A

Dissertation Report

On

Urban Land Cover change dynamics with increasing population scenario for Chandigarh and Ahmedabad cities, India

By

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CERTIFICATE

This is to certify that the dissertation report on **"Urban Land Cover change dynamics with increasing population scenario for Chandigarh and Ahmedabad cities, India"** prepared by **Chander (ID 2014PCW5460)** in partial fulfilment for the award of degree of Master of Technology in **Water Resources Engineering** to the Malaviya National Institute of Technology Jaipur, is a record of student's own work carried out by him under my supervision and guidance during academic session (2015-2016). This work is approved for submission.

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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled **"Urban Land Cover change dynamics with increasing population scenario for Chandigarh and Ahmedabad cities, India"** in fulfillment of the requirements for the degree of Master of Technology and submitted to the Malaviya National Institute of Technology, Jaipur is an authentic record of my own work carried out at Department of Civil Engineering during a period from July, 2014 to June, 2016 under the supervision of Dr. Sumit Khandelwal, Assistant Professor of Civil Engineering Department, MNIT, Jaipur.

The matter presented in this thesis has not been submitted by me for the award of any other degree or this to any other institute.

Place: Jaipur
Date: 30.06.2016 (Chander)

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"Grace of Almighty God"

Abbreviations

GIS	Geographic Information System
ETM+	Enhanced Thematic Mapper Plus
FCC	False Colour Composite
GCP	Ground Control Point
HPF	Pass Filter
IHS	Intensity-Hue-Saturation
IRS	Indian Remote Sensing
LULC	Land Use / Land Cover
LWIR	Long Wave Infrared
MS	Multispectral
MSS	Multispectral Scanner
NASA	National Aeronautics and Space Administration
RS	Remote Sensing
SWIR	Short Wave Infrared
TM	Thematic Mapper
UTM	Universal Transverse Mercator
VNIR	Visible and Near Infra-Red
WGS 84	World Geodetic System 1984
LANDSAT	Land Remote Sensing Satellite
USGS	United States Geological System

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ABSTRACT

Land use and land cover changes have been among the most important noticeable changes taking place around us. Although the changes are noticeable but the magnitude, variety and the spatial variability of the changes that are taking place around us and the world has made the quantification and assessment of land use and land cover changes a challenging task for the scientists. Moreover, since most of the land use and land cover changes are directly affected by human activities, they less frequently follow the standard ecological theories. The Remote Sensing and Geographic Information System has proved to be very important in assessing and analyzing the land use and land cover changes. Satellite-based Remote Sensing, by virtue of its ability to provide synoptic information of land use and land cover at a particular time and location, has revolutionized the study of land use and land cover change. The changes in land use and land cover which occurred between 1991 and 2015 in the Chandigarh Metropolitan area located in India, were monitored using such advanced spatial technologies. The study area covered is 228.40 km^2, and had previously undergone substantial land use and land cover changes, mainly due to high population pressure. The land cover and land use changes occurred between 1998 and 2013 in the Ahmedabad city located in India too were also monitored using the same technologies and the study area covered is 472.64 km^2.

The main objective of the study was to assess and evaluate the extent and direction of changes in LULC in the mentioned cities, to explain the changes and identify its relation with the increasing population. LANDSAT images taken by L4-5, L-7 and L-8 in the period from 1991 to 2015 were used along with the geographic information system (GIS) techniques used monitor the changes and to generate maps of the LULC of the area in these periods for both the cities. The population data was collected from the census of India and respective Municipal Corporation of the mentioned cities. A remarkable 27.52% growth in the built up area has been observed along with the depletion of the agricultural and bare land in case of Ahmedabad city and 153.93% in case of Chandigarh Metropolitan area. The changing scenario of the water bodies has shown a mixed trend but in the later year, the water body has increased significantly. The built up has increased accordingly with the increase in the population.

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Chapter 1

Introduction

Land use / land cover (LULC) changes are influenced by human involvement and certain phenomena that are caused by natural processes such as agricultural demand and trade, population growth and consumption patterns, urbanization and economic development, science and technology, and many other factors (Research on Land use change & Agriculture, International Institute for Applied Systems Analysis, 2007). As a result, it is needed to have the LULC information which is necessary for all kinds of natural resource management and planning must for the development of an area. Information on regular intervals about the LULC change detection of earth's surface is extremely important for understanding the nature of relationship and interactions occuring between human and natural processes for making better decisions for the management purpose (Lu *et al.*, 2004). The demand for the accurate and latest LULC information for any kind of sustainable development program is increasing where LULC serves as one of the major criteria. As a result, the importance of creating LULC maps and its change as well as updating the same through time has been acknowledged by various research workers for decision making activities.

1.1 Problem Definition

The various applications of remote sensing (RS) for the extraction of the LULC information has been utilized since the emergence of the optical satellite systems. Various improvements and techniques have been developed through past decades with the development of RS technology. Various change detection techniques have been evolved and utilized by several research workers. Due to the importance of monitoring LULC changes, research of change detection techniques is a dynamic field and several new methods are emerging regularly. Recent advancement in RS with a wide range of spectral and higher spatial resolution of satellite images and repetitive coverage, this research field of change detection has been developing strongly. When combined with the availability of historical RS data, the reduction in the aquistion of data and processing as well as higher spatial, spectral and temporal resolution, the application of RS has shown a great impact on growing development in the filed of change detection techniques (Rogan & Chen, 2004). Successful use of RS for LULC change detection widely depends upon adequate understanding of the study area, the satellite imaging system and the various information extraction methods for change detection in order to achieve the goal of the present study (Yang & Lo, 2002). Extracting useful LULC change information from the satellite data using various techniques has been performed and established by many authors. However, it is still sometimes a challenge to select a good change detection method. Moreover, the choice of methods mainly depends upon the RS data available, the performed time limit and the objective of the study. A number of challenges has been faced in applying suitable set of techniques from change detection considering a series of factors ranging from the selection of input data and their classification algorithm, to accuracy assessment to the ultimate aim of the study. Most of them have been discussed by Lu *et al.*, 2004. However, change detection methods have their own advantages and disadvantages as well and no single method has been proven as enough accurate to all the cases. In the present study, investigating the efficiency of the preferred change detection method, selected based on existing case studies, availability of resources and objective of the work, to fulfill the target is one of the major challenges.

1.2 Research Objectives

To address the above mentioned problem, the primary objective of the study is to identify the change detection of land use / land cover (LULC) in the study area with emphasis up on:

- Creating FCC of the images obtained directly from the USGS sources.
- Supervised classification of the satellite images of the study area using different category of classes.
- Accuracy assessment to judge the correctness of supervised classification method in this case study and to ensure the accurate change detection.
- Identify the LULC changes in the study area during the time period of 1991 to 2015 for Chandigarh and 1998 to 2013 for Ahmedabad.
- To calculate the population corresponding to the year of the LANDSAT images using curve fitting equations on excel from the past data available from the census of India and Municipal Corporation of the study areas.
- Finding out a correlation between the population and built up changes during the period from 1990 and 2015 for both the study areas.

1.3 Scope of the Work

The present research has been performed under certain limitations. First of all, the technical aspects of the satellites images used are restricted to certain spatial and spectral resolution have been considered. The effectiveness of the SC method has a great impact on the resolution. Secondly, for accuracy assessment, a true good quality data which can be either reference data or ground truth data with the same number of classes was not available. Thirdly, due to time limitations, the choice of data, aerial extent of the study area and list of methodologies used are also restricted.

1.4 Thesis Outline

The thesis outline can be divided into six chapters (fig. - 1.4.1). The chapter 1 primarily gives the objective of the present research work. After chapter 1, the rest of the thesis has been arranged as follows: Chapter 2 is for the literature review which includes the related research work that has been completed by other people and has been discussed thoroughly. This chapter shows how the application of remote sensing is utilized for the LULC change detection study and briefly reviews various existing techniques. After this chapter, a workflow has been proposed for the present work. Chapter 3 is allocated for the description of the study area and data used for the complete work. Chapter 4 illustrates the methodologies used in detail concentrating mainly upon the supervised classification method for image classification after image preprocessing, enhancement and fusion. Then the techniques and equations used for the calculation of the population to the corresponding years have also been discussed in the thesis.

Results and discussions have been collectively put in Chapter 5 along with the detailed analysis and output results of LULC change detection. The discussion is provided in detail in its association with the objectives. Chapter 6 includes the conclusion that have been drawn from the study and the recommendations for the work that can be taken up in the future ahead of this study. The complete thesis hence consists of 6 chapters and at last the references have been listed from where certain amount of material for the study has been extracted. All the tables, figures and abbreviations used in the thesis have been listed in the thesis prior to the contents table. It has been taken care of that the language used in the thesis is simple and can be understood by every person perusing research.

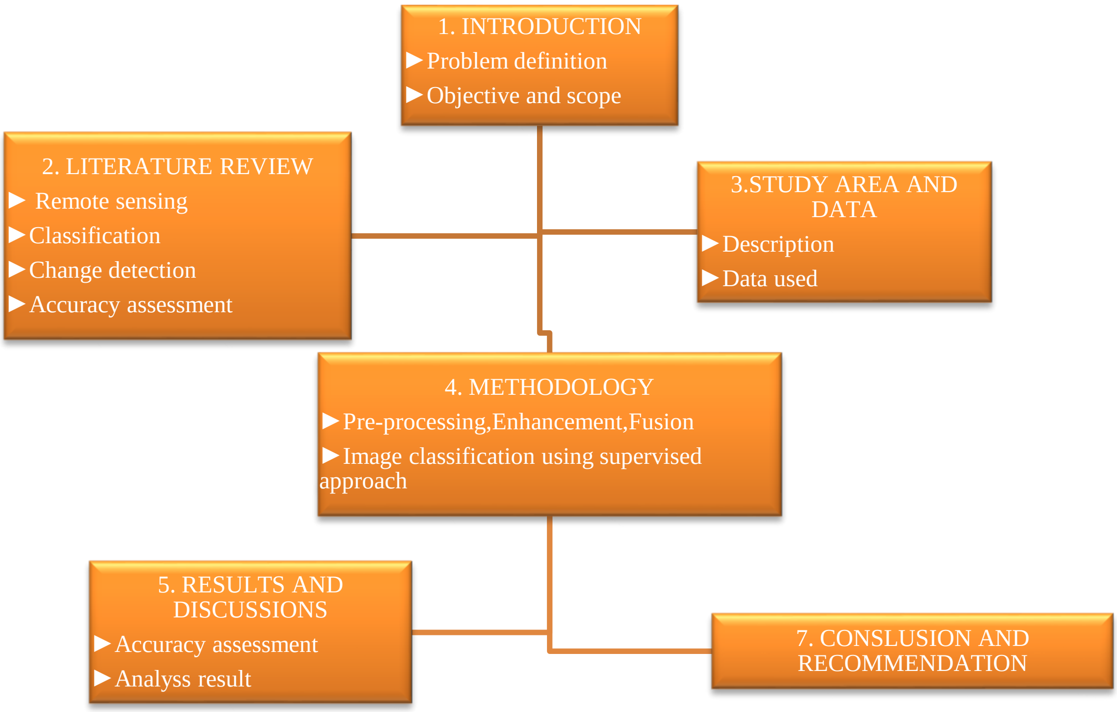


Fig.1.4.1: Tree diagram of thesis outline

Chapter 2

Literature Review

Over the past few decades, Remote Sensing (RS) has played an important role in studying the land use / land cover (LULC) changes occuring in the surrounding areas. LULC change detection studies are becoming a demanding task with the availability of a bunch of wide range sensors operating at various imaging scales and scope of using various techniques as well as increasing directions for monitoring effective and accurate LULC change. Considerable research has been directed at the various components of LULC change including the accuracy assessment which is drawing an equal attention by scientists nowadays. The literature review looks into the following aspects considering the objective of the present study.

2.1 Remote Sensing: For Change Detection

"Remote Sensing is the science of obtaining information about an object, area, or the phenomenon through the analysis of data acquired by a device that is not in contact with object, area, or the phenomenon under investigation" (Lillesand and Kiefer, 1987). It serves with a huge variety and amount of data about the surface of earth for detailed analysis and change analysis with the help of various space borne and airborne sensors. It presents useful capabilities for understanding and managing earth resources. RS tool has been proven to be very valuable for the change detection occuring in the Land Cover (Matinfar, Sarmadian, Panah, Heck, 2007). Several number of change detection techniques have been developed since after the development of the orbital system (Lillestrand 1972). Weismiller *et al.* (1977) have used several RS techniques for the evaluation of change detection for coastal zone environments. In 1980, Byrne, Crapper and Mayo have illustrated and shown that the Landsat multispectral data can be used to identify LULC changes occurring in an effective way. Change detection and monitoring involves the use of many multi-date images to evaluate the differences in LULC due to various environmental, biological and human actions between the acquisition dates of images (Singh 1989). Successful use of satellite RS for LULC change detection depends upon sufficient understanding of the landscape features, imaging systems, and methodology applied in relation to the aim of the analysis (Yang & Lo, 2002). Various RS data products over time and decades have often been implied to obtain the land use information of the earlier periods (Acevedo, Foresman, & Buchanan, 1996; Clarke, Parks

& Crane, 2002; Meaille & Wald, 1990). With the availability of RS data of earlier periods, the reduction in the cost of data and increased resolution of satellite images, RS technology appears equally useful and helpful to make a suffient impact on the monitoring of land-cover and land-use change (Rogan & Chen, 2004). In general, change detection of LULC consists of interpretation and study of the multi-temporal and multi-source satellite images to identify the phenomenon or changes which are temporary in nature through a certain period of time. RS data is the fundamental source for the detection of changes that has been occurred in the recent decades and have made a greater impact on urban planning agencies and land management initiatives (Yeh and Li 1999, Yang and Lo 2002, Rogan and Chen 2004).

2.2 Concept of Land Use and Land Cover

Land cover indicates the vegetation (natural and planted), water, bare rock, bare soil and similar surface and also man-made constructions occur on the earth's surface. While land use indicates a series of operations on land which are carried out by humans, with the objective to manufacture products and/or to benefit through using land resources including soil resources and vegetation resources which is part of land cover (DeBie *et al*. 1996). Thus, land use often influences land cover. In this context, the change is defined as the variation in the surface component of the landscape and is only considered to occur if the surface has a different appearance when viewed on at least two successive occasions (Lemlem, 2007). The increasing population and change in the demand of socio-economic necessities creates a pressure on land use/land cover. This pressure results in uneven changes in LULC (Seto, 2002). The LULC changes are generally caused by inappropriate management of agricultural, urban, range and forest lands which results in severe environmental problems such as landslides, floods etc. Every segment of land on the earth's surface is covered in a way which is unique in nature. Land use and land cover are distinct but they closely linked characteristics of the Earth's surface. The land on the earth's surface could be used for various purposes like grazing, agriculture, urban development, transporation facilities, man-made water bodies and mining among many others. While land cover categories could be cropland, forest, river or lake bed, wetland, pasture, roads, urban areas among others. According to Meyer (1995), the term land cover originally referred to the type of vegetation, such as forest or grass cover occruing on the surface but it has expanded in subsequent usage which includes other things such as manmade structures like building, soil type, biodiversity, surface and ground water.

According to Riebsame, *et al*. (1994), land use affects land cover and changes in land cover affect land use. Changes in the land cover by various kinds of uses of the land do happen but it doesn't imply the degradation of the land. However, many different land use patterns that have been caused by a variety of reasons that are social in nature and has, resulted in the land cover changes that affects biodiversity, water and solar radiation packets, gas emissions and other processes that come together to affect climate and environment.

