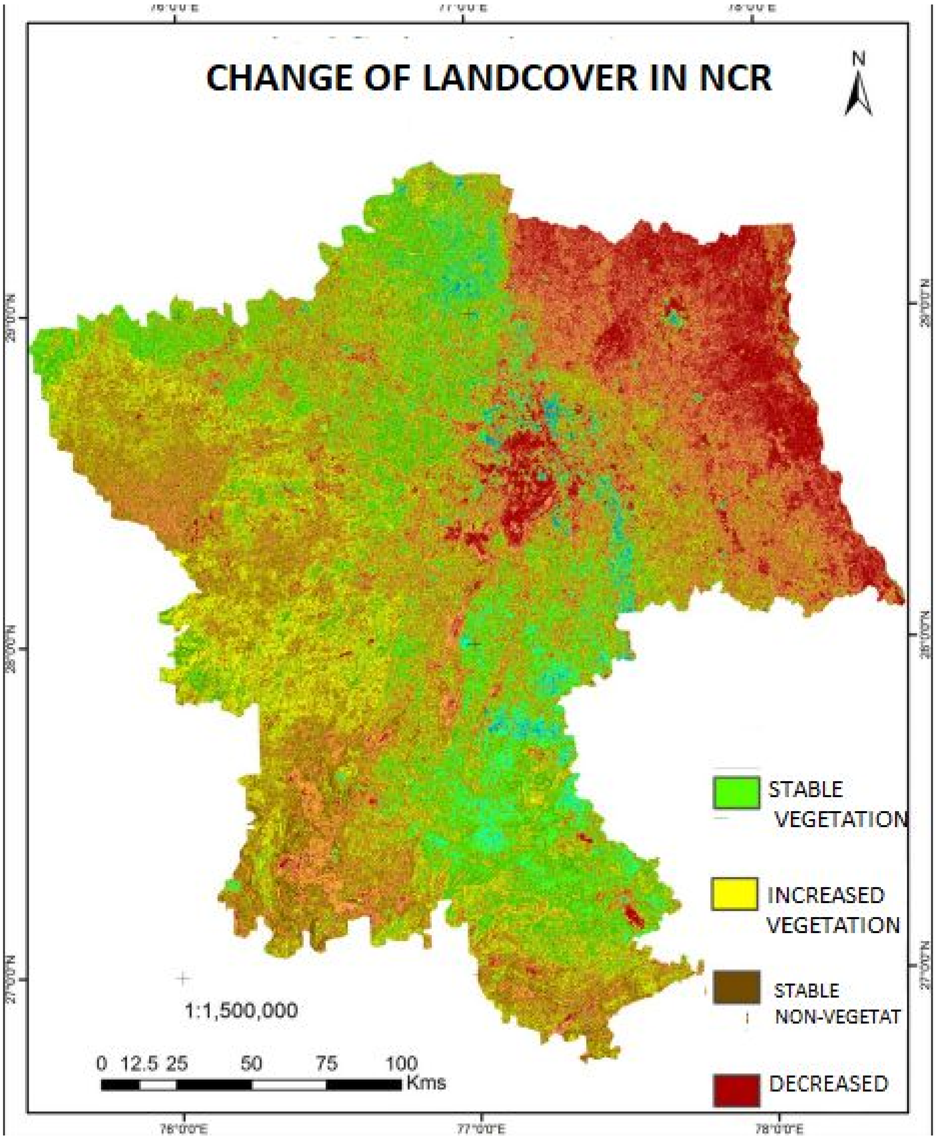


FIG: CHANGE IN VEGETATION COVER FOR 2009-2017

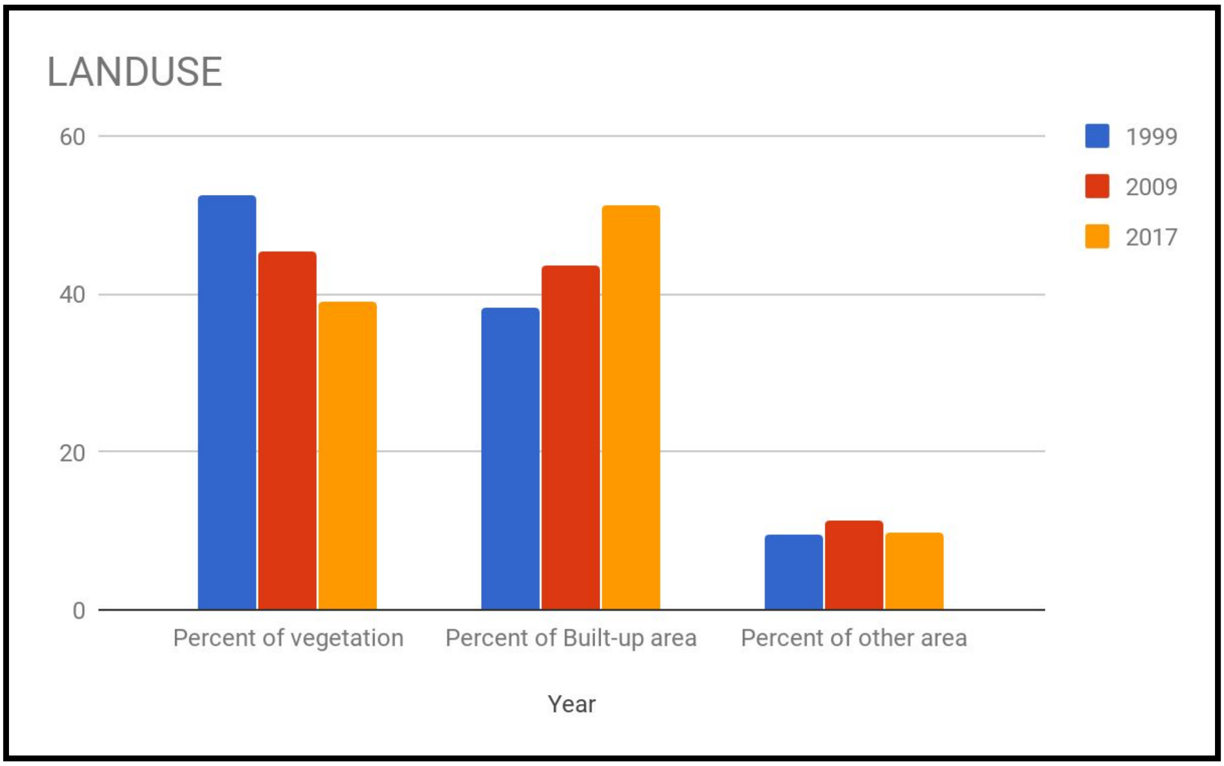
RESULTS AND DISCUSSION

CLASSIFICATION ACCURACY

The following table shows the point clusters used for testing and what different tools of arcMAP produced as result

Area	Actual Land cover	Land cover by maximum likelihood	Land cover by class probability	Land cover by principal component
Nehru Park	Vegetation	Vegetation	Vegetation	Vegetation
National Zoological Park of Delhi	Vegetation	Vegetation	Vegetation	Vegetation
Rajpura, Gurmandi	Built-up	Built-up	Built-up	Built-up
Nehru Place	Built-up	Built-up	Built-up	Built-up
JNU	Built-up	Built-up	Built-up	Vegetation
Garden of Five Senses	Vegetation	Vegetation	Built-up	Vegetation
Jahanpanah City Forest	Vegetation	Vegetation	Vegetation	Vegetation
North Campus	Built up	Vegetation	vegetation	Vegetation
Ghazipur Landfill	Other	Other	Other	Other
Noida Sector 123 Dumping ground	Other	Other	Other	Other

We find that feasibility of maximum likelihood is best for us. After calculating the areas of each type of land use and areas of land falling in one of the change category, we made following graphs.



