

## Land Use/Land Cover Changes Pattern Using GIS and Remote Sensing Techniques - Satara District: A Case Study

Mr. Akshay Babaso Patil<sup>1</sup> & Dr. Sachin Pandurang Hudale<sup>2</sup>

<sup>1</sup>Associate Research Scholar, Mahila Mahavidyalaya, Mangalwar Peth, Karad.

<sup>2</sup>Head & Associate Professor Yashvantrao Chavan College, Ishwarpur.

Corresponding Author – Mr. Akshay Babaso Patil

DOI - 10.5281/zenodo.18477500

### Abstract:

Land use and land cover (LU/LC) are crucial for understanding the relationship between human activities and the environment, making it essential to simulate and monitor these changes. This paper aims to map and analyze the LU/LC patterns and changes between 2020 and 2025 using satellite imagery, with a primary focus on quantifying surface water availability in the region. The study applies an integrated approach combining remote sensing and Geographic Information Systems (GIS) to assess the LU/LC status in the Satara District of Maharashtra. It generates LU/LC maps for the district at two different time points to detect changes in various natural resources. Using supervised maximum likelihood classification, the imagery was categorized into five LU/LC classes: Water Bodies, Scrub Land, Natural Vegetation, Fallow Land, and Agricultural Land. The classification results indicate significant changes, particularly in agricultural areas. Change detection analysis reveals a reduction in Natural Vegetation from 21.31% in 2020 and 15.64% in 2025, marking a decrease of 5.67%. Similar change detection analysis was conducted for other land use categories. This information on urban growth and LU/LC changes is invaluable to local governments and urban planners, as it supports better decision-making for sustainable development and water resource management in the district.

### Introduction:

Human alterations of the environment have grown exponentially over the past few decades, particularly since the industrial revolution. While the Earth's landmass has remained relatively unchanged over time, human demands on the land have drastically increased, leading to significant impacts on the Earth's ecosystems. As a result, understanding land use and land cover changes has become critical as nations seek to address issues such as uncontrolled development, declining environmental quality, loss of prime agricultural land, destruction of vital wetlands, and the depletion of fish and wildlife habitats (Nagraju Avreti et al., 2016). In the past thirty years, remote sensing technologies and methods have evolved

significantly. Today, a wide range of sensors operating across various imaging scales are used, providing valuable insights for planners and land managers. Remote sensing has become a key tool for understanding the global physical processes that affect the Earth. Satellite data, combined with Geographic Information Systems (GIS), has allowed for the interpretation of vast amounts of geographical data. Digital change detection techniques, using multi-temporal and multispectral remotely sensed data, are now essential for understanding landscape dynamics and detecting, identifying, mapping, and monitoring changes in land use and land cover patterns over time (Priti Attri et al., 2015).

The spatial pattern of relief, which forms the topographic mosaic of a terrain, is typically

extracted from topographical maps. These maps, available in various scales, are the most accessible data sources for terrain analysis, although they may not always be ideal for all forms of analysis (Zende Abhijit et al., 2012). The core principle behind using satellite images for change detection is that land cover changes result in alterations in radiance values that can be detected remotely. Over the last two decades, numerous digital change detection techniques have been developed, including mono-temporal post-classification comparison, image differencing, image rationing, change vector analysis, regression, multi-temporal biomass indices, and background subtraction. Of these methods, the post-classification approach is the most commonly used. This technique involves classifying and labeling two images from different years (e.g., 2012 and 2013). The area of change is determined by comparing the classification results, and the accuracy of the investigation is dependent on the precision of the classification of each image.

The study area is one of the fastest-developing cities in Maharashtra, experiencing rapid population growth, economic development, industrialization, and transportation activity, all of which negatively impact the environment. Factors such as urbanization, tourism (since it is a world-famous tourist destination), population growth, and the demand for forest products have driven significant changes in land use and land cover. Other global issues, such as rising energy prices and climate change, further influence the urban ecosystem. Population projections indicate that urban sprawl will continue to expand into rural areas, partly due to people commuting between urban work locations and their homes in the countryside. This has led to a significant increase in built-up areas, a decrease in agricultural land, water bodies, and forest areas, clearly

highlighting the impact of population growth and development on the quality of life in the region.