2.3 Classification Method

Classification of the satellite images obtained through registered websites to extract the land use / land cover status is the one of the major steps in this type of study. Classification is a process of denoting various pixels of the image with different classes. Moreover, optimal utilization of remotely sensed data for LULC studies needs careful selection of accurate data sets and image processing technique(s) (Lunetta, 1998). The classification method common in practice for the image analysis so as to extract the LULC is digital image classification. Sabins (1997) explains that the image classification techniques are usually implemented to the spectral data of a single perdiod image or to the spectral data that has been showing variations in a series different periods. The selection of a classification technique that is quite reliable can cause complication and it usually ranges from the use of a simple threshold value for a single spectral band to complex statistically based decision rules that depends on the multivariate data. The main purpose of image classification is to signify the pixels in the image with the real ground characteristics (Jensen & Gorte, 2001). Through the classification of the spectral image, thematic maps such as the LULC can be obtained (Tso and Mather, 2001). Classification involves indicating the pixels as belonging to a particular class using the spectral data available. There are broadly two types of classification methods and each finds application in processing of RS image. One is called as supervised classification and the other one is unsupervised classification. Both the supervised and unsupervised classification methods used for classifying various multispectral images are mainly based upon the traditional pixel-based method which has been played a great role in the classification of low resolution images. On the other hand, when using new generation images, characterized by a higher spatial and spectral resolution, it is still challenging to obtain appropriate and decent results (Lewinski and Zaremski, 2004).

2.4 Basic Concept in Image Analysis

Remotely sensed data consists of a different variety of data source that are defined on the basis of the range of spectrum of electromagnetic radiations. Aerial photography is used to capture signals that get reflected from the visible and near infrared portion of the spectrum. Most of the digital scanners work in a similar section of the spectrum. Thermal and radar sensor systems are responsive to the different section of the energy spectrum. Remotely sensed data provides an operational GIS with timely and precise data. Image analysis techniques are mainly utilized to perform vegetation mapping of the study area and to update existing vegetation maps. According to Jensen (1995), the suitability of a sensor system for the detection of surface phenomena must be assessed along four dimensions: spatial resolutions (area or size of features that can be identified), spectral resolution (number and width of electromagnetic bands for which data are collected), radiometric resolution (detector sensitivity to various level of incoming energy) and temporal resolution (frequency of satellite overlaps).

Airborne and satellite digital sensor collects and stores the data values for discrete units corresponding to the surface of the earth. A scene is composed of large matrix of these cells. Each cell is referred to as a picture element or pixel and may correspond to a square meter, hectare or square kilometer, depending on the sensor. The spatial resolution of the sensor is usually defined as the length of one side of the cell. Advanced Very High Resolution Radiometer (AVHRR).

2.5 Common Operations in Digital Image Processing of Satellite Images

Digital Image Processing is defined as the manipulation and interpretation of digital images obtained from the satellite, by a computer system, to generate an image for display, interpretation, extract and gather useful information from the image. There are possible forms of digital image manipulation that are literally infinite (Lillesand *et al*., 1998). Digital Image Processing is largely divided into following basic operations: image rectification and restoration, image transformation, image enhancement, and image classification (Lillesand *et al*., 1998).

2.5.1 Pre-processing

The image obtained directly from the satellite is called raw satellite image and is full of errors and cannot be directly utilized for the identification the features and any applications. It needs some correction. Pre-processing is done before the analysis of the main data and before the extraction of the information from that data. Pre-processing involves two major processes: geometric correction and radiometric correction. Remote sensing imageries are inherently subjected to geometric distortions. These distortions mainly occur due to the visualizations made by the sensor optics, the movement of the scanning system, the changing of the platform (the platform altitude, attitude and velocity), the terrain relief, or the curvature and rotation of the earth (Lillesand and Kiefer, 2000). The aim of Pre-processing is aim to correct the distorted data in order to create a more clear representation of the original scene with minor errors, which typically consists of the initial processing of raw image data to correct for geometric distortions, data calibration by radiometric process, and to eliminate the noise present in the data.

2.5.2 Image Enhancement

Image enhancement is used to increase the details of the image by altering the image maximum and minimum brightness values to maximum and minimum display values, and it is done on the basis of pixel values, and this makes visual interpretation more easier by increasing the visual differentiation between features in a scene and assists the human analyst: False color composite (FCC), spatial re-sampling, etc.

2.5.3 Image Transformation

According to Rechards (1999), image transformation are obtained by the derivation of new imagery as a result of some mathematical treatment given to the raw image bands. Image transformation consists of the processes that are similar in concept to those processes in image enhancement, but unlike image enhancement these process are normally implemented on multi-channel (band) images. Principal Components Analyses (PCA) and Vegetation Indices (VIs) belongs to the image transformation processes. The multispectral or multidimensional characteristic of remote sensing image data can be gathered by creating a vector space with as many axes or dimensions as there are spectral components associated with each pixel. In the case of Landsat Thematic Mapper data it will consists of seven dimensions while for SPOT HRV data there will be three dimensions. For hyper spectral data there may be axes that can range up to hundreds. A particular pixel in an image is plotted as a point in such a way in the space with coordinates that corresponds to the brightness value of the pixel in the suitable spectral components (Rechards, 1999).

2.6 Image classification

According to Bakker *et al* (2000), in the application context the most important thing in image classification is the thematic characteristics of the study area (pixel) except its reflectance value. Thematic characteristics which consists of land cover, land use, soil type etc. can be used for further analysis and input to various models. In addition, image classification can also be referred to as data reduction: a number of multispectral bands resulted in a single value raster file. Image classification is a methodology which involves the replacement of visual analysis of the image data by the quantitative techniques for processing the identification of the features in a particular space. This normally consists of the analysis of multispectral image data and the application of statistically based decision and rules for determining the land cover identity of each pixel in an image.

Image classification is defines as the process of creating thematic maps from the satellite imagery of an area. A thematic map is a representation of the various features of an image that shows the spatial distribution of a particular theme. The computerized interpretation of the images from the remote sensors is known as a quantitative analysis due to its ability to identify pixels that is based upon numerical properties. For quantitative analysis usually different procedures of classification are used (Diday, 1994). Classification is a method that denotes the pixel groups with various categories according with the spectral character. There are two main spectrally oriented classification methods for land cover mapping: unsupervised and supervised classifications.

According to Diday (1994) unsupervised classification is computer-automated and it enables the user to specify some parameters that the computer uses to reveal statistical patterns that are already inherent in the data. These patterns are simply bunch of pixels with similar spectral characteristics. In some cases, it may be more important to identify group of pixels with similar spectral characteristics than it is to group the pixels into categories that are recognizable .Lillesand and Kiefer (2000) described, in supervised classification the image analyst/user supervises the pixel categorization processes by specifying, to the computer algorithm, numerical descriptors of the various land cover types present in a particular space. To do this, reference sample sites of known cover type, called training areas are used to create the parametric signatures of each class. According to Jensen (1996) and Landgrebe (2003), each pixel in the data set is then compared mathematically to each category in the interpretation key and is denoted with the name of the category. There are different types of algorithms under this classification category in which minimum distance, variance and covariance of various classes are considered during classification. Of all these algorithms the best suited is maximum likelihood classifier. It quantitatively calculates both the variance and covariance of the category spectral response patterns while classifying an unknown pixel. It is believed that at the more generalized first and second levels, accuracy in interpretation can be achieved that will make the Land use/land cover data comparable in quality to those obtained in other ways. For Land use/land cover data needed for the planning and management purposes, the accuracy of the interpretation is generalized at first and the second level is satisfactory when the interpreter makes the correct interpretation of 85 to 90 percent of the time. According to Rechards (1999) supervised classification is the procedure which is commonly used for quantifying of remote sensing data. It rests up on using suitable algorithms to denote the pixels in an image as representing particular ground cover types or classes. An important assumption which is usually adopted under supervised classification in remote sensing is that each spectral class can be described by probability distributions in multispectral section: this will be a multivariable distribution with as many number of variables as dimensions of the space. Such distribution explains the chance of finding a pixel which belongs to those classes at any given location in many multispectral spaces. This is not contrary since it would be imagined that most of the pixels in distinct cluster or spectral class would lean towards the center and would decrease in density in the positions away from the class center, there by resembling a probability distribution. The distribution which is found to be of most value is the normal distribution. It gives rise to tractable mathematical descriptions of the supervised classification process and robust in the sense that classification accuracy is not affected by overlay to account to the violations of the assumptions that the classes are normal.

2.7 Accuracy Assessment

Accuracy assessment is a significant and most critical segment of studying image classification and eventually change detection occurring in the LULC in order to understand and study the changes with more accuracy and decent outputs. It is an essential task to obtain the accuracy for each classification if the resulting data is to be useful in change detection analysis (Owojori and Xie, 2005). Another part that is continuing to gain attention among research workers is classification accuracy methods (Lillesand et al, 2004). The post-classification method for LULC change detection has a wide dependency on the accuracy of the results obtained through the classification of various classes. (Foody, 2002). Moreover the change map of two multi-date classified images after the classification of LULC often reveals accuracies similar to the product of multiplying the accuracies of each individual classification (Stow *et al.*, 1980; Mas, 1999). Error in the individual classifications may also be confused with change detection (Khorram, 1999) – which can lead to misinterpretation about the actual change in reality. Sometimes it is quite impossible to get ground truth or referenced data for assessing the accuracy for the classified result from the historical image data. As a result of these and many other problems which are not listed, the estimation of the accuracy of a result of the change obtained is more difficult and a challenging task when it is compared to the assessment of the accuracy of a single image classification (Congalton & Green, 1999). Furthermore there is not even a single and satisfactory method for assessing the accuracy of change detection products. The common and popular method followed for the accuracy assessment for LULC is the error matrix or confusion matrix method which can be later used for change detection and accuracy assessment (Foody, 2002). The components of change detection confusion matrix are also used for displaying individual from/to class change scenarios (Congalton & Green, 1999; Khorram, 1999). The related assessment components consists of overall accuracy, producer accuracy, user accuracy, and kappa coefficient. Studies in the past have provided the meanings and ways for the calculation of these statistical elements for judging the accuracy (Congalton 1991, Congalton and Green 1999, Foody 2002).

$$\textit{Overall Accuracy} = \frac{\textit{Number of pixels correctly classified}}{\textit{Total number of pixels}}$$

The two common approaches usually followed to assess the accuracy is by using these methods – random sampling or using referenced data. Bock *et al.* (2005) have shown the accuracy assessment by the use of random sampling method for and by means of error matrix based which is based up on the selection of random points across the classified image. Instead of using the purely random method, stratified random sampling is usually selected and recommended so that the sampling points are fairly and equally spread in each LULC change class (Congalton 1991). He also gave the valuable suggestions about the number of sample size i.e. the collection of minimum 50 samples for each class. On the other hand, accuracy assessment by considering error matrix using the reference data requires a high-accuracy LULC data with the same number of classes which cannot be obtained easily sometimes. Stanislaw Lewinski in the research studies of land use classification of ASTER image (2005) and applying fused Landsat data to object oriented classification (2006) has offered that the accuracy assessment can be performed using a method of visual interpretation according to the way adopted by CORINE Land Cover (CLC) 2000 project. The interpreter edits the edges of the objects and the codes of various classes directly on the screen simultaneously displaying the vector database and the satellite image in the background. "*As a result of this interpretation, a so-called change layer was obtained, which provided information about the correctness of the classification*" (Lewinski, 2006).

The accuracy of the classified image is fundamentally a measure of how many number of ground truth pixels were classified correctly. When looking towards the land cover map, it is important to keep it in mind that there is no map which is a perfect representation of reality. There are always possibilities of errors in the maps and we need to keep that in mind that how accurate they are, and if the level of accuracy obtained is sufficient for the in the fields we want to use the map information (Awotwi, 2009). Based on the 30-meter resolution of the LANDSAT data which is used to create a map, it is very important to remember that the map will be most accurate for displaying geographic variations over areas that are considerably large in size. The result of an accuracy assessment shows us the overall accuracy of the map based up on the average of the accuracies for each class that are taken in the map. Kappa is fundamentally used to measure the accuracy between the classification map derived through remote sensing application and the reference data that is indicated by the major diagonals and the chance agreement, which is indicated by the rows and columns total (Jensen 2003). Producer's accuracy is defined as the total number of correct pixels in a category divided by the total number of pixels of that category as extracted from the reference data. This statistics indicates the probability of a reference pixel being correctly classified and is a measure of omission error. The Kappa factor is given by the formula (Jensen 2003):

$$\textit{Kappa (K)} = \frac{P_o - P_e}{1 - P_e}$$

Where: P_o = is the proportion of correctly classified classes
P_e = is the proportion of correctly classified classes by chance

Producer's accuracy gives an idea about well a certain area can be classified (Jensen 2003). User's accuracy is derived when the total number of correct pixels in a class category is divided by the total number of pixels those were actually classified in that class category, the result is a measure of commission error. The user's accuracy or dependency is the probability of the pixel classified on the map actually whether represent that category on the ground or not (Jensen 2003).

2.8 Summary

Reading and understanding various literature of related work has revealed that the use of RS application is an important aspect and tool for studying LULC change detection. However, a careful selection of RS data has to be made considering the scope and type of actual work that has to be done. With rapid advancement in the field of RS and its applications, a number of classification techniques have been developed accordingly. Those techniques can be primarily grouped into two broad types which are fundamentally pixel based method and advance object oriented method. The preference of implementing them is fairly driven by the resolution of RS data. The advancement in RS technology has also boosted up the growing development in the field of various change detection techniques which are implemented through a number of case studies. The case studies in this regard have greatly influenced the development of new techniques. However, there has not been any single technique yet that can prove to be optimum and best. Each and every technique is equally useful in its own way and has a balance between its pros and cons. Because of the impact of complex factors and objectives, different researchers have often arrived at different conclusions about the efficiency of various methods. Although accuracy assessment is also a part of correct change detection research work but at the same time it is an active field of research nowadays. The method for classification used in this study is the supervised classification method and the accuracy assessment is obtained by taking Google Earth image as the reference image for the particular study year. The accuracy assessment tool in ERDAS Imagine has been used to calculate the accuracy of the classification, error matrix and kappa statistics.

The chapter briefly reviews the background and methods for various accuracy assessments that are most commonly used and recommended. In this chapter several aspects (fig. - 2.5.1) of related work for LULC change detection have been discussed.