Graph : Different vegetation areas

We observe many patterns in the graph that we generated. Some of the observations are-

1. Public institutes, monuments and city park don't saw a decrease in vegetation, rather there was an increase in vegetation.

2. The core area of Delhi saw less decrease in vegetation in comparison with the periphery area. This means that in the process of development, the corner areas of the NCR are getting affected worst.

3. The Built up area is more towards NCR region of uttar pradesh in comparison to Delhi, Rajasthan and Haryana.

4. Rajasthan showed stable vegetation. There are only two districts of Rajasthan in NCR and one of them houses a wildlife sanctuary so the credits can go to bharatpur wildlife sanctuary.

5. The built-up area is increasing at the fastest pace in the transitional region.

6. Wherever the road projects came during 90's, those regions have transformed into built-up area at an alarming rate. So this shows that roads are the roads of urban development.

7. Planned areas in Delhi like Dwarka have shown decrease in vegetation but now the change is stable.

8. Core regions like central secretariat, have shown increase in vegetation. This shows efficiency of public administered areas.

9. The cantt area near dhaula kuan have shown increase in vegetation. This shows that the area controlled by cantonment board of delhi is doing good.

Conclusively, NCR is a big region and houses a big portion of country's workforce. People around the country migrate to NCR for job opportunities. Being the country's capital it has some of the best job opportunities and working environment. But as the number of migrators and job seekers are increasing, the number of buildings required to house them and to provide a working is increasing. Now everything comes at an opportunity cost. This increase in employment is causing decrease in vegetation. The increasing pollution level and decreased water quality of the region is indicative of that. The vegetation percent has dropped down to 38% which is lower than the national average of 47%. If we only talk about City of Delhi, Then the situation is even more alarming. We need to increase the capacity of the region to handle more population on the same time, we can't forgo our forests and vegetation anymore. There is a need of a changed approach in further planning. There are some good models like that of greater noida and dwarka. The core of the city cannot be changed but we can control the further depletion at periphery. And we can make core better by densifying forest cover in the public controlled institutes and monuments.

APPENDIX 1: IMAGE ACQUISITION

EarthExplorer (http://earthexplorer.usgs.gov) provides online search, browse display, metadata export, and data download for earth science data of the U.S. Geological Survey (USGS). EarthExplorer uses JavaScript libraries, Hypertext Preprocessor (PHP), and the advanced Oracle spatial engine to provide enhanced user interface.

The key features in EarthExplorer are:

- Fast, Geospatial search engine
- Simple and fast GUI
- Textual query capability
- Save and export results and map overlay for reuse
- Request on demand products
- Access to LandSat Data Continuity Mission (LDCM) quality band data

System requirements:

- Minimum of 256 MB RAM.
- Minimum of 20 GB hard disk space.
- Display resolution of 800x600 with 256 colors.

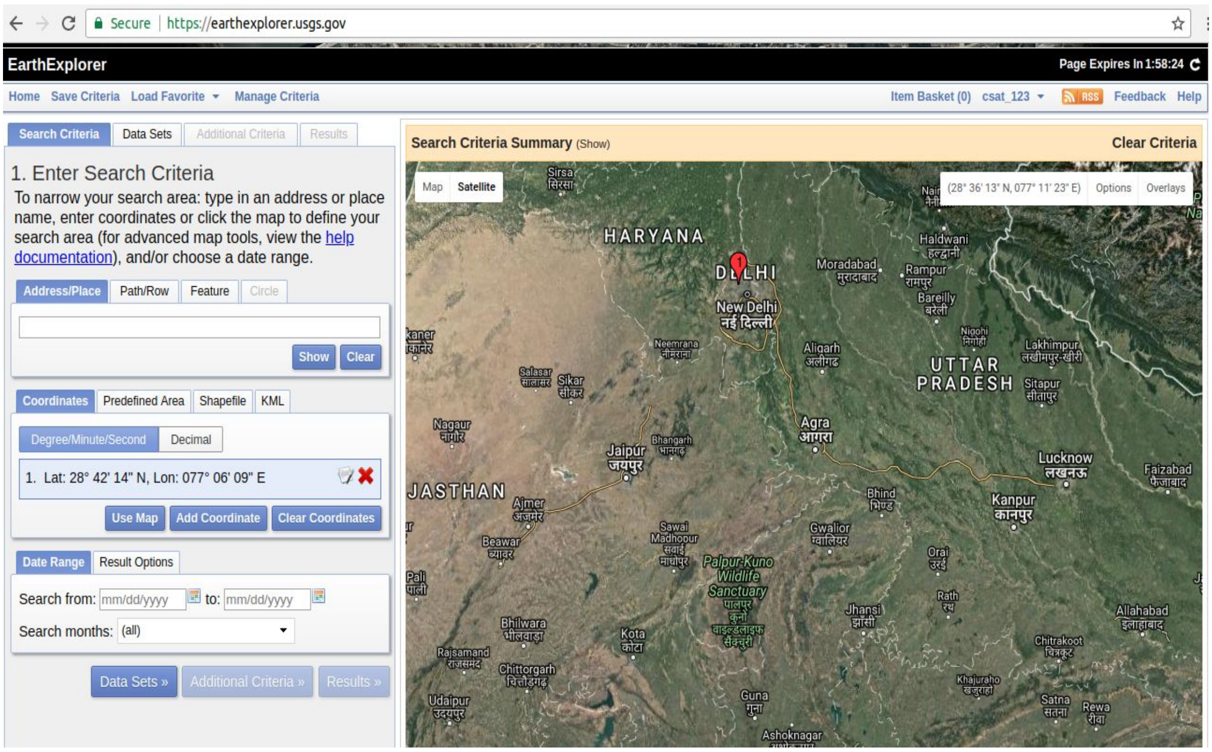


Fig. EarthExplorer Home page

Source:[https://earthexplorer.usgs.gov/]

The users who register themselves on the site will be able to use all features which include search criteria, downloading data and ordering bulk data and also can choose dataset as per requirement. The information provided by the user is kept private and is only used to find trends in usage of data. The same login details can also be used for the USGS Global Visualisation Viewer(GloVis) and USGS Hazards Data Distribution System(HDDS) systems. The EarthExplorer registration service uses HTTPS protocol to provide privacy and security. Every year each user need to reverify their login credentials.

The EarthExplorer Registration interface has the following key elements:

- Registration
- Login
- Profile

To register, use the Register menu from EarthExplorer menu. You just need to create a username ,password and select a secret question and type the answer to that. The user Data Usage Information Usage page allows user to enter the affiliation and identify uses of the data. This information is used to gather statistics on types of organisation using remotely sensed data. To use the data from EarthExplorer you need to login using your username and password.