The interpretation of land use/land cover (LU/LC), the factors driving changes in land use and land cover, and their related aspects have become increasingly important, as they form the foundation of many environment-development policies. Remote sensing and GIS are essential tools for providing accurate and timely information about the spatial distribution of land use and land cover. GIS offers a versatile platform for collecting, storing, displaying, and analyzing the digital data required for LU/LC assessment. With the advent of remote sensing and GIS technologies, land use/land cover mapping has become an effective and precise method for improving the identification and selection of areas designated for agricultural, urban, and industrial purposes within a region (Savitree Patidar et al., 2015).

Therefore, accurate information on land use/land cover (LU/LC) is essential for implementing various development, planning, and land use schemes to meet the growing demands for basic human needs. Satara, an ancient capital of the Maratha Empire, and its surrounding area were selected for this study due to their significant population growth, rising water demands, expanding industries, transportation, economic development, tourism, and status as an educational hub. As a result, this study aims to analyze population growth, water demand, and monitor the dynamics of LU/LC and its changes.

**Objective:**

To identify land cover/land use changes and examine the dynamics of these changes at different spatial and temporal scales.

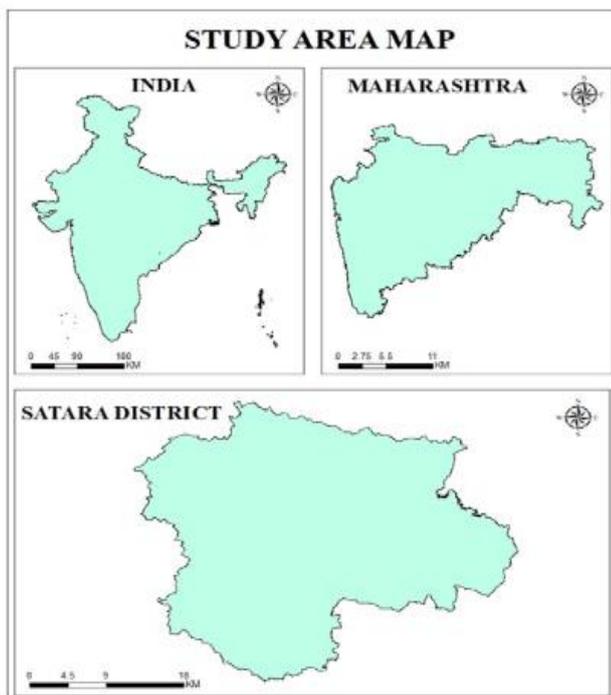
**Study Area:**

Satara district is a significant region in the state of Maharashtra, renowned for its agricultural

development. The district's rich agricultural and rural-based cultural heritage, along with the author's familiarity and connection to the area, motivated the researcher to undertake this study.

The Satara district is situated in west part in Maharashtra state. This district consists eleven tahsil with 1,727 villages. The total area is covered with 10,480 sq.km and extending between 170 5' and 180 11' North latitudes and 730 33' to 740 54' East longitudes.

According to the census of 2011 Satara district has a population of 3,003,741, nearly equal to the democracy of Albania or the US state of Mississippi. This gives it a positioning of 122nd in India (in association with a total of 640). The district has a population density of 287 occupants per square kilometer (740/sq. mi). The population growth rate of Satara district was 6.93% over the decade 2001-2011. The climate ranges from the rainiest in the Mahabaleshwar region, which has an average annual all of over 6000 mm to the driest in Man tahsil where the average annual rainfall is about 500 mm.

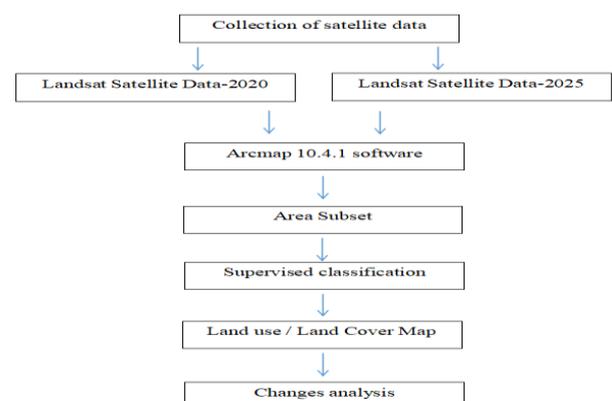


**Figure 1: Satara District: A Study Area**  
(Source: Survey of India)

### Materials And Methods:

The objective of this study is to detect changes between the Landsat 8 image from March 2020 and the Landsat 9 image from March 2025. The data were sourced from the United States Geological Survey (USGS). The detailed methodology for the study is presented in Fig. 2. Both Landsat 8 and 9 images have a spatial resolution of 30 meters. The selection of images was limited to the same season to minimize seasonal variations. Multispectral and multi-temporal images were chosen as they cover the intended study period, and their resolution is suitable for image classification. The land cover maps are generated exclusively from these images.