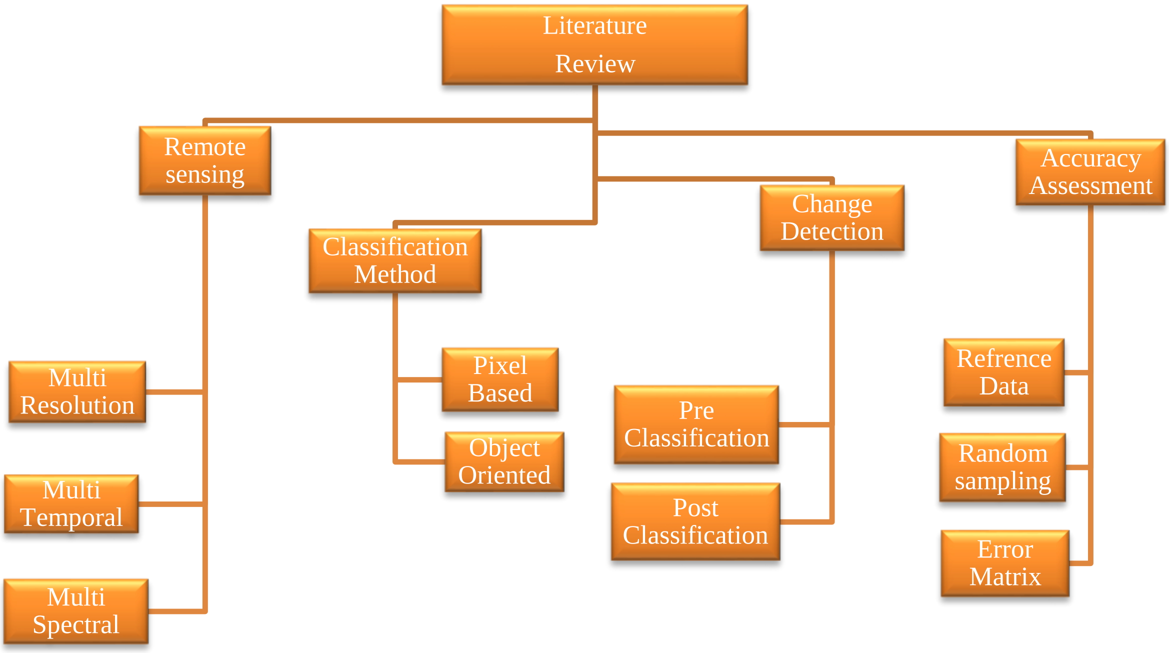


Fig. - 2.8.1: Literature review summary

Chapter 3

Study Area and Data

This chapter describes the area under study and the data obtained/used for the study. At first, precise details about the study area is given to demonstrate the features of the area in terms of geography, land use / land cover and general narrative. Then, it explains the technical details of the different kinds of data used for the study.

3.1 Study Area

3.1.1 First Area under Study: Chandigarh Metropolitan

The first area selected for the study is Chandigarh Metropolitan area or Tri-city located in the states of Punjab and Haryana in India. The Tri-city consists of three urban areas which are Chandigarh, Mohali and Panchkula. The study area is located between 30˚37'30"N to 30˚47'30"N latitudes and 76˚37'30"E to 76˚55'00"E longitudes covering 228.41 km^2 area of states of Punjab and Haryana (Fig.1). The beautiful city of Chandigarh is one of the early planned cities after the India got independence and is famous in the world for its architecture and urban design. The master plan of this city has been prepared by Swiss-French architect Le Corbusier, after bringing about certain modification in the earlier plans which has been made by the Polish architect Maciej Nowicki and the American planner Albert Mayer. Most of the public buildings and housing in the city, however, has been designed by the Chandigarh Capital Project Team which has been led by Pierre Jeanneret, Jane Drewand Maxwell Fry. In 2015, an article published by BBC awarded Chandigarh as one of the perfect cities in the world in terms of architecture, planning, cultural growth and modernization. The city has an average elevation of 321 meters (1053 ft.). The city is rich in forest and vegetation area and has few man made water bodies which still has suffient amount of water in it. Most of Chandigarh is covered by dense banyan and eucalyptus plantations. Asoka, cassia, mulberry and many other kinds of trees flourish in the forested ecosystem. The city consists of many gardens that have been developed in the recent times. Due to good amount of vegetation in the city, the city has air which is quite fresh and has less percentage of toxic gases in it.

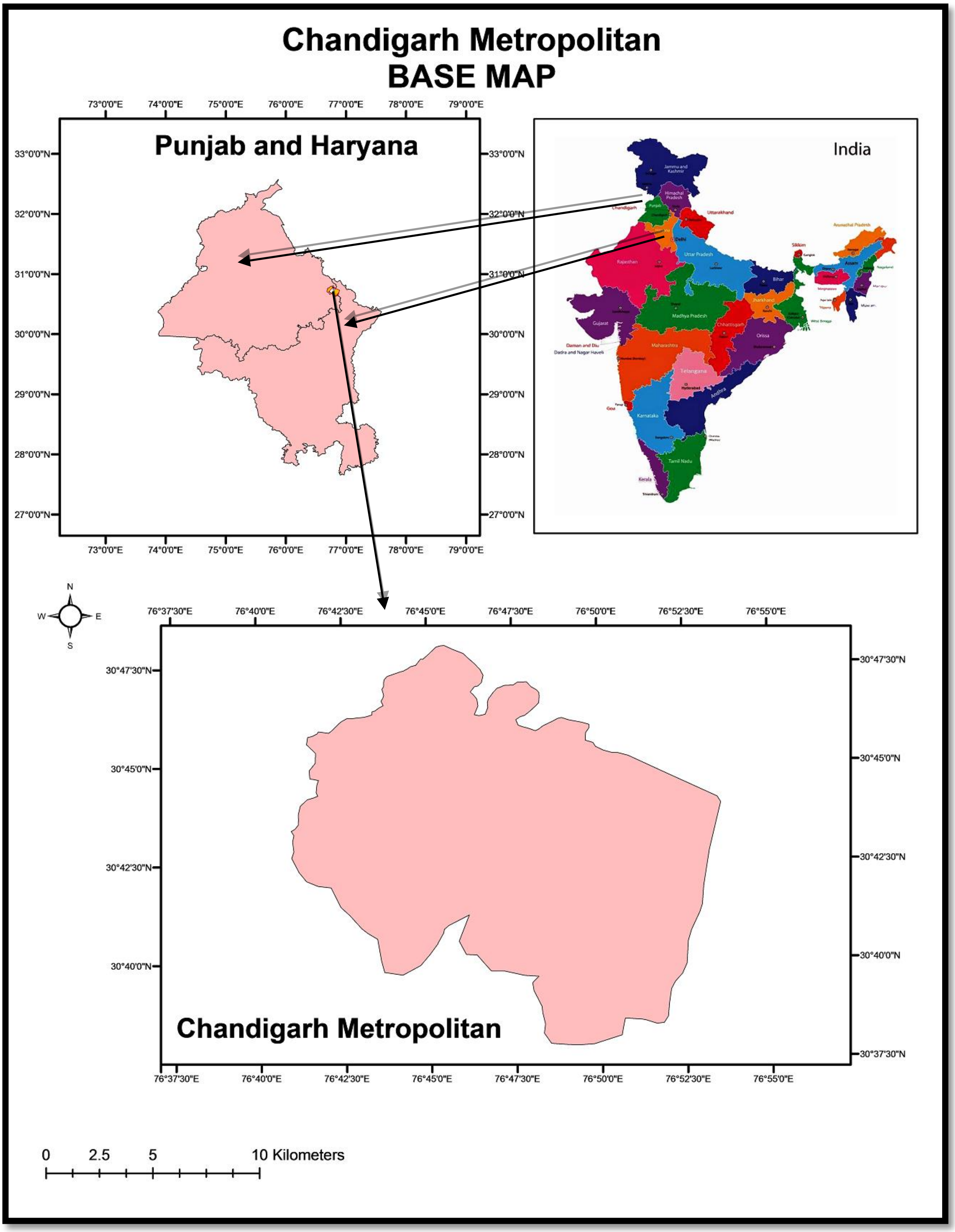


Figure 3.1.1: Location of the Study Area

3.1.2 Second Study Area: Ahmedabad City

The second area selected for the study is Ahmedabad city located in the state of Gujarat in India. It is the largest city and former capital of the Gujarat state. It is the sixth largest city of India. Ahmedabad is located on the banks of the Sabarmati River, 30 km from the state capital Gandhinagar. The area is located between 22˚55'00"N to 23˚07'30"N latitudes and 72˚22'30"E to 72˚47'30"E longitudes covering 472.64 km^2 area of state of Gujarat (Fig.2). Ahmedabad has developed as an important economic and industrial hub in India. The liberalization of the Indian economy has boosted the city's economy by increasing the scope of the activities like commerce, communication and construction. Ahmedabad's increasing population has led to the increase in the construction of new buildings and housing industries which has been led to the formation of multi-storey structures called skyscrapers. The Sabarmati has dried up oftenly in the summer season, leaving only a little stream of water, and the city is in a sandy and dry area. However with the start of the Sabarmati River Front Project and Embankment, the diversion ooof the waters has been made from the Narmada river to the Sabarmati to keep the river flowing throughout the year, thereby eliminating Ahmedabad's water scarcity problems. The gradual expansion in the area of Rann of Kutch has threatened an increase in the desertification around the corners of the city area and much of the state; however, the Narmada Canal network is expected to end such problems. In 2010, Forbes magazine published that Ahmedabad city that has shown a rapid growth in the past years in country India, and listed it as third fastest-growing in the world after the Chinese cities of Chengdu and Chongqing. The city has an average elevation of 53 meters above the sea level. The Sabarmati river, various lakes and ponds located in the city have attained water in the past years of the study. There is a significant increase the area covered by water body although the water body has showed mixed trends due to drying of the Sabarmati river in the past. Since it is a fastest growing city in the state, hence there is a remarkable increase in the construction profile of the city which includes built up and roads. Ahmedabad is divided by the Sabarmati into two regions that includes eastern and western sides. The eastern bank of the river contains the old city, which includes the central town of Bhadra. This part of Ahmedabad is covered by packed bazaars, the system of closely clustered buildings, and numerous places of worship. It has the main railway station, the main post office, and some buildings of the Muzaffarid and British times.

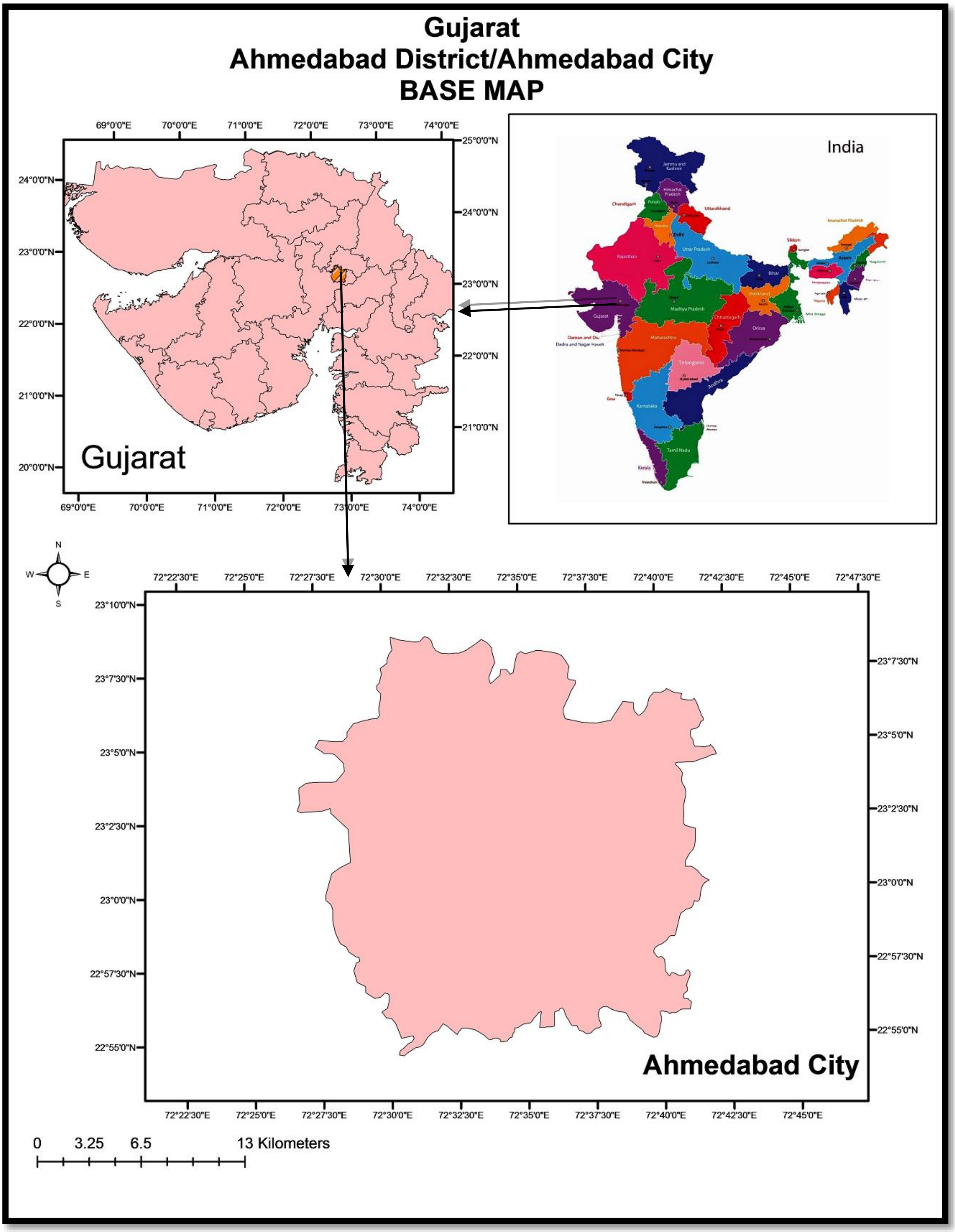


Figure3.1. 2: Location of the Study Area

3.2 Data

3.2.1 Spatial Data

There are several types of data that have been utilized for this research work which are listed in the table 3.2.1. The data generally used for such research work can be divided into two types' i.e. remote sensing data and ancillary data. In this study both remote sensing and ancillary data has been used. The satellite images have been used for classification by using remote sensing application to obtain the desired results. Apart from this, some vector data have also been used from different sources.

RS Data	Year of Acquisition	Band /Colour	Resolution	Source
Landsat TM	1991(1),1997(1),1998(2),2008(2) and 2009(1)	Multi-spectral	30 m	U.S. Geological Survey
Landsat ETM+	2003(1,2)	Multi-spectral & Panchromatic	30 m (MS) 15 m(Pan)	U.S. Geological Survey
Landsat OLI/TIRS	2013(2) and 2015(1)	Multi-spectral & Panchromatic	30 m (MS) 15 m(Pan)	U.S. Geological Survey

Table- 3.2.1: Details of the data used for study

Note* Year (1) denotes year of acquisition for Chandigarh, Year (2) for Ahmedabad and Year (1,2) for both study areas.

3.2.2 Landsat Data

The Landsat images used for the study are from three Landsat operations. The Landsat TM imagery is part of Landsat 5 mission, launched in March 1, 1984 by NASA. And the Landsat ETM+ images are part of Landsat 7 mission, launched on April 15, 1999. Lastly, Landsat OLI/TIRS images are part of Landsat 8 mission launched on February 11, 2013 *(source, NASA web).* Landsat Thematic Mapper (TM) images are charatcerisized by seven spectral bands with a spatial resolution of 30 meters for Bands 1 to 5 and 7 and spatial resolution for Band 6 (thermal infrared) is 120 meters, but has been adjusted to 30-meter pixels. Landsat Enhanced Thematic Mapper Plus (ETM+) images consists of eight spectral bands with a spatial resolution of 30 meters for Bands 1 to 7 and the resolution for Band 8 (panchromatic) is 15 meters. Landsat 8 Operational Land Imager (OLI) and

Thermal Infrared Sensor (TIRS) images consists of nine spectral bands with a spatial resolution of 30 meters for Bands from 1 to 7 and 9. New band 1 (ultra-blue) is helpful in coastal and aerosol studies. New band 9 accounts for cirrus cloud detection. The resolution for Band 8 (panchromatic) is 15 meters. Thermal bands 10 and 11 are responsible for providing more accurate surface temperatures and are collected at 100 meters.