EarthExplorer allows users to search any data from the Globe , download the data, and order data (in case it’s not available) held in USGS archives through a number of query options. EarthExplorer uses tabs in the search application to move through each portion of the process. The EarthExplorer search process/component is divided into four main areas :

- Search Criteria Tab – Provides the interface for entering various search options.In the search option you can search using either the location of a place or by the coordinates of the location. This tab also provides you the option of selecting the date range for the desired requirement.
- Data Sets Tab – Provides the interface for selecting the datasets to be searched. This tab comes up with many dataset options which includes Landsat, Aerial photography, LIDAR, Digital photography, etc. You can choose the dataset you need.
- Additional Criteria Tab – Provides an interface for entering additional search criteria specific to the selected datasets. It provides you with the different criteria page for different datasets. Some search criteria includes:
  - * Date category
  - * Cloud cover
  - * Day Night
  - * Landsat Scene Identifier

- Results Tab – Provides the interface for displaying a textual and graphical view of the query results. This tab displays the result based on the search criteria , dataset and additional criteria selected.

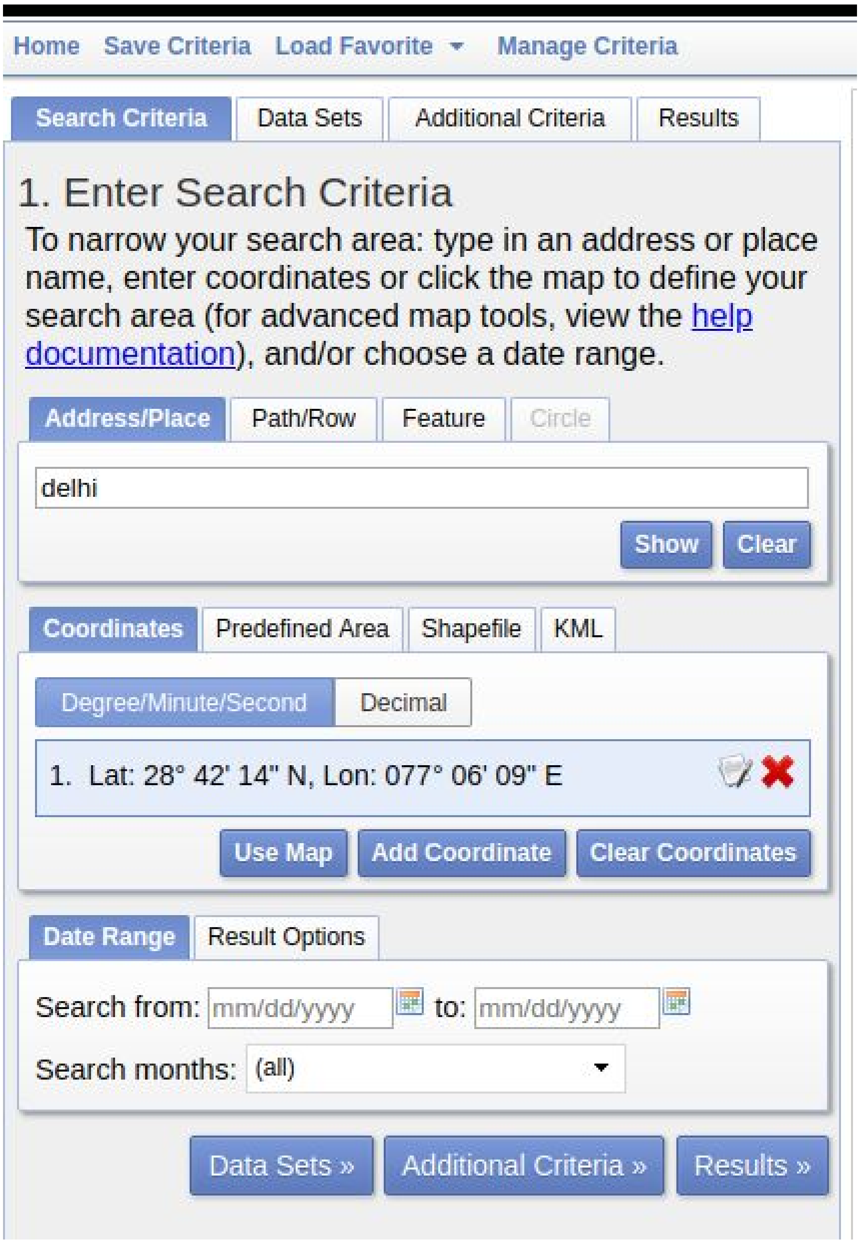


Fig. EarthExplorer Search Component
Source:[https://earthexplorer.usgs.gov/]

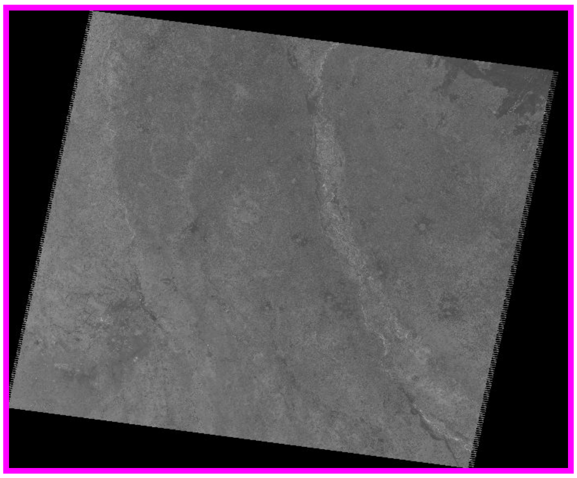
APPENDIX 2: LAYER STACKING

Layer Stacking is a process of getting a composite image by combining multiple images. For layer stacking the images must have same number of rows and same number of columns(same extent). This means that you need to resample the images of different bands having different resolution in order to perform proper layer stacking. For layer stacking , all the bands must have same resolution. Layer stacking will increase the size of the output image and hence increasing the processing time of the image. Depending on the purpose of your work, you can choose images/bands that need to be stacked.

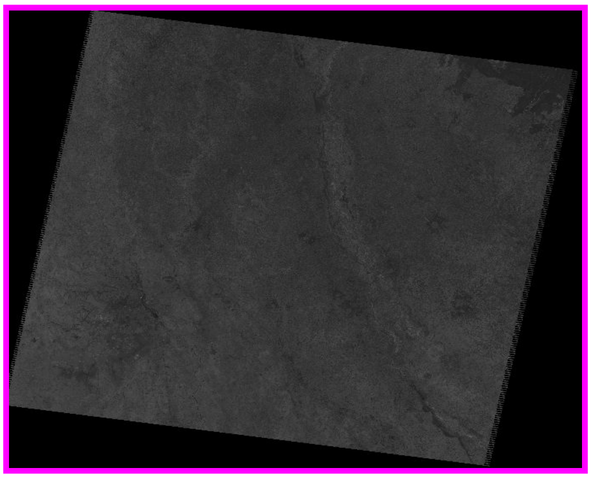
To create layer stacked image we used the image analysis extension in arcmap toolbox. The process of combining separate image bands into a single multispectral image is layer stacking. When we download satellite image of any particular area and particular dataset, the downloaded file contains satellite images distributed in many images band. Like,"The Landsat Multispectral Scanner (MSS) was carried on Landsats 1-5, and images consist of four spectral bands with 60 meter spatial resolution , the Landsat Enhanced Thematic Mapper Plus (ETM+) sensor is carried on Landsat 7, and images consist of seven spectral bands with a spatial resolution of 30 meters and Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) images consist of nine spectral bands with a spatial resolution of 30 meters."(source: https://landsat.usgs.gov/).