**1.Pre-Processing of Images:** For the analysis of imagery, pre-processing was performed on the images. The pre-processing steps included restoration and rectification of the images. The downloaded Landsat 8 image from March 2020 underwent image stacking, scene mosaicking, and subsetting to focus on the essential study area. The base layer created through this process was used for image subsetting. To accurately position ground features in the image, image enhancement and extraction techniques were applied. Similarly, the Landsat 9 image from March 2025, which contains four bands, was processed by performing image stacking in Arcmap 10.4.1 software to create a composite image.



**Figure 2: Workflow for Change Detection Analysis of Study Area**

**2.Subsetting and Mosaicking:** Often, we do not need to interpret the entire area of a satellite image; instead, we focus on specific areas. In such cases, the region of interest should be extracted from the whole image to reduce its size and speed, improving the reliability of calculations. This process is referred to by different names depending on the software: "cut," "clip" (ArcGIS), "extract" (ArcGIS), "subset" (ERDAS), etc. The term **subset** is commonly used in **ERDAS Imagine**, a satellite image interpretation software. Sub-setting can be done in most software programs by providing coordinates, such as the coordinates of two opposite corners for a rectangular subset. Alternatively, you can draw a polygon over the desired area of the image and use that to define the subset (Kuldeep Pareta et al., 2015).

Images in the same coordinate system can be accurately positioned relative to each other based on their coordinates using most GIS software. Images of adjacent areas can be placed next to each other and saved as one large image. This process is known as **mosaicking** (K. Kavitha, 2012). Mosaicking involves more than just placing images next to each other; it is a technique of image processing that is useful for tiling digital images. Mosaicking blends multiple images together seamlessly, ensuring that the boundaries between the original images are not visible. Any number of geocoded images can be combined using specified cut lines (polygons). Mosaicking is a special case of geometric correction, where registration is performed on the existing image (T.V. Ramachandra et al., 2004).

**3.Layer Stacking:** Various types of measurements can be made from the ground area covered by a single pixel. Each type of measurement forms an image that carries specific information about the area. By "stacking" these images from the same area together, a multilayer image is created. Each individual image becomes

a layer in the multilayer image. Layer stacking is the process of combining the required bands for different types of studies into a single output file (Y. Babaykalpana et al., 2010).

**4.Land Cover Image Classification:** Image classification is the process of assigning pixels of a continuous raster image to predefined land cover classes. In this study, the land cover classes generated include Residential Area, Fallow Land, Water Bodies, and Vegetation. The classification process results in a land use/land cover image of the area, which helps in understanding the spatial distribution of various land cover types. Table 1 shows the nomenclature used for the land cover classes.

**Table 1: Color Assignment for Land Cover Classes**

Sr. No.	LULC Classes	Colors Assign to Classes
1.	Water Bodies	Blue
2.	N. Vegetation	Green
3.	Agricultural Land	Yellow
4.	Fallow Land	Red
5.	Open Scrub Land	Pink

The result of classification is influenced by factors such as the values of input images, classification methods, and algorithms (Prakassam C., 2010). To improve classification accuracy, selecting the appropriate classification method is crucial. Image classification is performed to identify and assign real-world thematic classes to the pixels in the image. In this study, image classification was conducted using the supervised maximum likelihood classification method, and the classified image is shown in Figure 3.

The maximum likelihood classification algorithm was selected because it can incorporate the statistical properties of the training samples before assigning landcover types to each pixel. The training data provided by the user instructs the software on which types of pixels should be

selected for each specific land cover class.

**5.Change Detection Analysis:** Change detection analysis is used to describe and quantify the differences between imagery of the same area taken at different times. The process of change detection depends on the phenomenon or scene being observed at various time intervals. For this study, the post-classification comparison method was adopted for change detection. This method was chosen because it is simple to implement and

provides comprehensive "from-to" statistics, which are useful for decision-making.