Band	**µm**	**Resolution**	**Band**	**µm**	**Resolution**	**Band**	**µm**	**Resolution**
1	0.45-0.52	30 m	1	0.45-0.52	30 m	1	0.45-0.52	30 m
2	0.52-0.60	30 m	2	0.52-0.60	30 m	2	0.52-0.60	30 m
3	0.63-0.69	30 m	3	0.63-0.69	30 m	3	0.63-0.69	30 m
4	0.76-0.90	30 m	4	0.76-0.90	30 m	4	0.76-0.90	30 m
5	1.55-1.75	30 m	5	1.55-1.75	30 m	5	1.55-1.75	30 m
6	10.4-12.5	120 m	6	10.4-12.5	60 m	6	10.4-12.5	30 m
7	7 2.08-2.35	30 m	7	7 2.08-2.35	30 m	7	7 2.08-2.35	30 m
-			8	0.52-0.9	15 m	8	0.52-0.9	15 m
-			-			9	1.36 - 1.38	30 m
-			-			10	10.60 - 11.19	100 * (30)
-			-			11	11.50 - 12.51	100 * (30)

Table- 3.2.2: Bands of Landsat TM (left), ETM+ (middle) and OLI/TRIS (Right) (source, NASA web)

The technical details of Landsat TM and Landsat ETM+ bands have been given in the table- 3.2.2. For other specification; refer to the official portal of Landsat (Landsat Program, NASA web).

3.2.3 Ancillary Data

In general, ancillary data is used facilitate many targets including geometric correction of the remote sensing data and also to extract some base layers like road, railways, contour etc. In the present study, the type of data that have been used is discussed further. The thematic layers/Vector data have been used for delineating the study area, creating the area of interest (AOI). Those layers are mainly administrative boundaries of Chandigarh and Ahmedabad cities of India in shapefile format. All those shapefiles are capable of getting imported into GIS software so as to obtain proper reference system with required non-spatial attribute data. Some of the data from sources other than remote sensing have also been used to support the classification, to assist in image processing and to assemble the metadata as well. The shape file of the study areas has been obtained from DIVA-GIS. DIVA-GIS has been developed by Robert Hijmans. Previous versions were co-developed with Edwin Rojas, Mariana Cruz, Rachel O'Brien, and Israel Barrantes.

It is also important to mention that Google map and Google Earth have been used frequently whenever some confusion arose regarding the assigning of classes for land use / land cover type. As we know Google Maps is a free web mapping service application and technology provided by Google. It is also a fine source of high-resolution satellite images for most of the areas that are covered under urban and rural category. Another related product called Google earth - is a virtual globe and map which provides geographic information about a particular area. It maps the earth by superimposing the images obtained from satellite imagery, aerial photography and GIS 3D globe (source: Wikipedia). It is suggested to check the classified data from remote sensing images using Google Earth. The land use / land cover data obtained can be easily superimposed upon high resolution images used by Google Earth in order to check and compare the accuracy of the classes assigned to the classified images.

3.2.4 Population Data

The population data for both the cities has been obtained from the Census of India and the data furnished my Municipal Corporation of the cities under study. The population of the Chandigarh Metropolitan area has been calculated by adding up the population of individual city which are Chandigarh, Mohali and Panchkula. The tables listed below explains the growth of population in Chandigarh city from 1901 to 2021 although the population of 2021 is predicted by Department of Urban Planning, Chandigarh.

Chandigarh Population Growth (1901-2021)		
Year	Population	Percentage Increase
1901	21967	
1911	18437	-16.07%
1921	18133	-1.65%
1931	19783	9.10%
1941	22574	14.11%
1951	24261	7.47%
1961	119881	394.13%

1971	257251	114.59%
1981	451610	75.55%
1991	642015	42.16%
2001	900635	40.28%
2011	1054686	17.10%
2016	1165565	10.51%
2021	1950000	67.30%

Table- 3.3.1, Source: Census of India and Department of Urban Planning, Chandigarh

Population Data for the Mohali city and Panchkula Urban Estate has also been obtained so as to calculate the total population of the metropolitan area.

Name	**District**	**City of Growth**	**Population Census 3/1/1991**	**Population Census 3/1/2001**	**Population Census 3/1/2011**
S.A.S. Nagar	Mohali	S.A.S Nagar	70,375	140,925	211,355
Panchkula Urban Estate	Panchkula	Panchkula Urban Estate	78,457	123,484	146,213

Table- 3.3.2 Source: Office of the Registrar General and Census Commissioner (web), Delimitation Commission of India (web)

However, the population of Ahmedabad city has a record since 1881. The record has been used to get the more accurate results through various curve fitting equations so as to obtain the population of the year corresponding to the period of Landsat images.

Ahmedabad population growth (1881-2021)		
Year	Population	Percentage Increase
1881	127,621	
1891	148,412	16.29%
1901	185,889	25.25%
1911	216,777	16.62%
1921	274,007	26.40%
1931	382,768	39.69%
1941	591,267	54.47%

1951	837,163	41.59%
1961	1,149,918	37.36%
1971	1,585,544	37.88%
1981	2,059,725	29.91%
1991	2,876,710	39.66%
2001	3,520,085	22.36%
2011	5,577,940	58.46%
2021	8,800,000	57.76%

Table- 3.3.3, Source: Census of India and AUDA, Ahmedabad

Chapter 4

The Methodology Adopted

In this chapter, the methodology that has been followed for the study is explained in a precise manner. This research is a study based upon the technique of digital image processing using a case study to attain the expected result in order to give solution to the specific research problems. As a first step towards the research, the information is extracted by digital image processing using the remote sensing (RS) data. There are quite a number of techniques that are available for better extraction of data from various sources of RS consisting of simple visual interpretation of aerial photographs to complex automatic digital interpretation using various procedures that have been developed in the recent times. These techniques are affected by several technical factors including resolution and type of the image, specific information to be extracted, the purpose of the study and accuracy requirements which are worth mentioning. Supervised method of image classification along with required preprocessing; enhancement and post-classification analysis for change detection have been utilized for the whole study. The following flow chart describe the various steps (fig. - 4.1) of the present study.

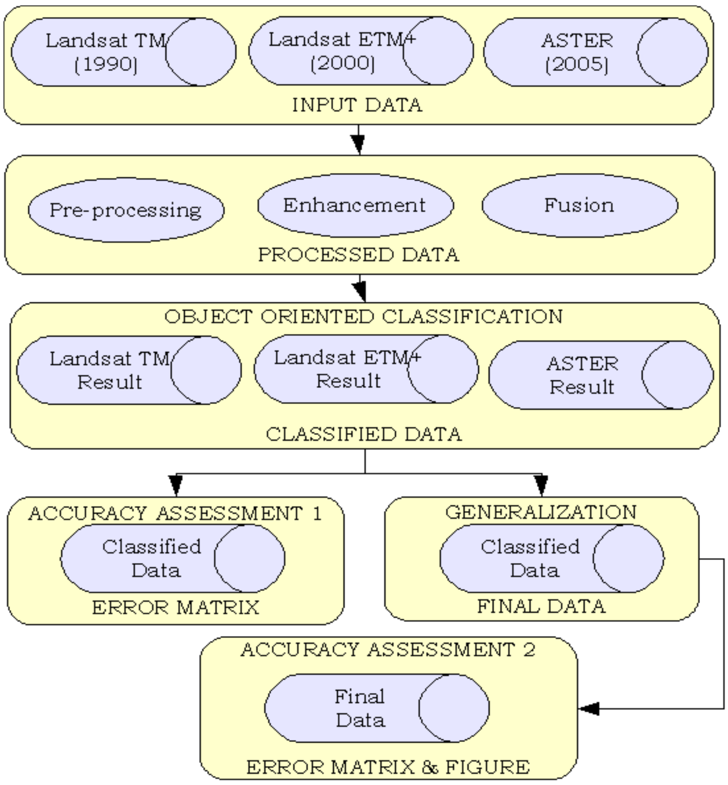


Fig. - 4.1: Flow Diagram for proposed methodology

4.1 Image Pre-processing

The Pre-processing of the image is done before doing the classification of the RS data as it is important to pre-process the data so as to correct the error caused due to scanning, transmission and recording of the data. It is related to the functions which are frequently performed to improve the qualities of the images which are geometric and radiometric in nature. Generally, the pre-processing consists of following steps; (i) radiometric correction to reduce the effect of atmosphere (ii) geometric correction which includes registration of the image so it can be used with other maps or images of the reference system that has been applied to it, and (iii) removal of any type of unwanted noise unwanted due occurring while the transmission and recording processes. In this study, the radiometric correction has not been adopted due to the reason that all the data used for the study were already corrected to some extent.

In the present study all the images have been obtained from the U.S. Geological Survey website. Hence, the data obtained is already geo-referenced by the source in UTM WGS 84 system. The vector data/shape file of the Ahmedabad city has been obtained by geo-referencing the image earlier in jpeg format from the Ahmedabad Municipal Corporation. The geo-referencing has been done by taking 24 GCP on the image to be geo-referenced comparing with the FCC image obtained by layer stacking of the individual bands. However, the qualities of all other images are good so the image enhancement hasn't been used in this study but still it is discussed in the other section of the chapter.

4.2 Image Enhancement

Image enhancement is a process which involves the techniques to improve the visual distinction among the features or classes established in the image. Image enhancement changes the value of the pixel of the image and therefore the image enhancement process is followed after the completion of the pre-processing step. The choice of enhancement technique entirely depends on the features that are to be extracted from the image. One of the most common methods that has been in practice is the simple contrast stretching technique. There are several other methods also available for contrast stretching. It has been found that linear stretching and histogram equalization are the suitable ones for this purpose.

4.3 False Colour Composite

After acquiring the data from the online source provided my U.S. Geological survey, before the classification process, the FCC image of the raw data has to be prepared. The data obtained from the online source is in TIFF format. The data of the study area consists of TIFF files of 7 bands if the data obtained is from Landsat 5, 8 bands in case of Landsat 7 and 11 bands in case of Landsat 8. Hence, it is essential to create a FCC of the study area by the process of layer stacking. This process is usually done in ERDAS Imagine. The file obtained after the process of layer stacking is in IMG format. After creating the FCC, the AOI can be extracted from the FCC layer by the process of subset image after imposing the shape file on the same layer. The resultant image is in the same format and it shows the area that is to be studied and worked upon.

Moreover, there are various techniques of image fusion (sometimes called merging or sharpening) that have been developed by scientists and software vendors. The most common of them are IHS (Intensity-Hue- Saturation), HPF (High Pass Filter), Colour Normalized, PC (Principal Component) Spectral, etc. Examples of using such methods have been found in various literature and case studies although in each case, analyst explains their own logic to use specific type of image fusion. However, after studying and understanding several literature and books, it has been observed that the most widely used and affective methods for this purpose are HIS (Intensity-Hue-Saturation) and HPF (High Pass Filter) image fusion. However, PC method has not been adopted even though it has been used as an enhancement for better classification later on. The image fusion techniques have not been used in this study but still it is discussed in the chapter so as to provide knowledge about the same.

The FCC of the study areas obtained has been obtained by stacking 6 bands from 1 to 7 excluding the 6th one as this band is not of any importance for this study. Every band has a different interpretation and denotes different classes for the image.

Band	**Wavelength**	**Useful for mapping**
Band 1 - blue	0.45 - 0.52	Distinguishing soil from the vegetation and deciduous from the coniferous vegetation
Band 2 - green	0.52 - 0.60	Emphasizes peak vegetation, which is useful for the assessment of plantation
Band 3 - red	0.63 - 0.69	Discriminates vegetation slopes
Band 4 - Near Infrared	0.77 - 0.90	Emphasizes on biomass content and shorelines
Band 5 - Short-wave Infrared	1.55 - 1.75	Discriminates moisture content present in soil and vegetation; penetrates thin clouds
Band 6 - Thermal	10.40 - 12.50	Thermal mapping and estimated soil

Infrared		moisture
Band 7 - Short-wave Infrared	2.09 - 2.35	Hydrothermally altered rocks associated with mineral deposits
Band 8 - Panchromatic (Landsat 7 only)	0.52 - 0.90	15 meter resolution, sharper image definition

Table 4.3.1: Landsat 4-5 Thematic Mapper (TM) and Landsat 7 Enhanced Thematic Mapper Plus (ETM+)

Band	Wavelength	Useful for mapping
Band 1 – coastal aerosol	0.43 - 0.45	coastal and aerosol studies
Band 2 – blue	0.45 - 0.51	Distinguishes soil from vegetation and deciduous from coniferous vegetation
Band 3 - green	0.53 - 0.59	Emphasizes peak vegetation, which is useful for the assessment of plantation
Band 4 - red	0.64 - 0.67	Discriminates vegetation slopes
Band 5 - Near Infrared (NIR)	0.85-0.88	Emphasizes biomass content and shorelines
Band 6 - Short-wave Infrared (SWIR) 1	1.57 - 1.65	Discriminates moisture content present in soil and vegetation; penetrates thin clouds
Band 7 - Short-wave Infrared (SWIR) 2	2.11 - 2.29	Improved moisture content present in soil and vegetation and thin cloud penetration
Band 8 - Panchromatic	0.50 - 0.68	15 meter resolution, sharper image definition
Band 9 – Cirrus	1.36 - 1.38	Improved detection of cirrus cloud contamination
Band 10 – TIRS 1	10.60 – 11.19	100 meter resolution, thermal mapping and soil moisture
Band 11 – TIRS 2	11.5 - 12.51	100 meter resolution, Improved thermal mapping and estimated soil moisture

*Table 4.3.2**:** Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS)*

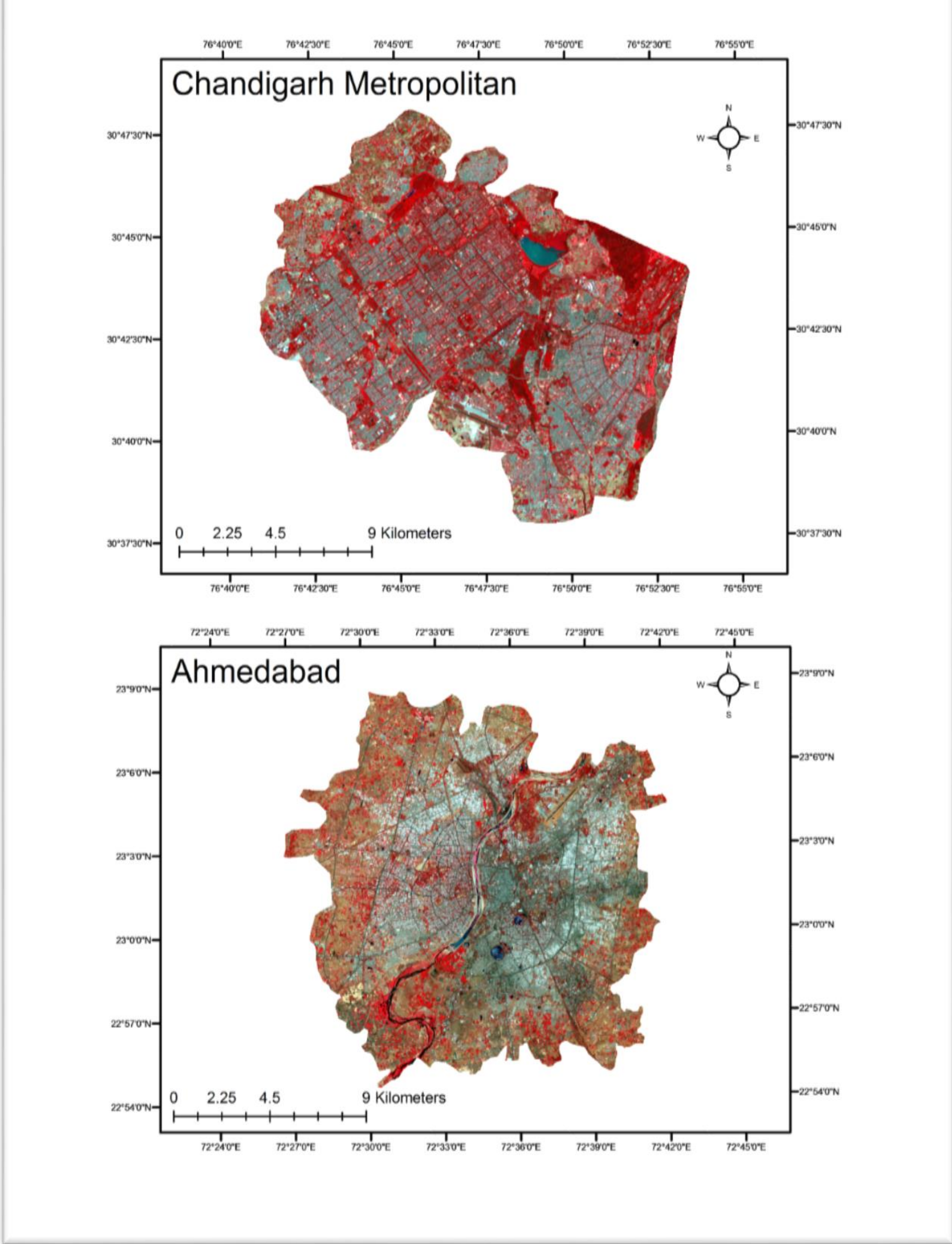


Fig. - 4.3.1: FCC images of Chandigarh and Ahmedabad for year 2015 and 2013

4.4 Image Classification to obtain Land use / Land cover

Image classification is a kind of technique which is the used in many remote sensing applications for the extraction of thematic information of the study area. In the present study, the land use / land cover (LULC) is the main ‘subject ‘that has to be extracted using a suitable classification method for LULC change detection. Basically, the classification of an image consists of a mapping process to accumulate the image pixels into significant groups each denoting different class for different land category (Jensen, 1995). The classification process requires a classification system which is a specifically designed algorithm for the application purpose because it mainly varies upon the objective and type of the work.