For layer stacking, one must have more than one image of same extent. We used Image Analysis extension in ArcMap to create a layer stack. Image analysis extension is available under Toolbar menu in ArcMap. Use the Add Data option the toolbar of ArcMap to add images to be stacked to the data frame. Layer Stack option is available in utilities section. Add the images to layer stack by clicking the add option. After completing layer stacking save and export the image to desired output location.

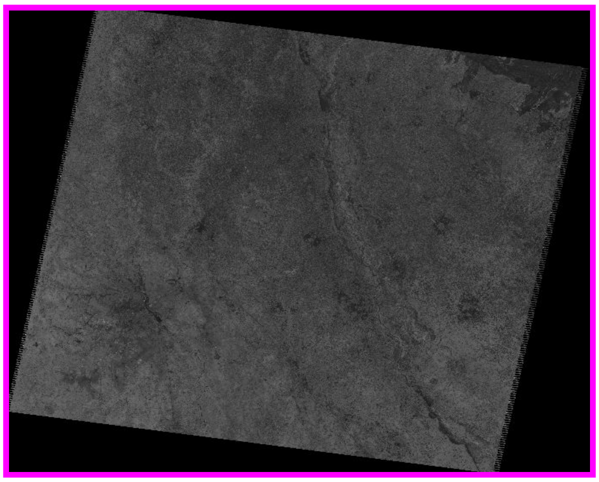
LAYER STACKING OF SATELLITE IMAGES(Sept. , 1999)