The change detection analysis was carried out using the two land cover maps generated for the years 2020 and 2025. The result of this analysis is a land cover change map that shows the differences between 2020 and 2025. Table 2 presents the statistical analysis of the change detection results for both images.

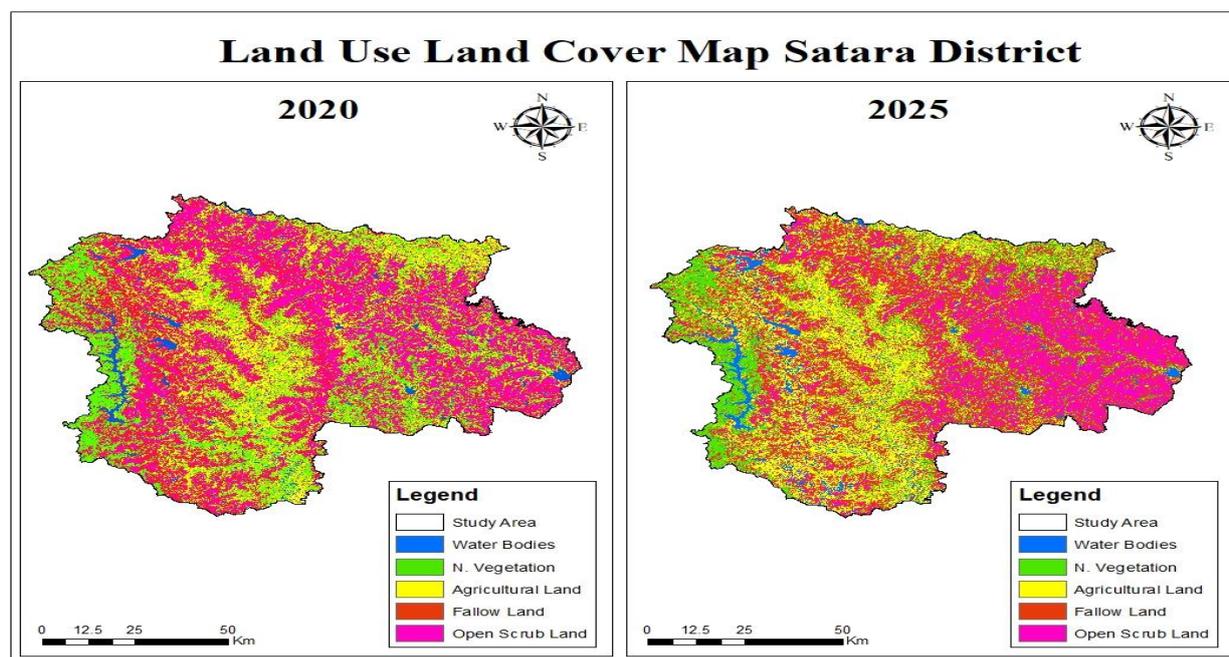


Figure 3: Landsat 8/9 2020 & 2025 Image Classification

Table 2: Land Covers Statistics Using Maximum Likelihood Classification

Class Name	2020 Area in km <sup>2</sup>	2020 Area in %	2025 Area in km <sup>2</sup>	2025 Area in %	Change Area In km <sup>2</sup>	Change Area In %
Agricultural Land	2226.2	21.26	2602.64	24.86	376.44	+3.6
Water Bodies	277.05	2.64	458.08	4.37	181.03	+1.73
Fallow Land	3158.78	30.2	3200.91	30.57	42.13	+0.37
N. Vegetation	2231.78	21.31	1625.98	15.64	-605.8	-5.67
Open Scrub Land	2574.85	24.59	2581.65	24.65	6.8	+0.06

Percentage of each class was calculated separately for each class of both the images. The statistical calculation of the classes is as follows:

$$\text{Area in percentage} = \frac{\text{Category}}{\text{Sum of all number of points}} \times 100$$

Table 2 shows positive and negative changes. The positive changes showed that there is increase in particular area and negative changes showed that there are decreased in particular area.