The most common method used for RS image classification is pixel based method which includes the process in which the classifier examine different pixel values and group them into different classes which is compeltly based on their spectral properties. This practice is based on statistical techniques such as supervised and unsupervised classification where the classes are supervised by the analyst and non-supervised (i.e. fully automatic based on spectral values) respectively. The benefit of the traditional pixel based image classification proves very efficient especially in case of the satellite images of low resolution.

In this study, the classification method used is Supervised Classification method. As discussed above, in this method the analyst groups different pixels in different classes accordingly.

4.5 Supervised Classification Method

In the supervised classification method, identification of the Information classes (i.e., land cover type) of interest in the image is done. These are known as Training Sites. The image processing software, ERDAS used in this study is then used to develop a statistical characterization of the reflectance values for each information class. This stage is often called signature analysis/signature editor and may involve developing a characterization which is as simple as the mean or the rage in which the reflectance values lies on each bands, or as composite as detailed analysis of the mean, variance and covariance over all bands. Once the statistical characterization has been achieved for each class, the image is then classified by inspecting the reflectance for each pixel and making a decision about which of the signatures it resembles the most. (Eastman, 1995).

Supervised Classification includes Select training area, Generate signature and File Classify. The following figure shows the steps involved in supervised classification in a simple way.

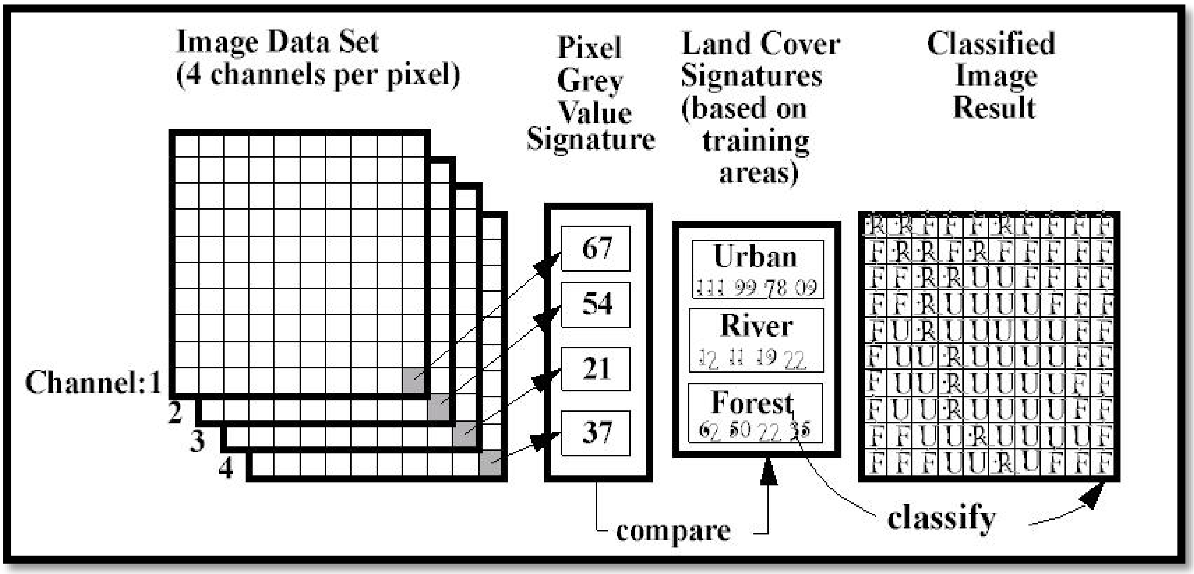


Fig. - 4.5.1: Steps involved in Supervised Classification Method

The LULC of the study area has been prepared by taking following classes to distinguish between different pixels in the FCC image.

Class	Description
Built Up and Roads	Man-made construction which includes buildings and transportation
Water Body	Rivers, Lakes, Ponds and Lagoons.
Forest and Plantation	Forest area includes tress, dense vegetation and plantation includes agriculture , grasslands, etc.
River and Lake Bed	Beds of river or lakes that have become dry due to less rainfall or improper human activities
Fallow Land	Includes land which is left after cultivation
Bare Land	Open grounds or lands which doesn't account for agriculture or cultivation.

Table 4.5.1: Different classes with their description

4.6 Accuracy Assessment

The accuracy assessment of the classified images have been achieved with the help of a tool called accuracy assessment tool in the ERDAS Imagine software. Since the data used in this study belongs to the past, hence ground truth cannot be obtained so as to obtain referral points. In this study Google Earth has been used as a referral platform by comparing the random points taken on the classified image with the Google Earth image of that period. The points get equally and randomly distributed on the classified image. The viewer in ERDAS can be linked with the Google Earth and the reference class can be assigned the same class if it shows the same feature when scrolled on Google Earth.

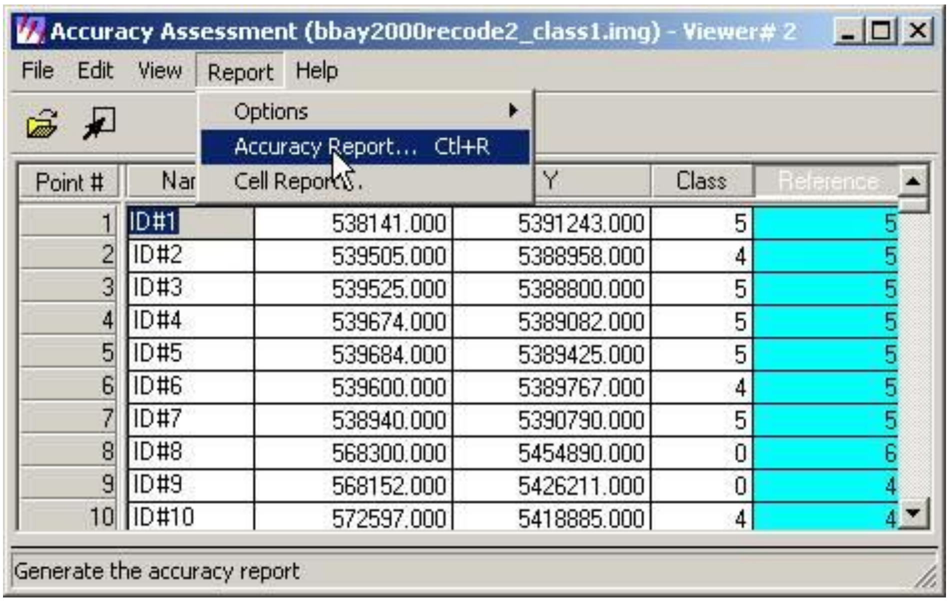
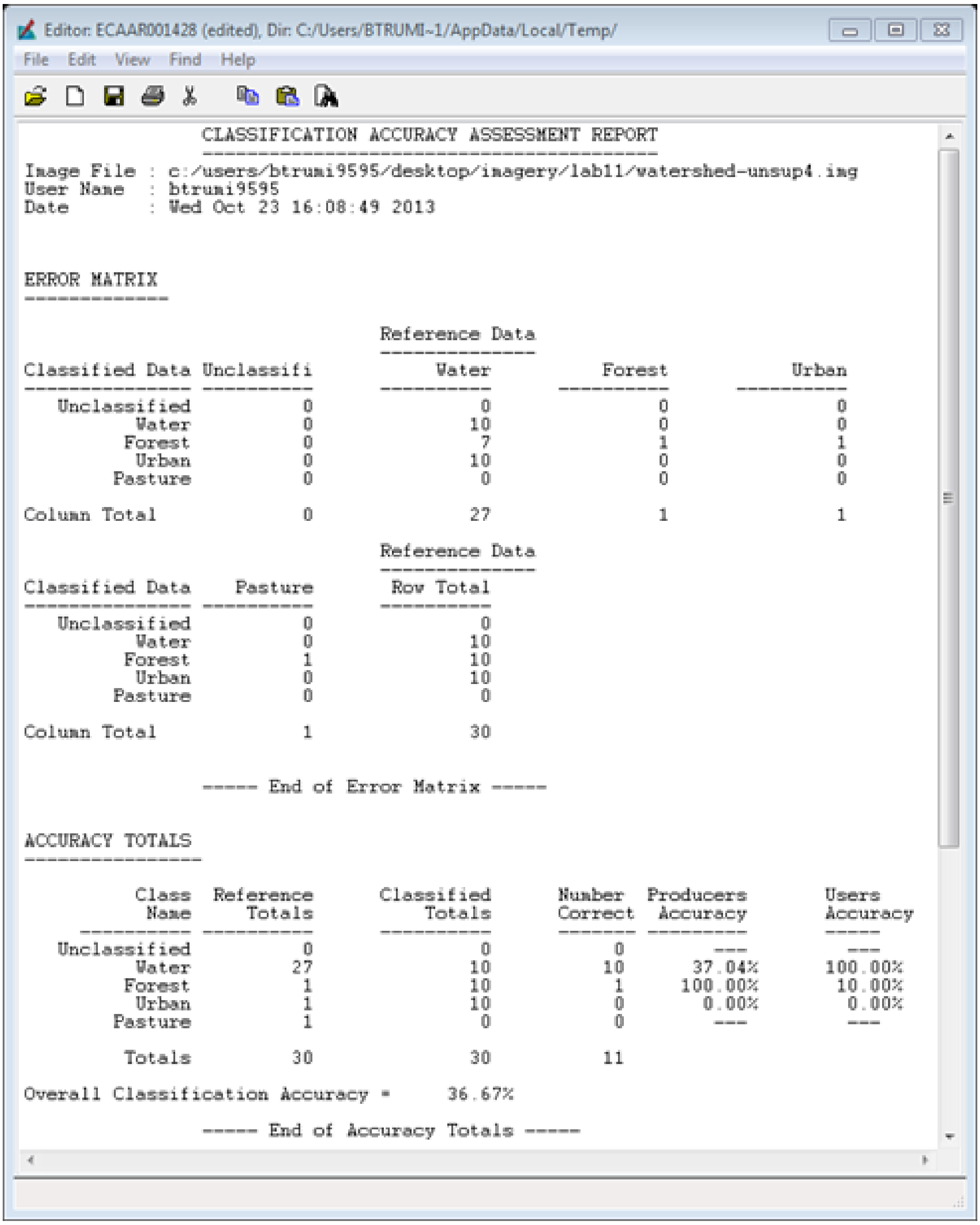


Fig. - 4.6.1: Accuracy assessment tool in ERDAS Imagine

The accuracy afterwards can be obtained by clicking the accuracy report as highlighted in the figure 4.4. The accuracy report is generated which consists of the producer's and user's accuracy along with the error matrix and kappa statistic. A sample accuracy report has been shown in the figure 4.6.2 which shows a combine report of error matrix, accuracy report and kappa coefficient.



Editor: ECAAR001428 (edited), Dir: C:/Users/BTRUMI~1/AppData/Local/Temp/

File Edit View Find Help

CLASSIFICATION ACCURACY ASSESSMENT REPORT

Image File : c:/users/btrumi9595/desktop/imagery/lab11/watershed-unsup4.img
User Name : btrumi9595
Date : Wed Oct 23 16:08:49 2013

ERROR MATRIX

Reference Data

Classified Data	Unclassifi	Water	Forest	Urban
Unclassified	0	0	0	0
Water	0	10	0	0
Forest	0	7	1	1
Urban	0	10	0	0
Pasture	0	0	0	0
Column Total	0	27	1	1

Reference Data

Classified Data	Pasture	Row Total
Unclassified	0	0
Water	0	10
Forest	1	10
Urban	0	10
Pasture	0	0
Column Total	1	30

----- End of Error Matrix -----

ACCURACY TOTALS

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Unclassified	0	0	0	---	---
Water	27	10	10	37.04%	100.00%
Forest	1	10	1	100.00%	10.00%
Urban	1	10	0	0.00%	0.00%
Pasture	1	0	0	---	---
Totals	30	30	11		

Overall Classification Accuracy = 36.67%

----- End of Accuracy Totals -----

Fig. - 4.6.2: Accuracy assessment report sample in ERDAS Imagine

Chapter 5

Results and Discussion

This chapter consists of land use/land cover distribution maps and percent area covered, land use/land cover changes occurring between different periods, accuracy report of the classified images and various graphs showing the changes occurring in the featured classes with the change in time. The relation of population with the built up area has also been discussed in this chapter. Population for the year corresponding to the period of Landsat images have been obtained by using curve fitting equations using Microsoft excel.