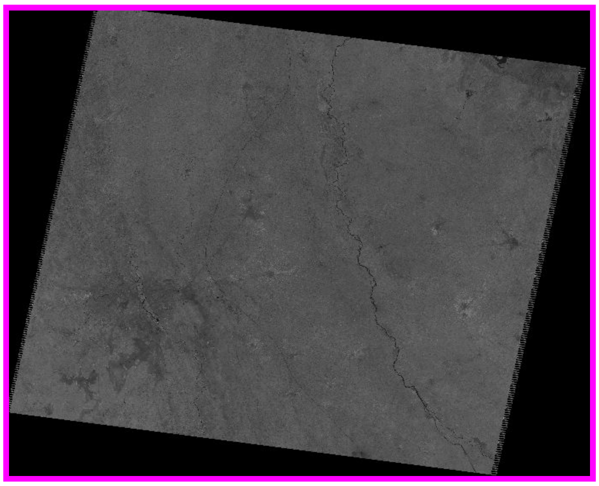
Band 1



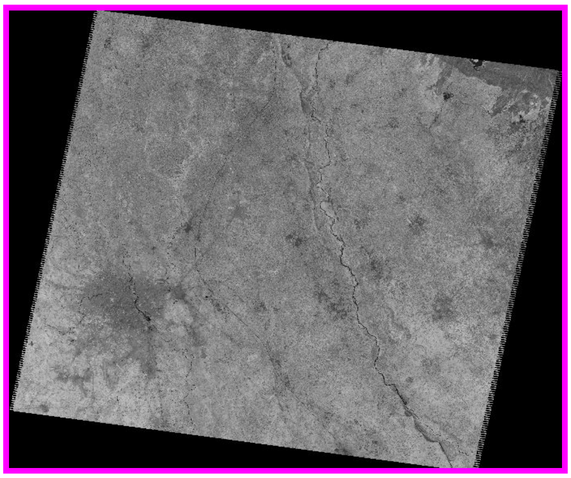
Band 2



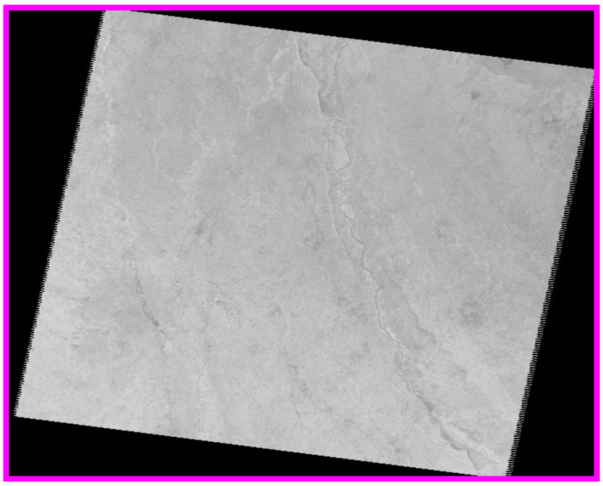
Band 3



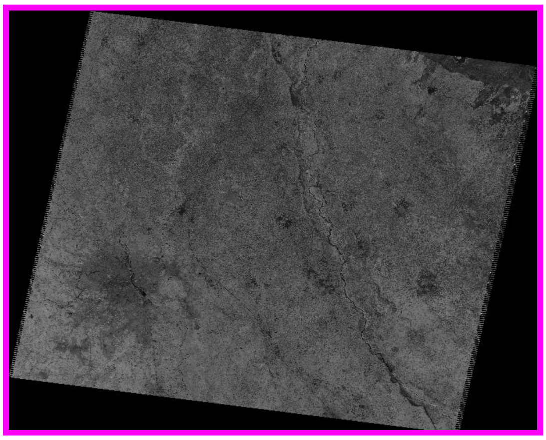
Band 4



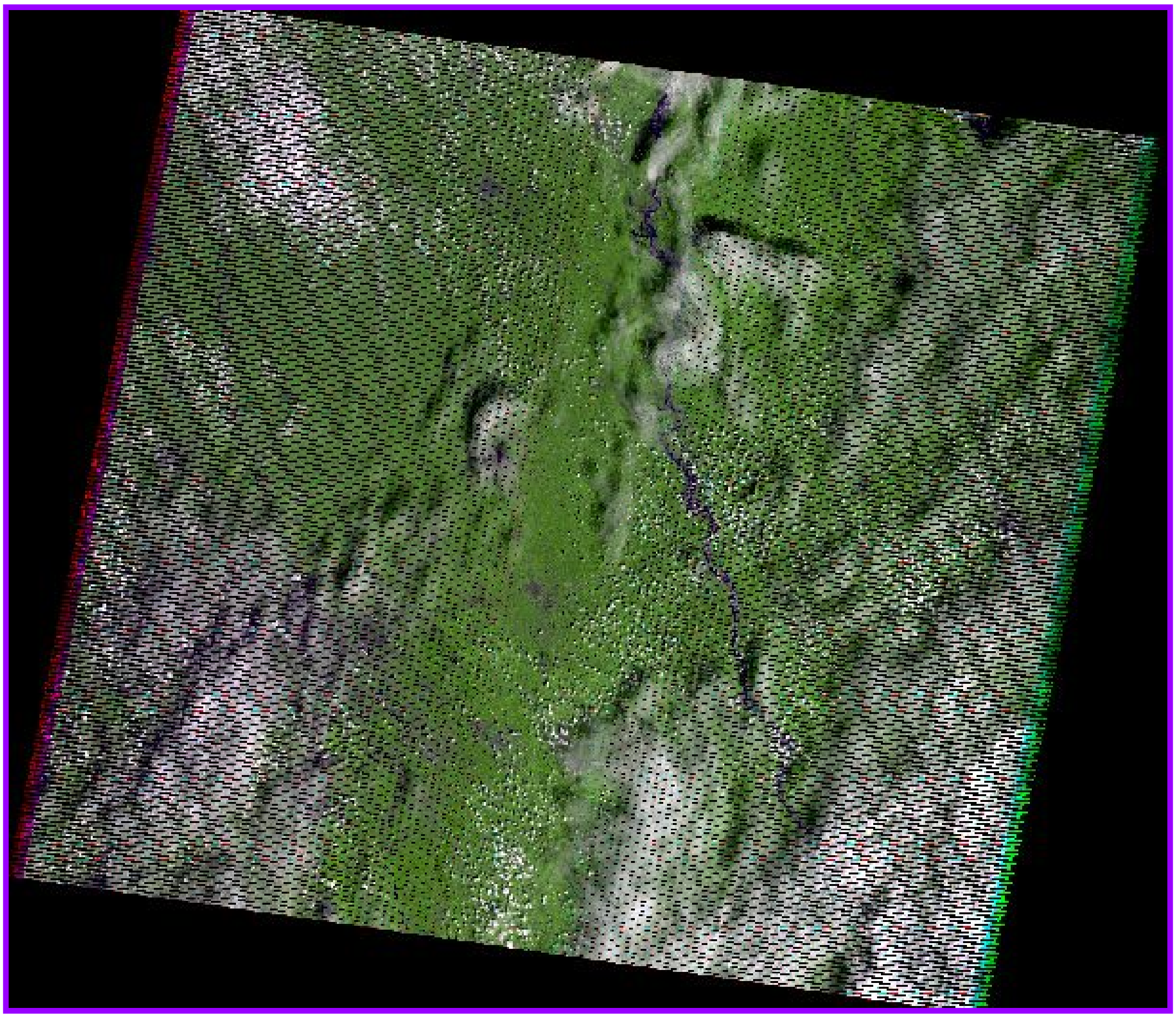
Band 5



Band 6

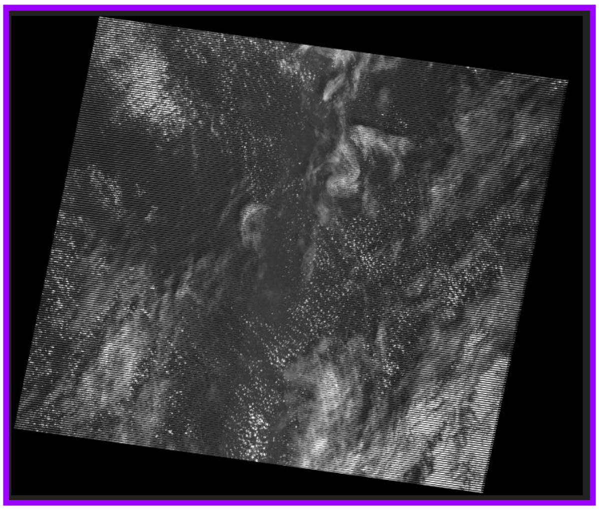


Band 7

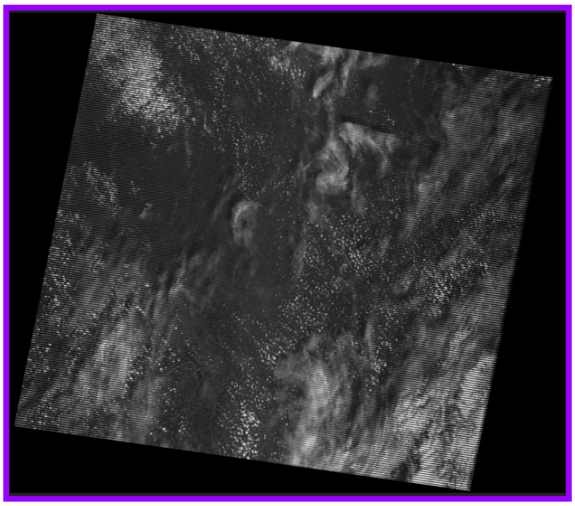


Stacked image of the above satellite images

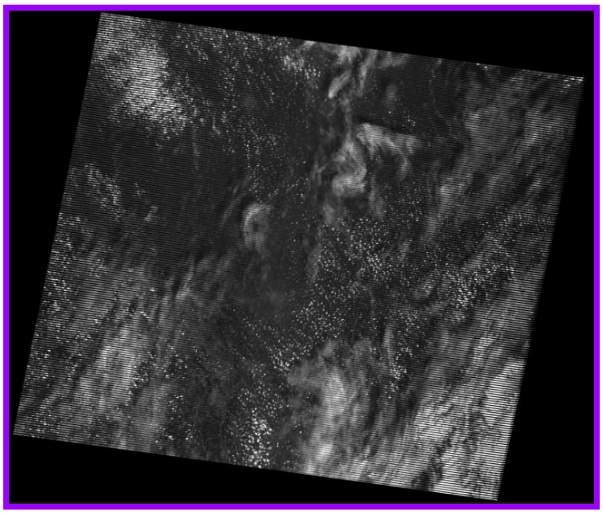
LAYER STACKING OF SATELLITE IMAGES(Sept. , 2009)