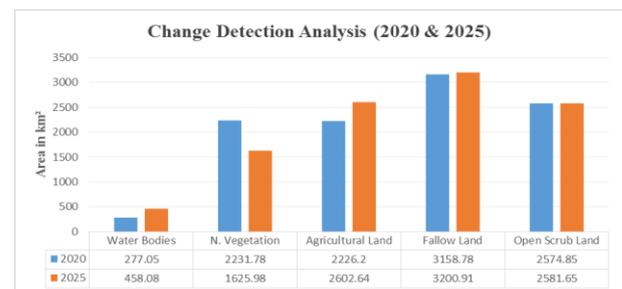
## Results and Discussion:

For the effective and comprehensive development and management of Satara district and its surrounding areas, it is essential to have accurate information on Land Use/Land Cover (LU/LC) and the driving forces that impact the urban ecosystem. Landsat 8 data at a 1:50,000 scale for the year 2020 was visually interpreted to delineate the LU/LC categories of the study area. The various LU/LC classification levels based on visual interpretation in the study area include Scrub Land, Agricultural Land, Forest Land, Water Bodies, and Wastelands. The statistical distribution of these LU/LC categories for the Satara area is presented in Table 2, and the corresponding land use/land cover map of Satara is shown in Figure 3.

**1. Agricultural Land:** Agricultural land refers to land primarily used for farming and the production of food, fiber, and other commercial and horticultural crops. This category includes land under crops (both irrigated and non-irrigated), fallow land, plantations, and similar uses. In the study area, agricultural land encompasses both agricultural plantations and croplands. In 2020, agricultural land covered approximately 2,226.20 km<sup>2</sup> (21.26%), and in 2025, this area increased to 2,602.64 km<sup>2</sup> (24.86%).

**2. Water Bodies:** Water bodies encompass both natural and man-made aquatic features, including ponds, lakes, tanks, reservoirs, as well as flowing streams, rivers, and canals. This category includes areas with surface water, either impounded in the form of ponds, lakes, and reservoirs or flowing as streams, rivers, and canals. On satellite imagery, water bodies are typically represented by tones ranging from light blue to dark blue, with a smooth to mottled texture. Water bodies appear dark in satellite images due to the absorption of incoming infrared radiation.

In the study area, surface water bodies such as tanks, reservoirs, rivers, streams, and drains have been identified, with their geographical distributions being 277.05 km<sup>2</sup> (2.68%) for tanks and reservoirs, and 458.08 km<sup>2</sup> (4.37%) for rivers and streams. Major drinking water resources in the Satara region include the Dhom, Balakwadi, Urmodi, Kanher, Tarali, and Koyana dams, all of which are situated within the Krishna Valley.



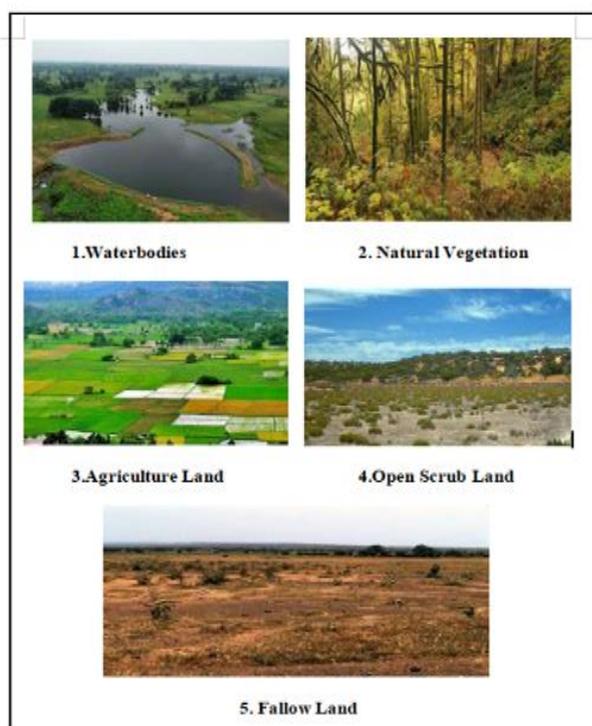
**Figure 4: LULC - Change Detection for Satara District**

**3. Fallow Land:** Wasteland refers to degraded or underutilized land that could potentially be restored to productive use through proper soil and water management practices. This category also includes land that is deteriorating due to inadequate water and soil management or natural causes. Fallow land, which may result from inherent or imposed limitations such as location, environmental factors, chemical and physical soil properties, or financial and management constraints, is also considered within this category. In the study area, fallow land covered an area of approximately 3,158.78 km<sup>2</sup> (30.20%) in 2020, and this area increased to 3,200.91 km<sup>2</sup> (30.57%) by 2025.