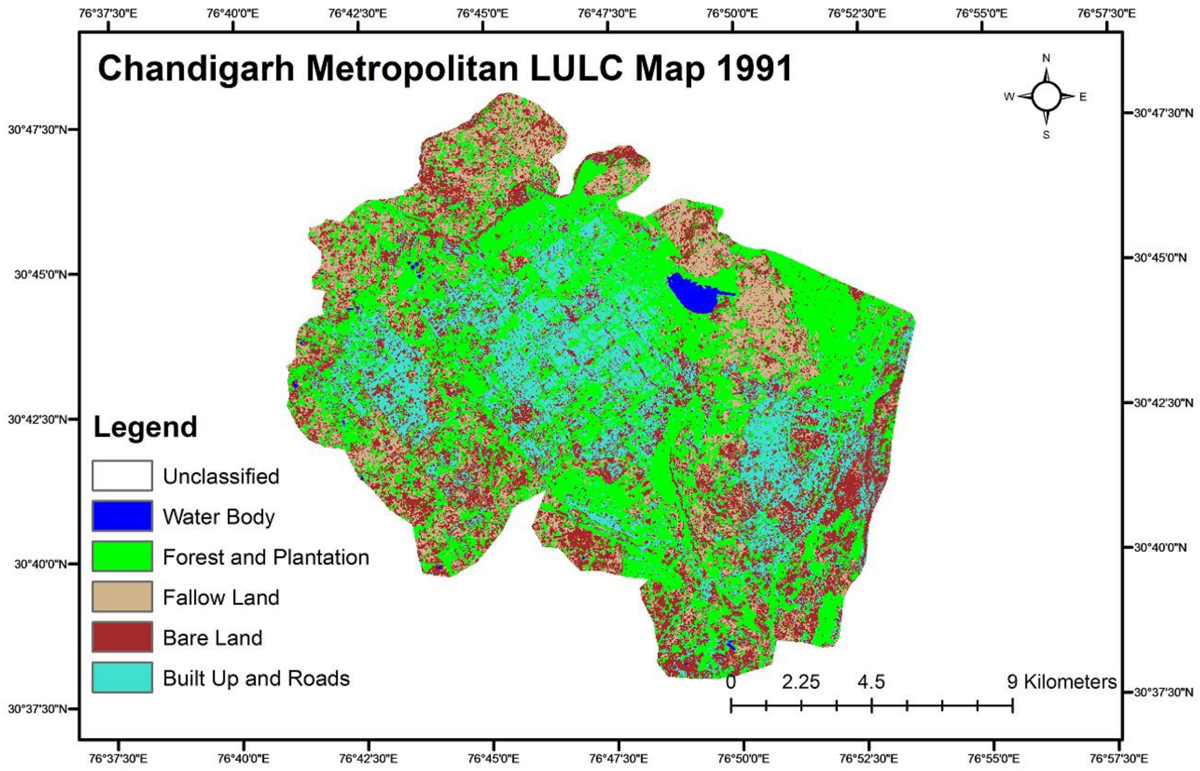
5.1 Classified Images and Maps Outputs

5.1.1 Chandigarh Metropolitan

The LULC distribution maps and area coverage in percentage for the Chandigarh Metropolitan area have been shown in this chapter from figure 5.1 to 5.5. The graphs that have been shown in this section displays the percentage area in that particular year for different classes. The total study area for this city is 228.40 km^2 which includes different categories of classes. The classes for this area are built up and roads, water body, forest and plantation, bare land and fallow land. Different classes have been displayed along the classified image with different colours assigned to them.

The classified images are provided with geometric coordinates which denotes the actual position of the study area in the world. There is no compromise with the quality of the exported image and hence all the data is clearly visible. The different colors have been assigned keeping it in mind that the contrast among each class has a clear and distinguishing property.

The accuracy assessment result report of each classified image has been discussed at the end of this chapter. Various tables showing the area in each class in hectares for each study year has also been tabulated and displayed in this chapter. Similarly the classified images along with the graph for the second study area which is Ahmedabad is shown in the later section of this chapter.



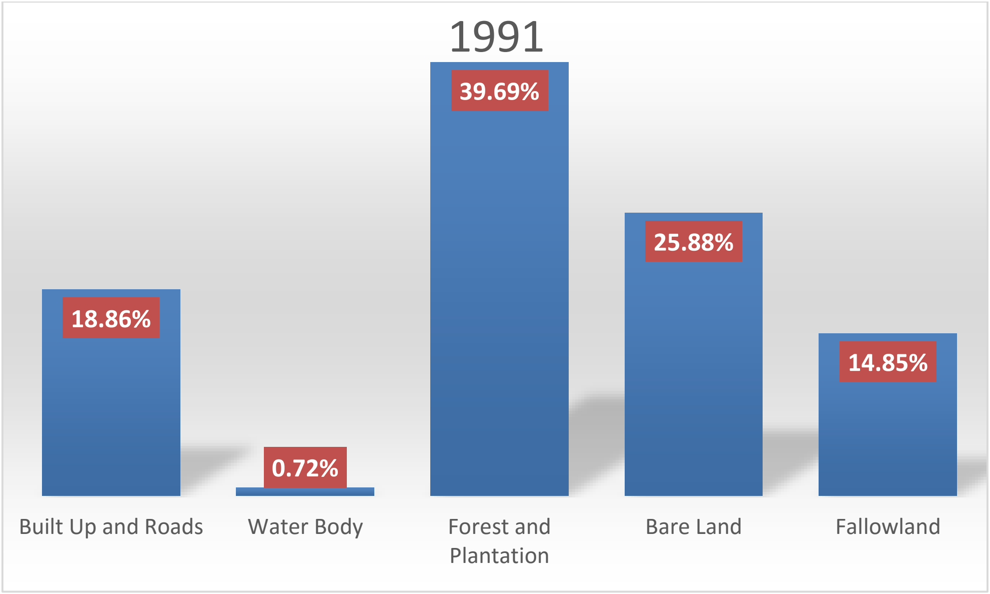
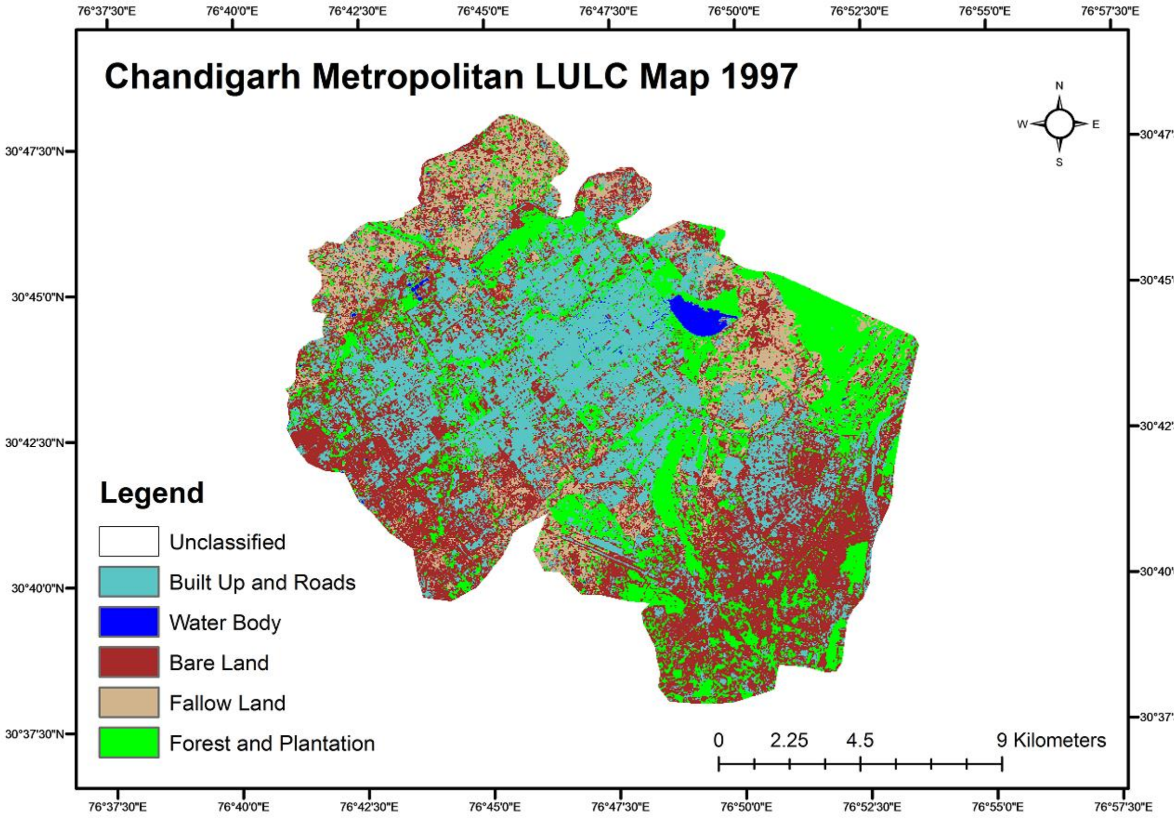


Fig. – 5.1: Land use/Land cover map for Chandigarh 1991



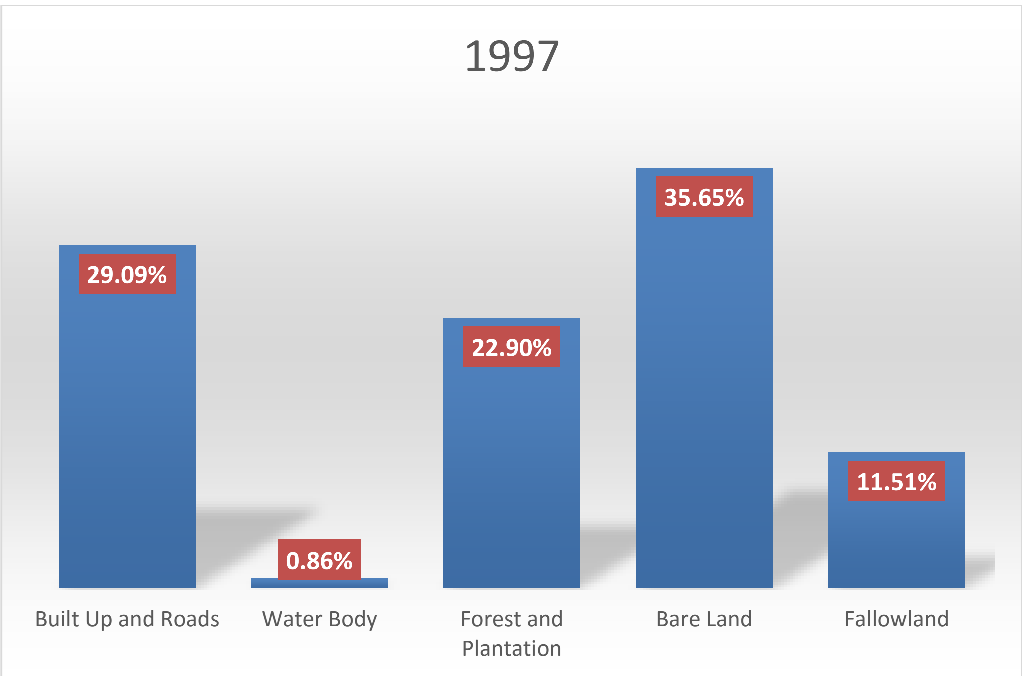
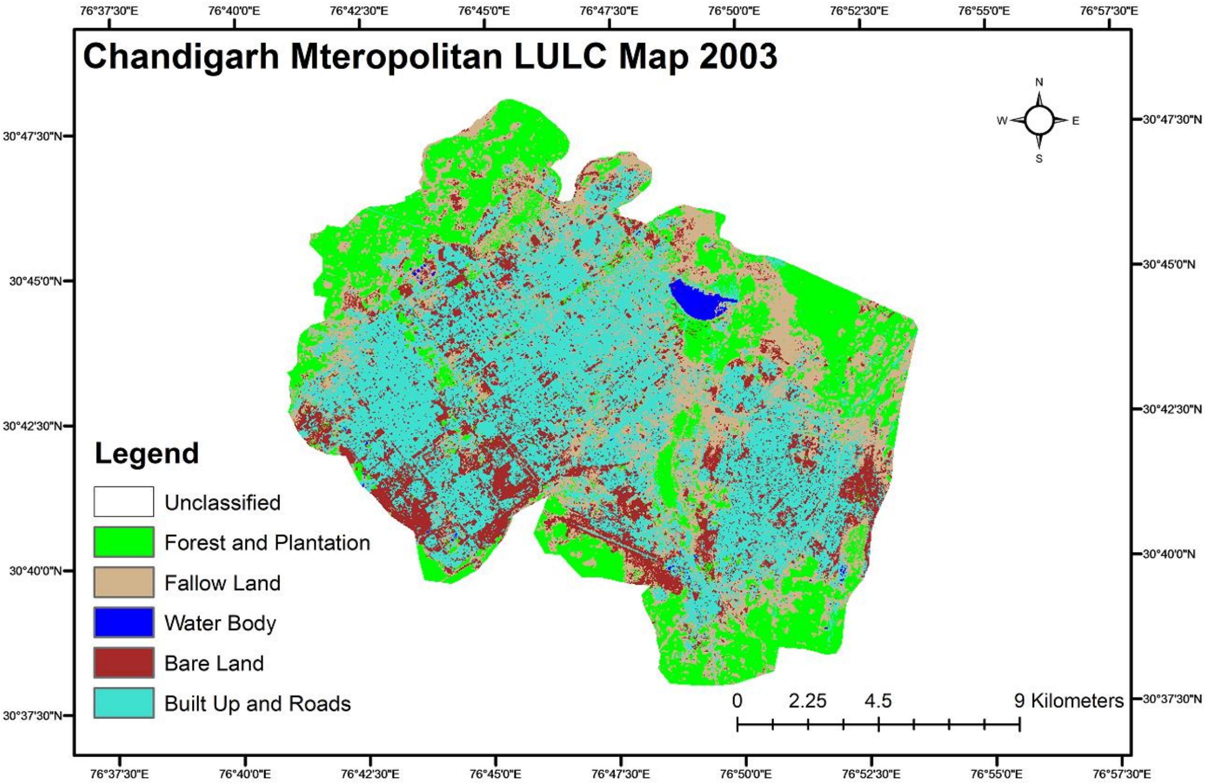