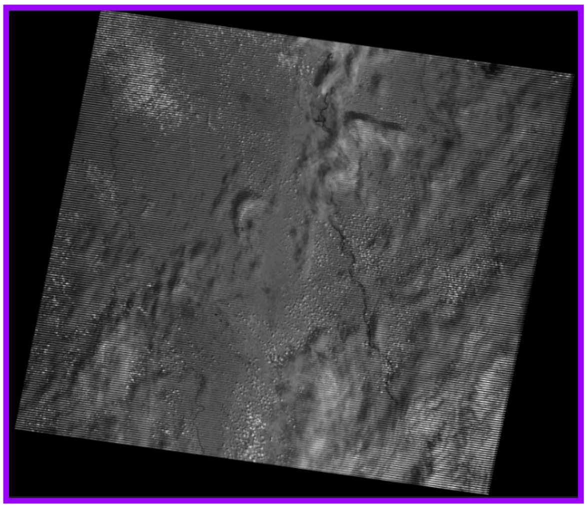
Band 1



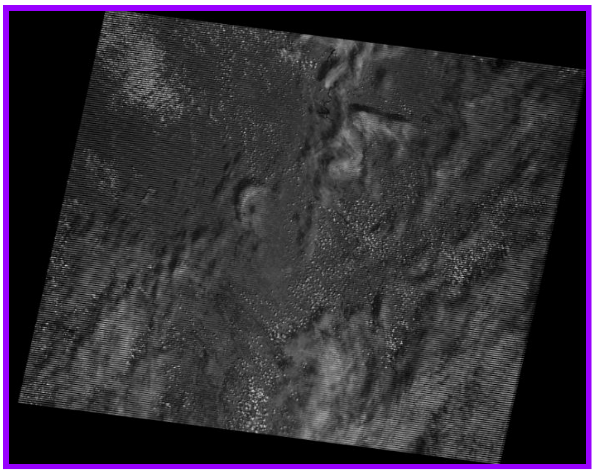
Band 2



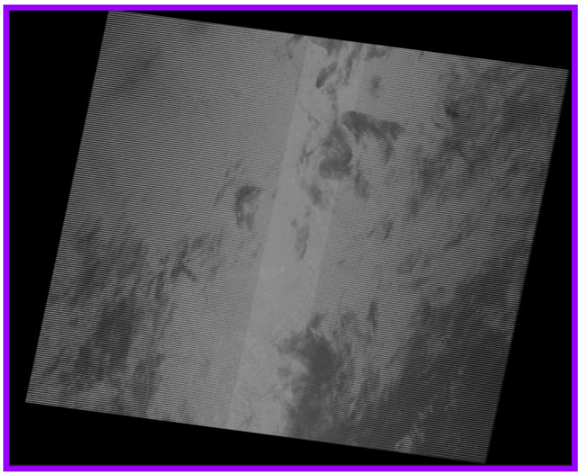
Band 3



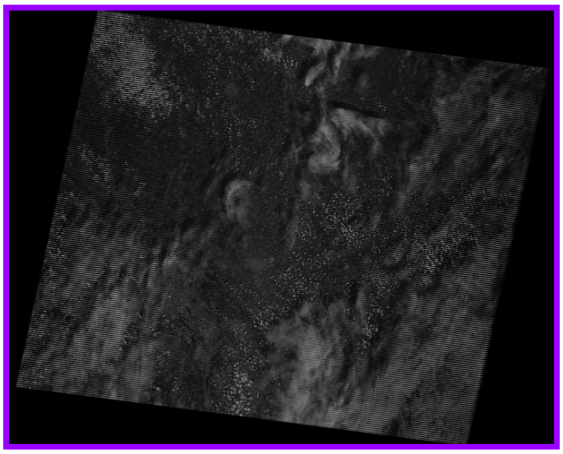
Band 4



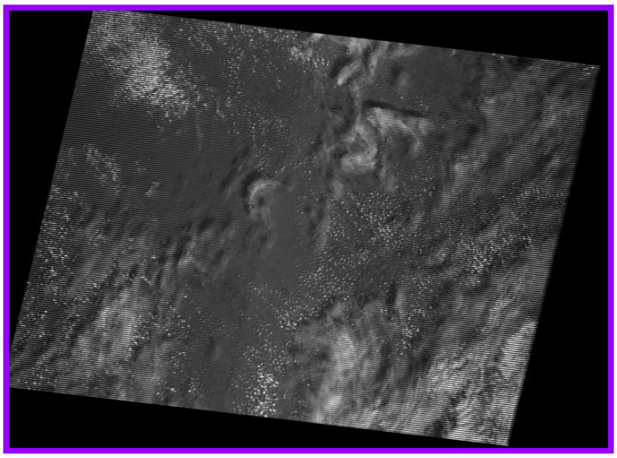
Band 5



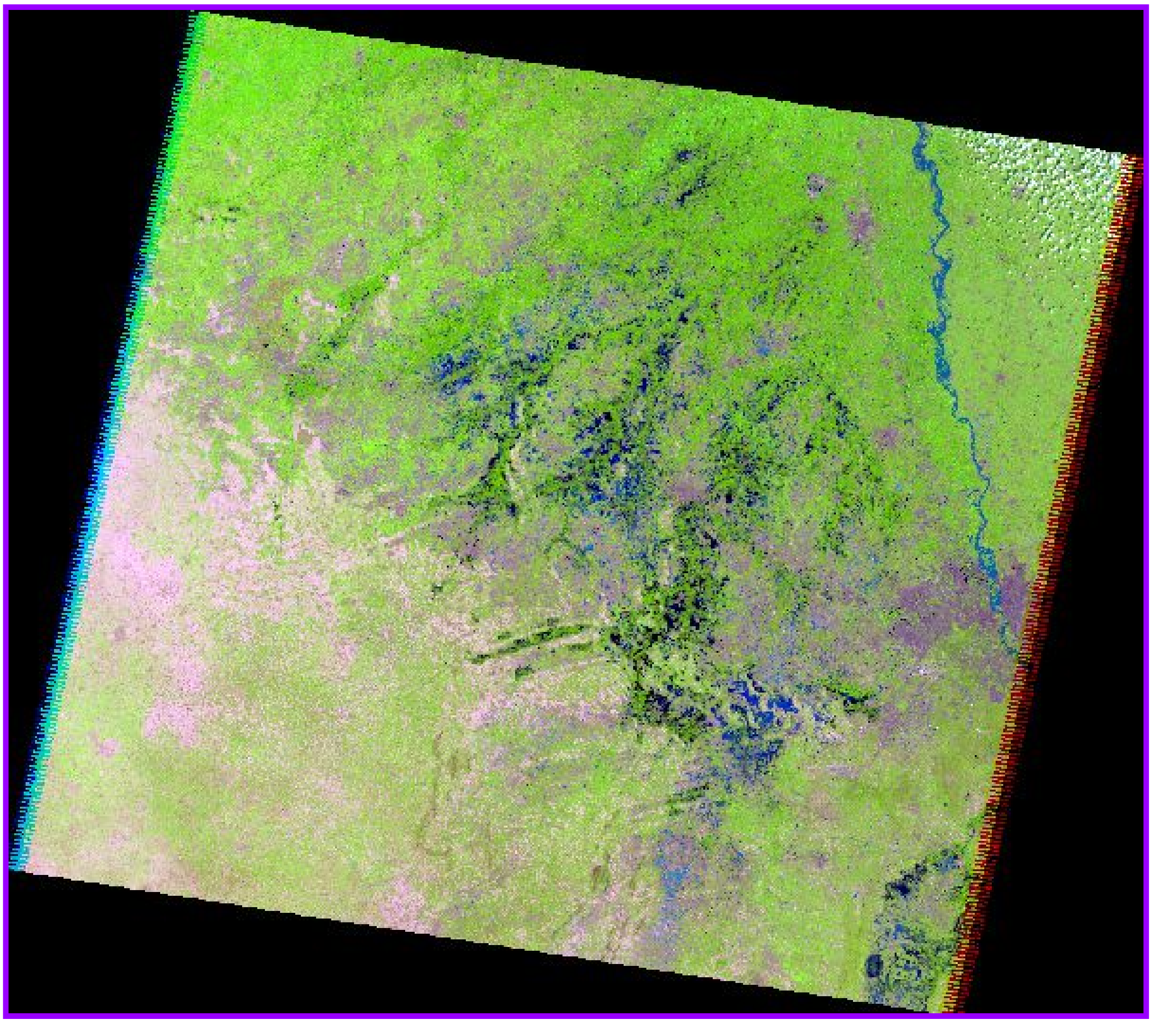
Band 6



Band 7

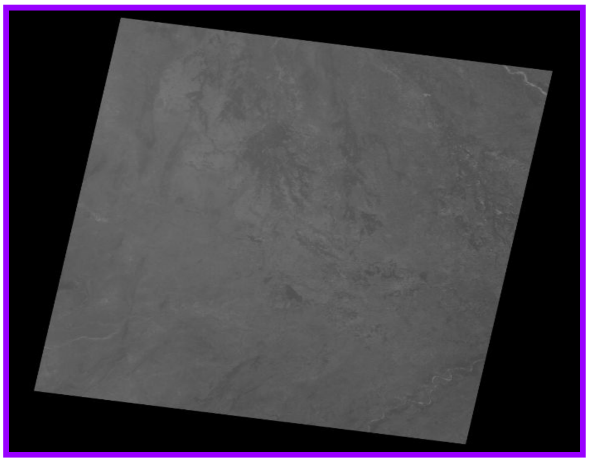


Band 8

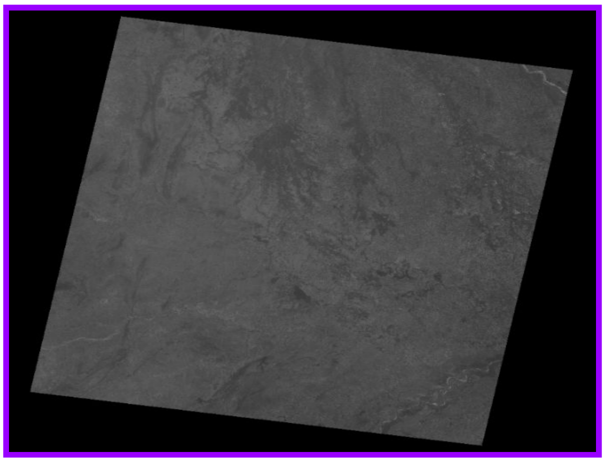


Stacked image of the above satellite images

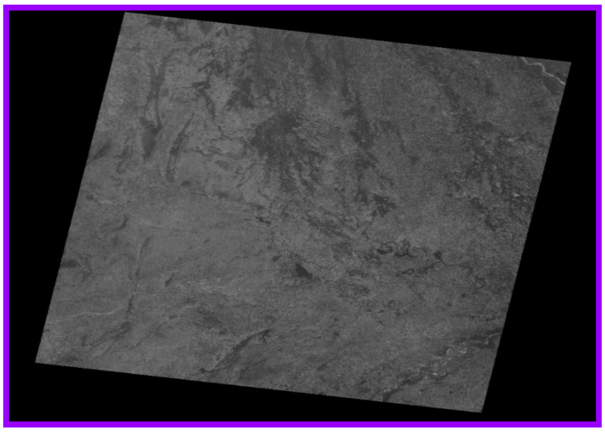
LAYER STACKING OF SATELLITE IMAGES(Sept. , 2017)