**4. Natural Vegetation:** These areas are primarily characterized by the presence of trees and other types of vegetation within the designated forest boundaries. On satellite imagery, forested regions are typically identified by a green tone and a coarse texture. This class is predominantly distributed in the western part of the study area. In 2020, forest land covered an area of

approximately 2,231.78 km<sup>2</sup> (21.31%), while in 2025, this coverage decreased to 1,625.98 km<sup>2</sup> (15.64%).

**5. Open Scrubland:** Scrubland refers to land that is prone to degradation due to erosion. These areas are typically found in the foothills of mountain ranges and on plains with moderate slopes. On satellite imagery, scrubland appears pink in color. In 2020, scrubland covered an area of approximately 2,574.85 km<sup>2</sup> (24.59%), and by 2025, this area slightly increased to 2,581.65 km<sup>2</sup> (24.65%).



**Figure 5: Land Use Classes-1. Water bodies 2. Natural Vegetation 3. Agriculture Land 4. Open Scrub Land 5. Fallow Land**

### Conclusions:

Satara district, a rapidly growing region, was selected as the study area to quantify the Land Use/Land Cover (LU/LC) pattern for the year 2020. The National LU/LC classification system developed by NRSC, USGS, and ISRO categorizes land in the study area into five levels. The hierarchical classification reveals that fallow land is the dominant LU/LC category in the

Satara area, covering 3,200.91 km<sup>2</sup> (30.57%), followed by scrub land 2,581.65 km<sup>2</sup> (24.65%), natural vegetation 1,625.98 km<sup>2</sup> (15.64%), agricultural land 2,602.64 km<sup>2</sup> (24.86%), and water bodies 458.08 km<sup>2</sup> (4.37%) of the total geographical area.

The study concludes that fallow land contributes the highest percentage (30.57%) of LU/LC in the Satara district, while water bodies contribute the lowest (4.37%). The study also identifies key driving forces that significantly impact the urban ecosystem. These driving forces include population growth, increasing demand for forest products, the need for locally produced food, as well as global issues such as rising energy prices and climate change. Additionally, future climate changes are likely to affect human settlement patterns and land use practices. The projected growth in human population indicates that urbanization will continue, potentially leading to further reductions in forest and cropland areas. Moreover, there will be increasing pressure on water storage structures in the study area.

### References:

1. Savitree Patidar and Vimit Sankhala, (2015), "Change Detection of Land Use and Land Cover of Deharadun City: A Spatio-Temporal Analysis," International Journal of Advanced Remote Sensing & GIS, Volume 4, Issue 1, 1170-1180.
2. Zende Abhijit M., R. Nagarajan, P. K. Deshpande, and K. R. Atal., (2012). Remote Sensing and GIS Applications for Terrain Evaluation and Land Resources Assessment in Yerala River Basin, Western Maharashtra, India. International Journal of Civil, Structural, Environmental and Infrastructure Engineering Research and Development Vol. 2, Issue. 2, 17-24.

3. Y. Babykalpana and K. Thaushkodi, (2010), "Supervised/Unsupervised Classification of LULC using Remote Sensed Data for Coimbatore City, India," International Journal of Computer Applications (0975-8887), Volume 2 - No.7, 679-956.
4. T. V. Ramchandra and Uttam Kumar, (2004), "Geographic Resource Decision Support System for Land Use, Land Cover Dynamics Analysis", Proceedings of FOSS/GRASS users Conference-Bangonk, Thailand, 12-14.
5. K. Kavitha, C. Prakasam and A. Shanthakumari, (2012), "Land Use Land Cover Change Detection In Madurai District, Tamilnadu, India: using Satellite Remote Sensing", International Journal of Physical and Social Sciences, Vol.2, Issue 8, 104117.
6. Prakasam C, (2010), "Land Use And Land Cover Change Detection through Remote Sensing Approach : A Case Study of Kodaikanal Taluka, Tamilnadu," International Journal of Geomatics and Geosciences, Vol.1, No.2, 150-158.
7. Savitree Patidar and Vimit Sankhala, (2015), "Change Detection of Land Use and Land Cover of Deharadun City: A Spatio-Temporal Analysis," International Journal of Advanced Remote Sensing & GIS, Volume 4, Issue 1, 1170-1180.