Fig. – 5.1.2: Land use/Land cover map for Chandigarh 1997



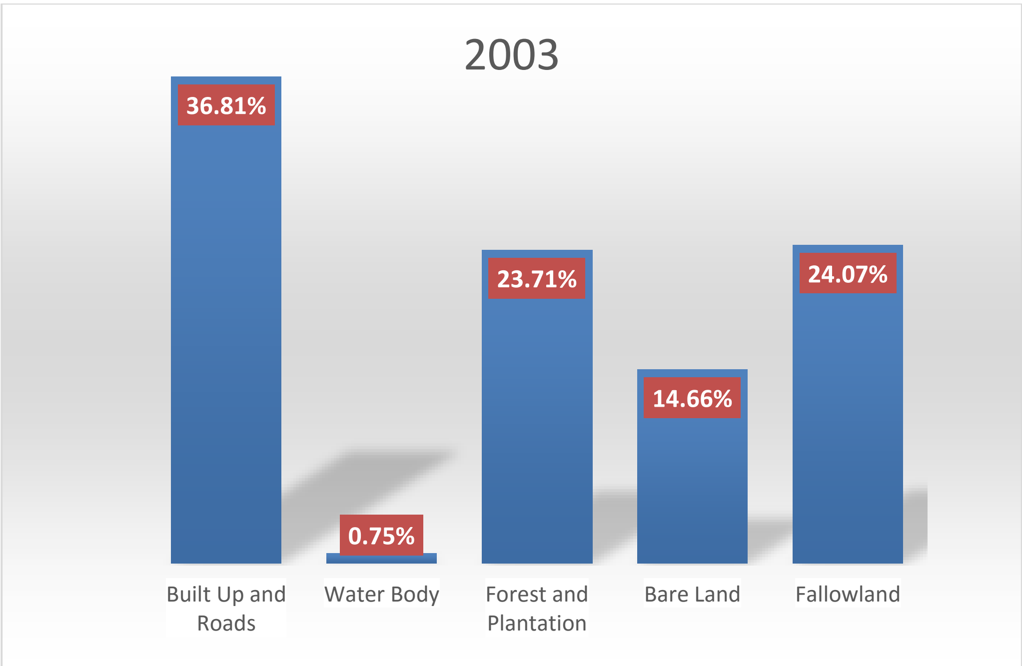
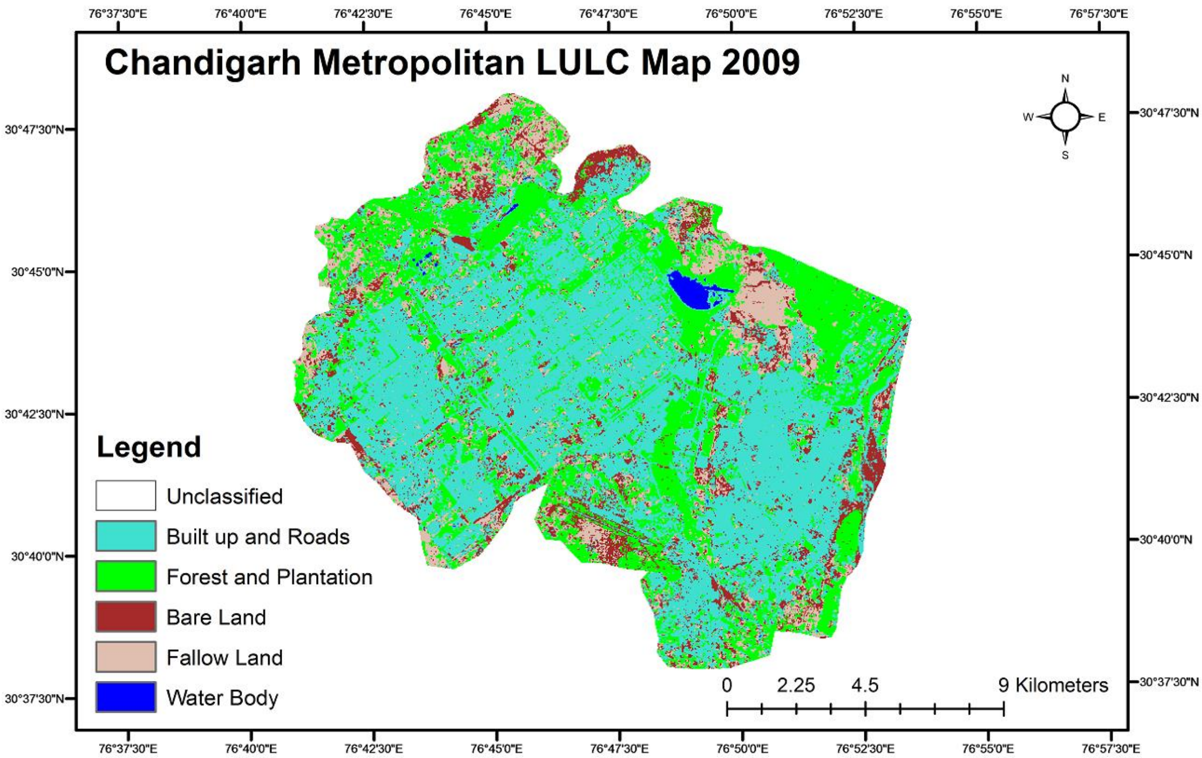


Fig. – 5.1.3: Land use/Land cover map for Chandigarh 2003



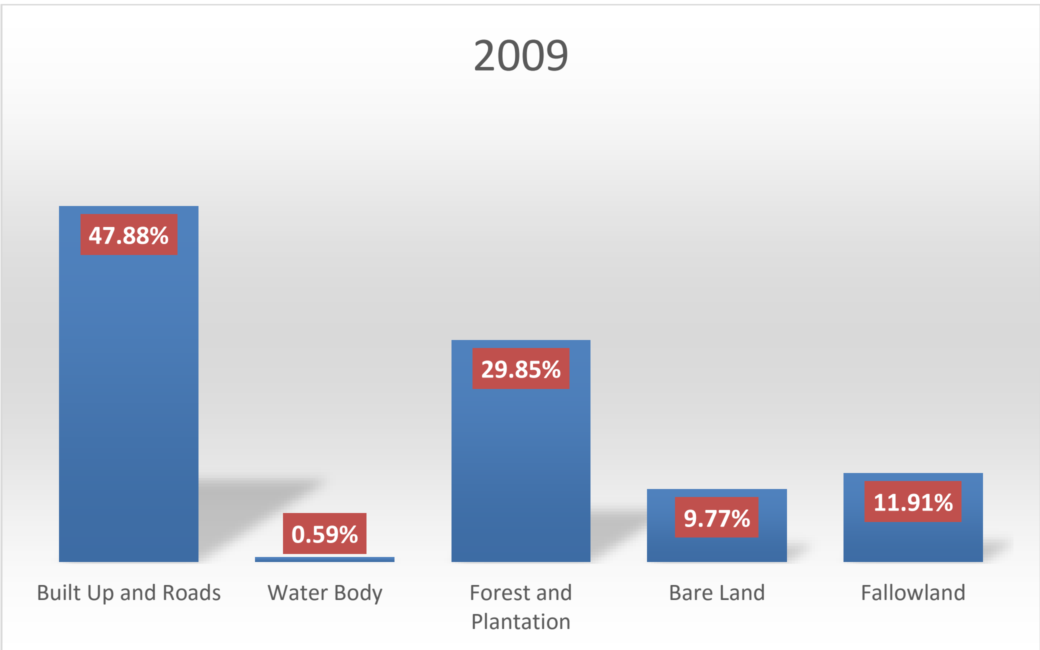
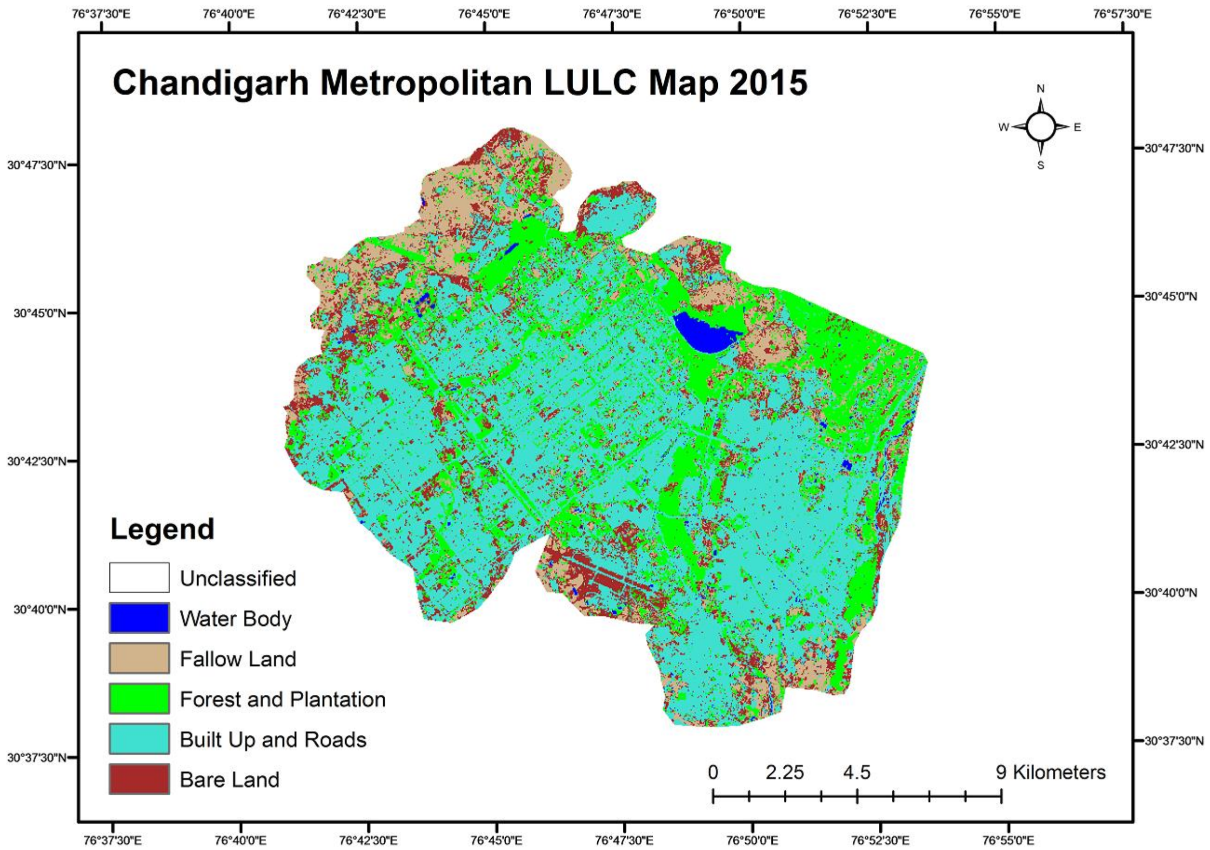


Fig. – 5.1.4: Land use/Land cover map for Chandigarh 2009



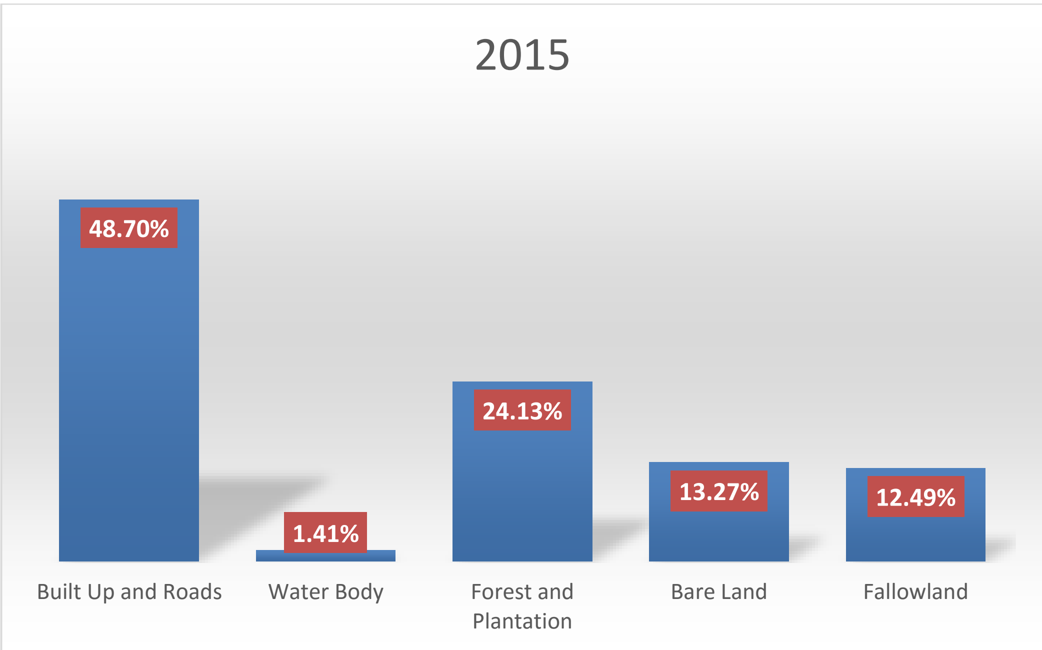
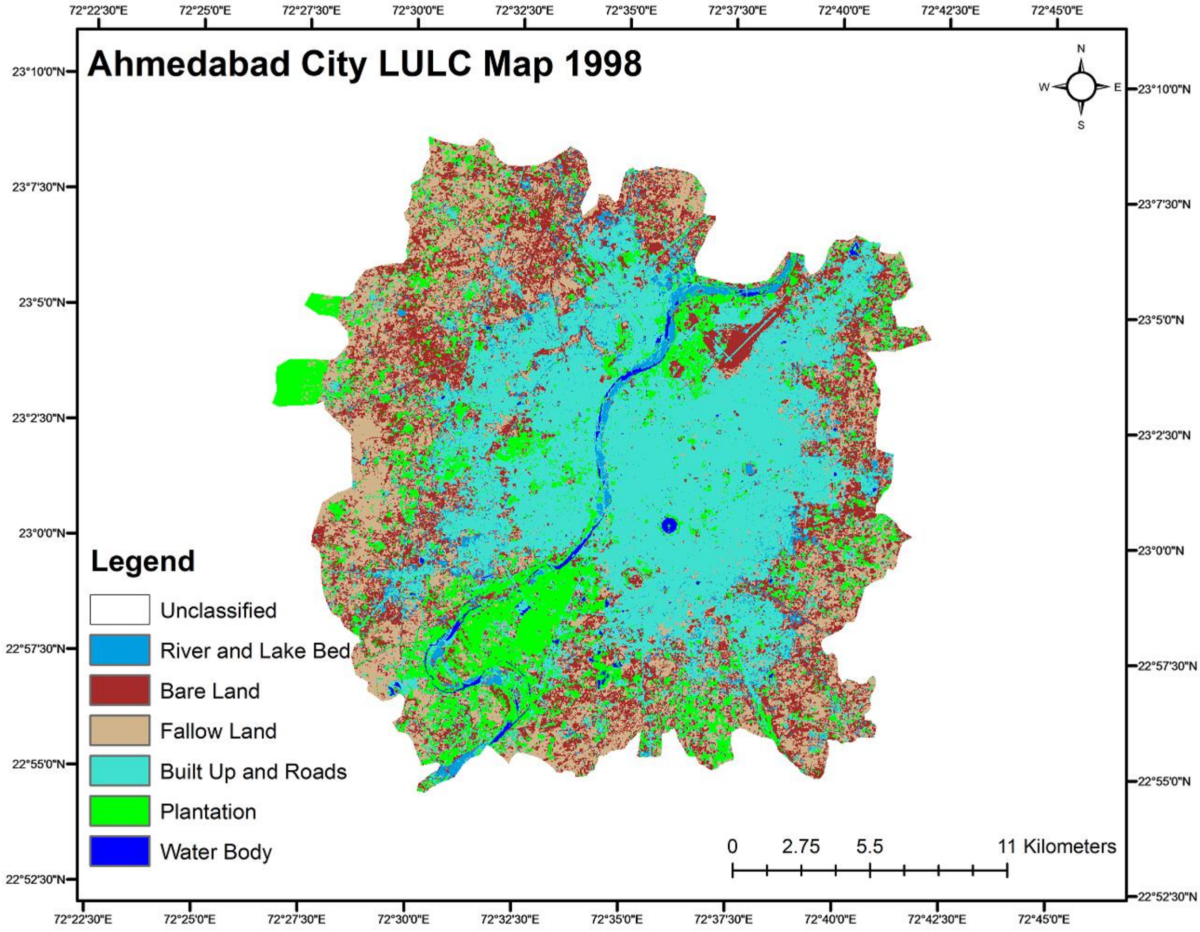


Fig. – 5.1.5: Land use/Land cover map for Chandigarh 2015

5.1.2 Ahmedabad City

The LULC distribution maps and area coverage in percentage for the Ahmedabad city area have been shown in this chapter from figure 5.6 to 5.9.