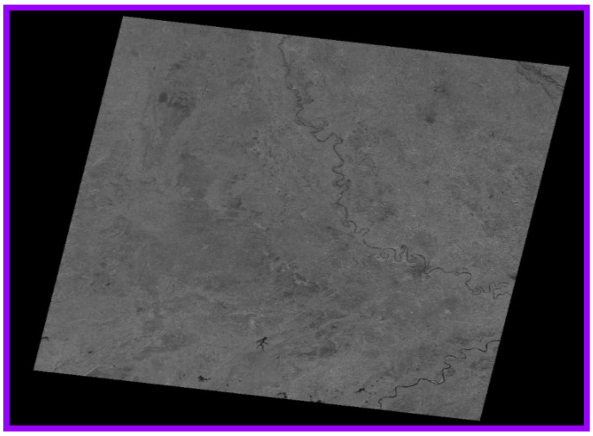
Band 1



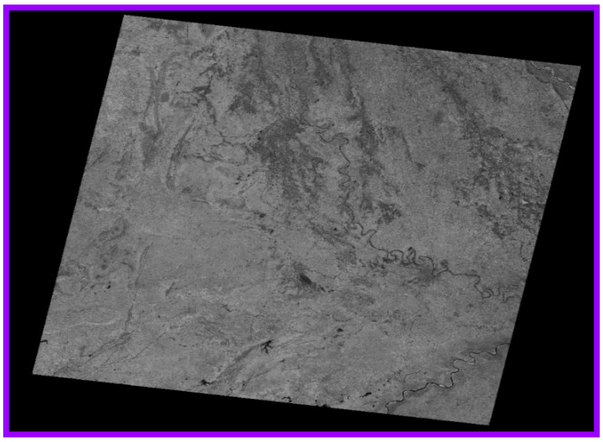
Band 2



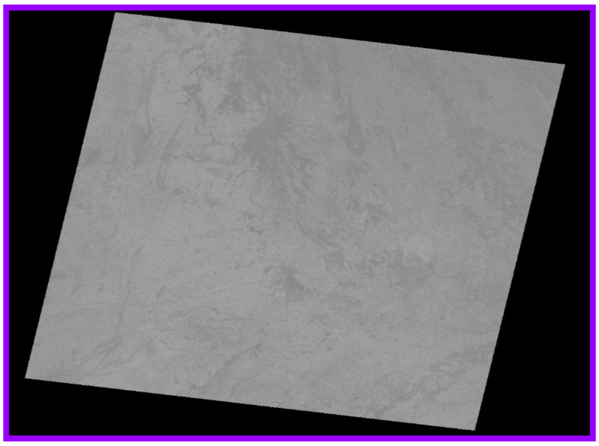
Band 3



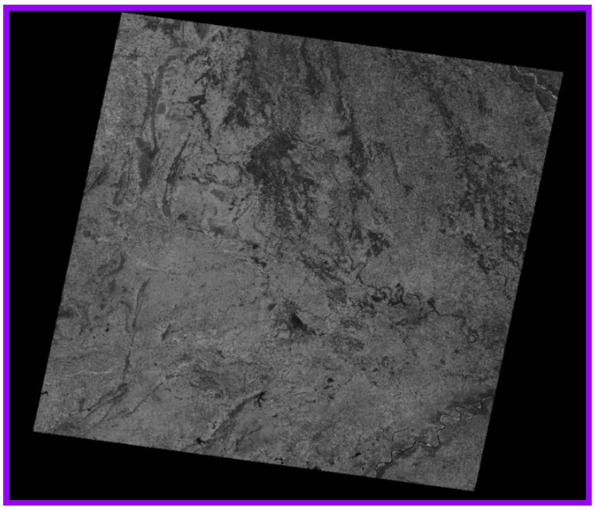
Band 4



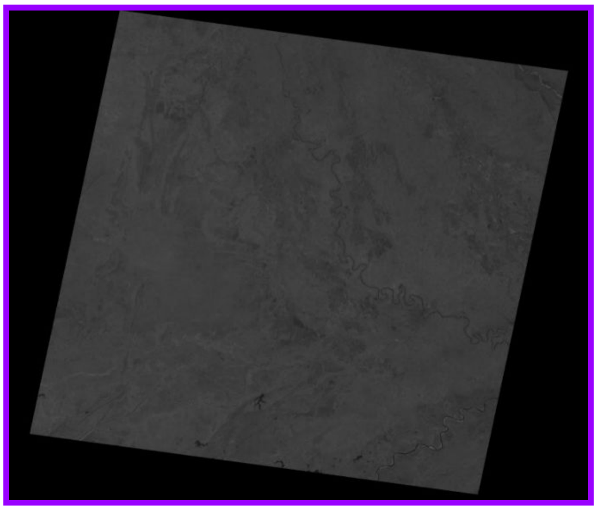
Band 5



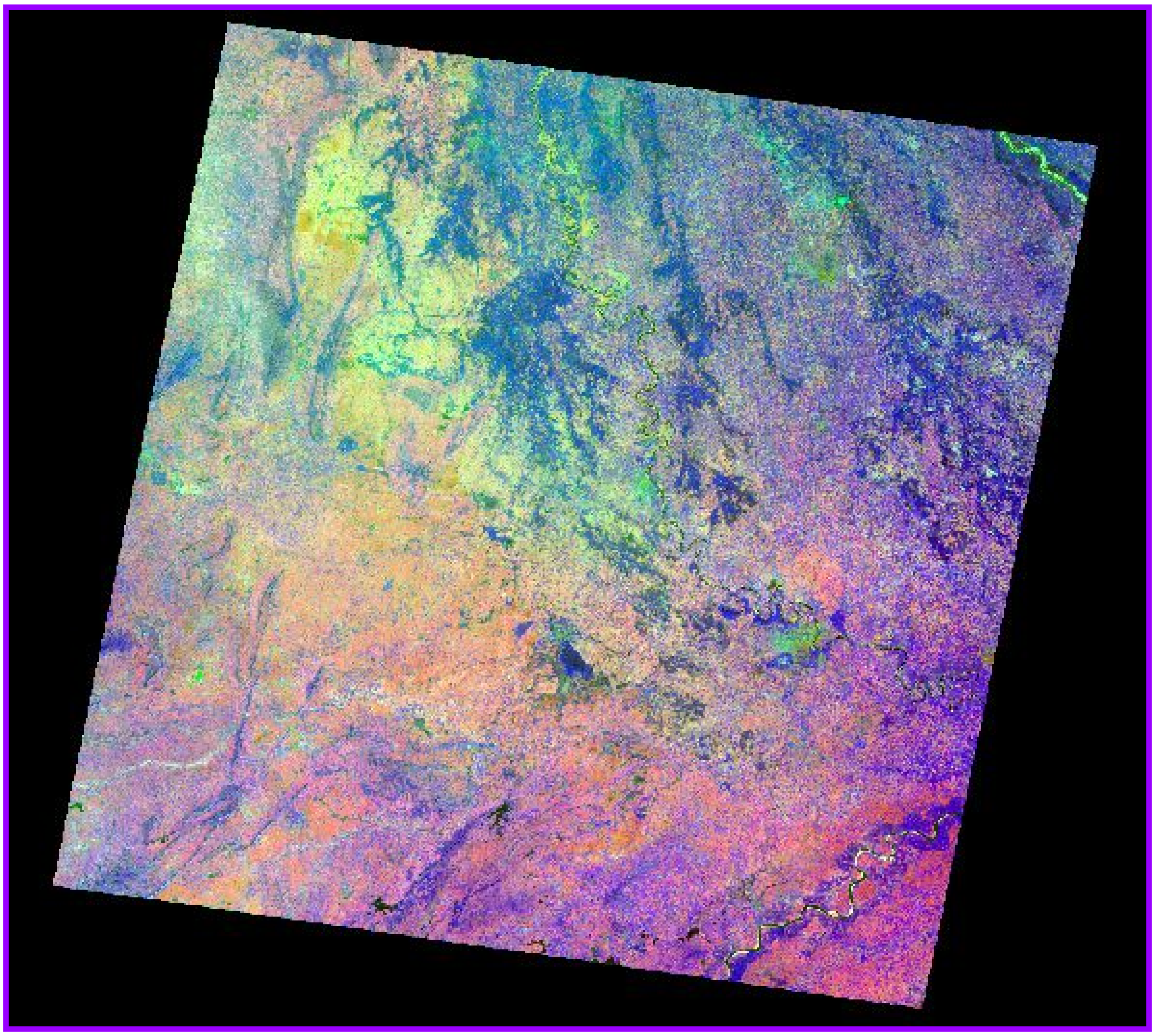
Band 6



Band 7



Band 8



Stacked image of the above satellite images

APPENDIX III : MOSAICING

Process of merging two or more images in a single targeted image is **mosaicing**. In ArcGIS, by mosaicing multiple datasets can be combined and formed into a single raster datasets.

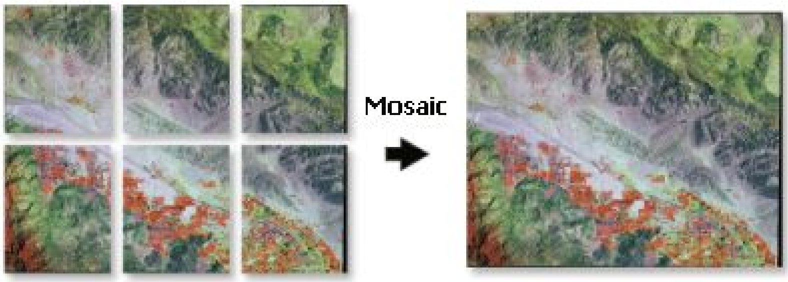


Fig. Illustration of mosaicing
Source:[http://desktop.arcgis.com]

For creating a mosaic dataset, you need to select a target raster data which can either be empty dataset or containing some dataset. This process is very helpful when two or more adjacent raster datasets need to be merged into a single datasets. Some mosaic techniques can help us reduce the abrupt changes along the boundaries of the overlapping raster. Sometimes, during mosaicing images there occur some problem in the overlapping areas which can be overcome in several ways , like , we can set the tool to keep data of only target raster dataset or we can blend the values of overlapping cell values and also we can use the color of target raster dataset to be the default one in case of overlapping.

The first raster in the list of input rasters can be target raster. First, minimum and maximum mosaic operators are used for discrete datasets and Blend and mean mosaic operators are best suited for continuous data. It is very important to notice differences across color maps for each raster datasets having different colors.The Mosaic tool doesn't use the output extent environment setting because the tool tends to create very large raster datasets and the output extent setting might accidentally clip your data.

In ArcMap, click on raster catalog in table of contents and open mosaic raster catalog box from the data menu in the ArcMap toolbox. This helps us to get a mosaicked dataset from the set of raster datasets. We can apply any color correction settings from the Layer properties. Use the mosaic button on the image analysis window to mosaic a selected set of raster layers together.
After mosaicking, save the mosaicked image at any location you want.

APPENDIX IV : REGISTRATION

Registration is the process of bringing different time series images into one coordinate system for the purpose of processing and comparison. For registration, we need a dataset that is already georeferenced. We register the data set that is not georeferenced to a georeferenced dataset. This aim can be easily achieved by using ArcMap. ArcMap provides the option of auto-registration. Auto-registration in done by placing non referenced dataset over the required correct location on the georeferenced map. Here in the project, we have registered our satellite image to political dataset of India taken from GADM website. The steps in registration are as follow -

1. Open ArcMap and add layers of the referenced dataset (GADM dataset) and the layer of non referenced dataset (2017 satellite image) .

2. Now open georeferencing toolbar by clicking on customize menu and then toolbars and then georeferencing toolbar.

3. Now zoom and resize and shift the dataset where it needs to be there.

4. Now we will fit the dataset in display using the fit into display tool.

5. Again shift the unreferenced image properly to more accurate position by shifting, moving and resizing.

6. Click on the auto-registration tool

7. The image will get fit to GADM administrative map.

8. Now, open the image from 2009 and repeat the same above process with referenced image as that of 2017.

9. Once the image from 2009 get registered, repeat the same above procedure for the image of 1999 and georeference it with 2009 image. Thats how all three image will now fall at the same dataset.

10. Lastly, save the updated georeferenced layer by selecting update georeferencing option from the drop down menu.

KEY ABBREVIATIONS

Multi-temporal images : multiple images of the same area acquired at different times.
GIS - Geographic Information System
NCR - National Capital Reason
NCTD - National Capital Territory of Delhi
NASA - National Aeronautics and Space Agency
GLS- Global Land Survey
USGS - United State Geological Survey
LandSat TM - LandSat 4-5 Thematic Mapper
LandSat ETM + - LandSat 4-5 Enhanced Thematic Mapper plus
TIFF - Tagged Image File Format
VNIR - visible and near infrared
SWIR - short-wavelength infrared
LWIR - Long wavelength infrared
UTM- Universal Transverse Mercator
GADM- spatial database of the location of the world's administrative areas

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15. **GADM team, gadm.org**