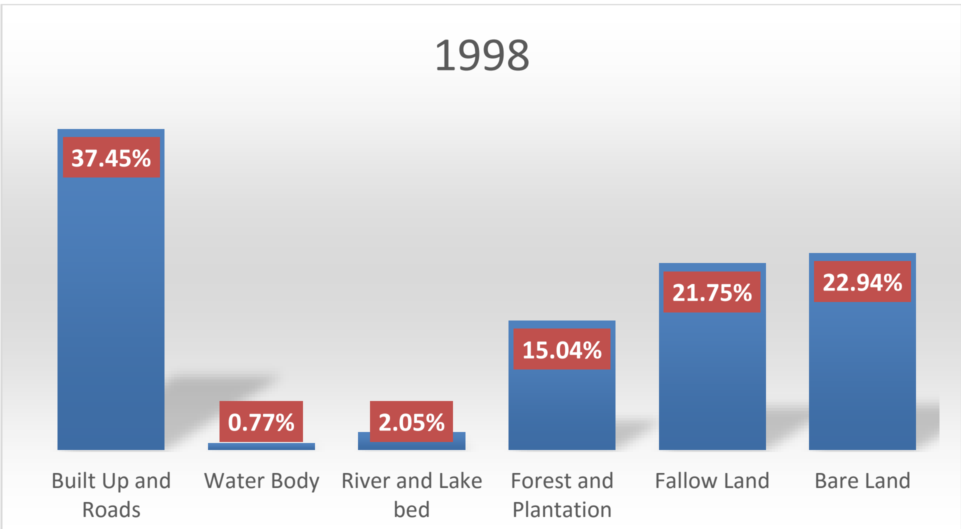
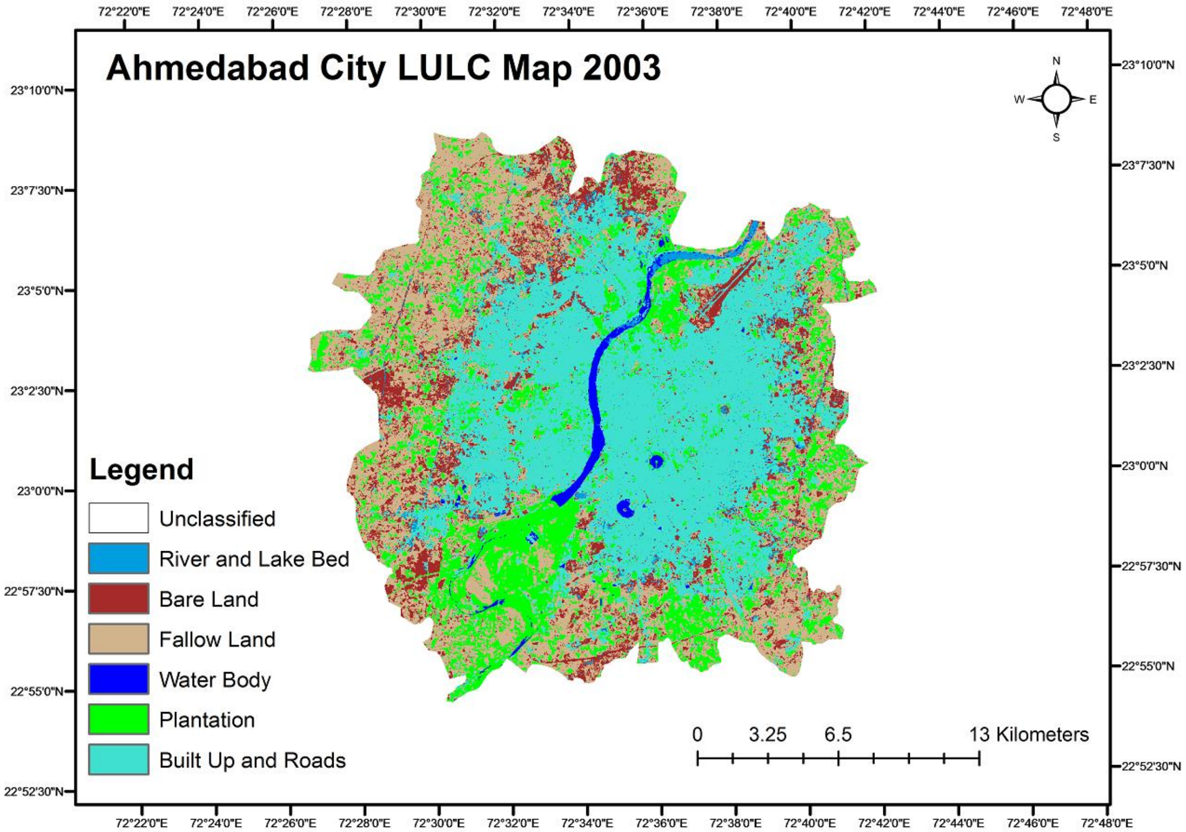


Fig. – 5.1.6: Land use/Land cover map for Chandigarh 2015



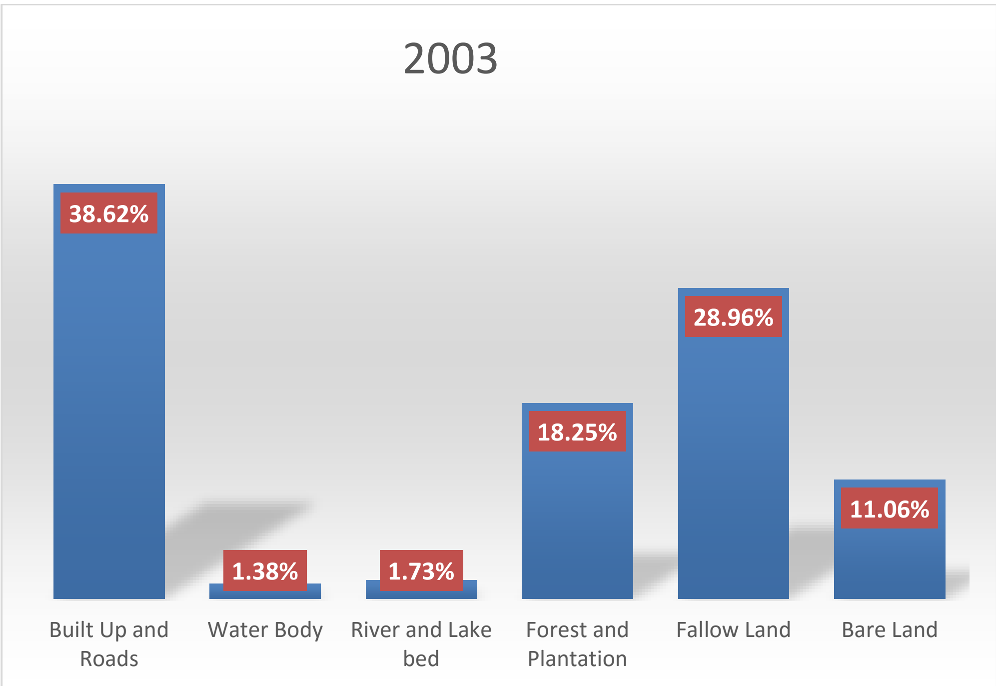
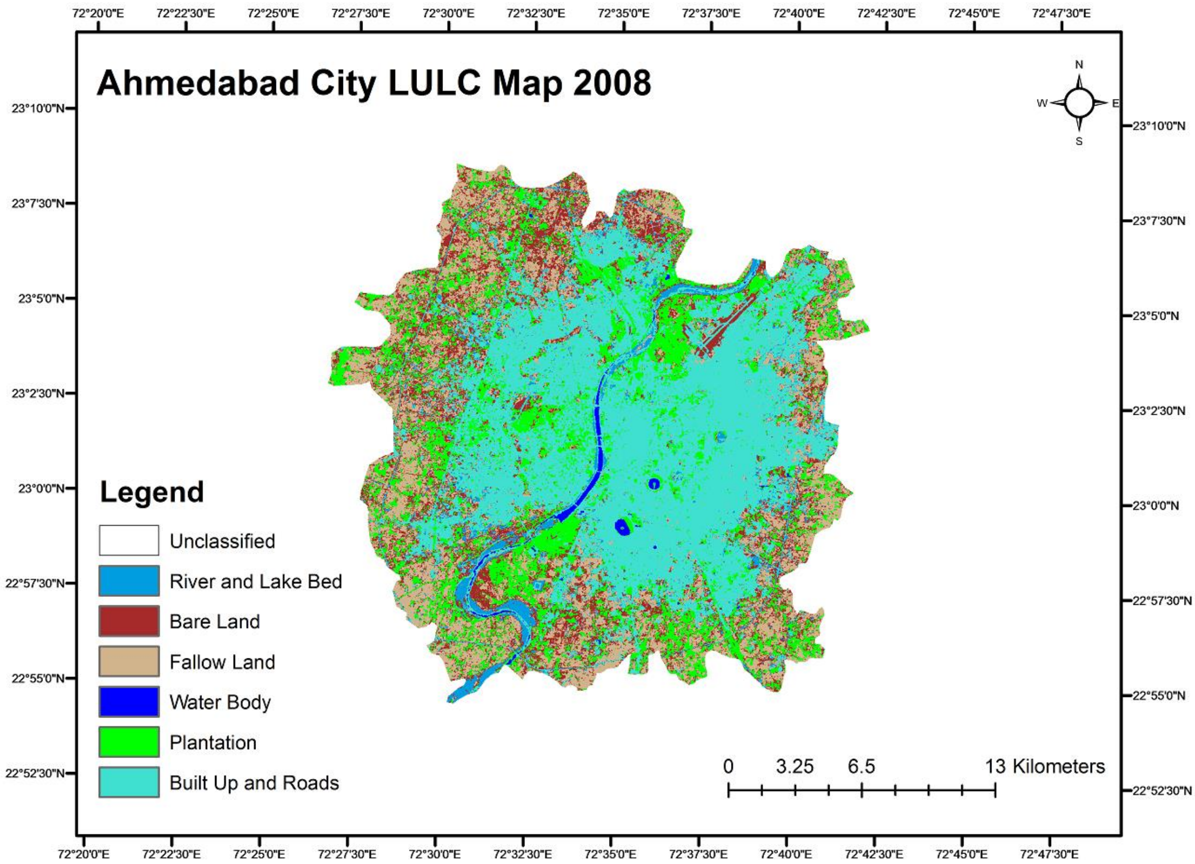


Fig. – 5.1.7: Land use/Land cover map for Chandigarh 2015



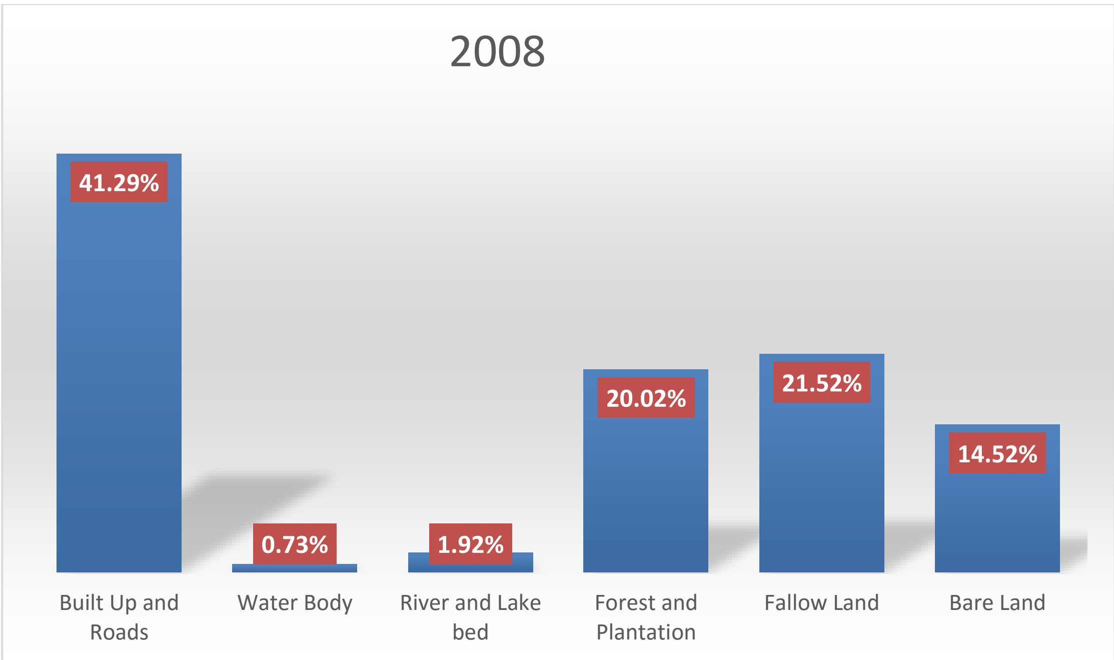
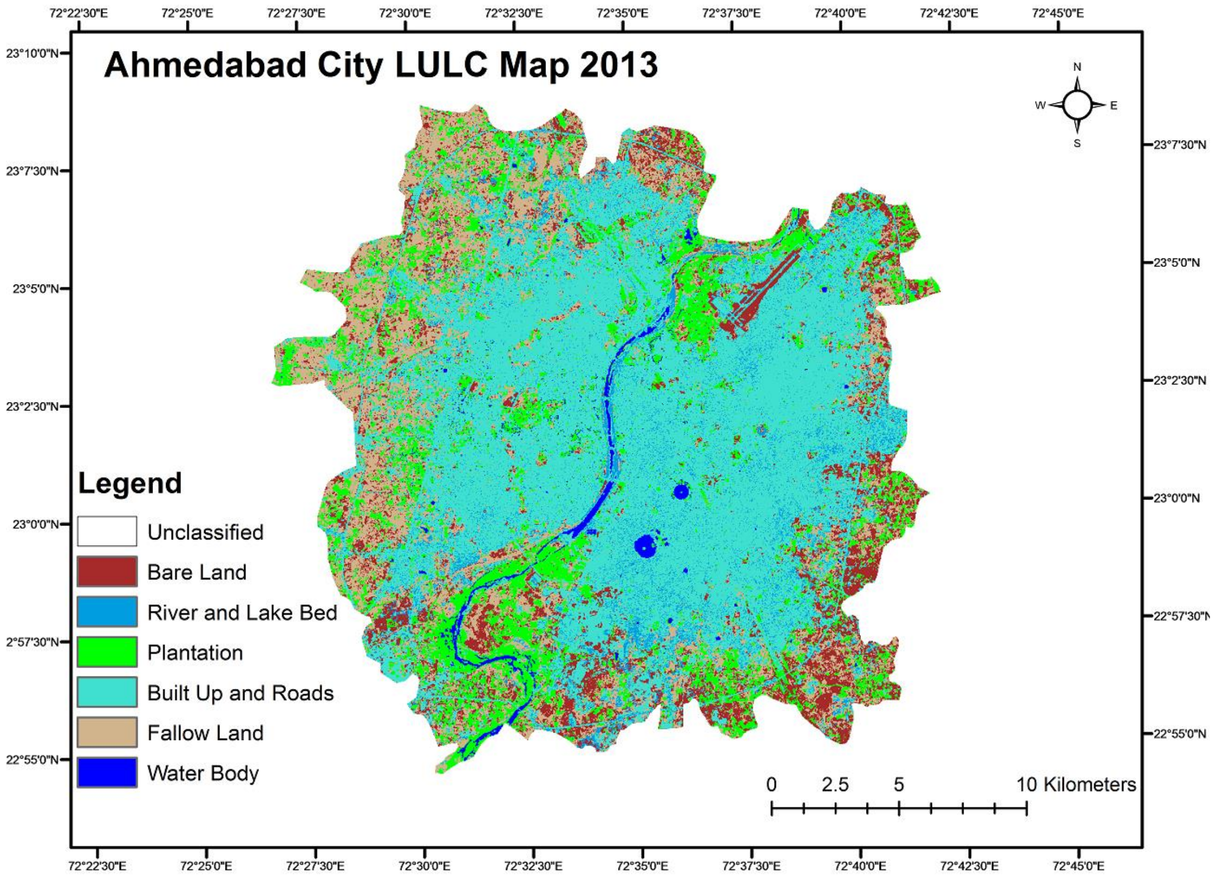


Fig. – 5.1.8: Land use/Land cover map for Chandigarh 2015



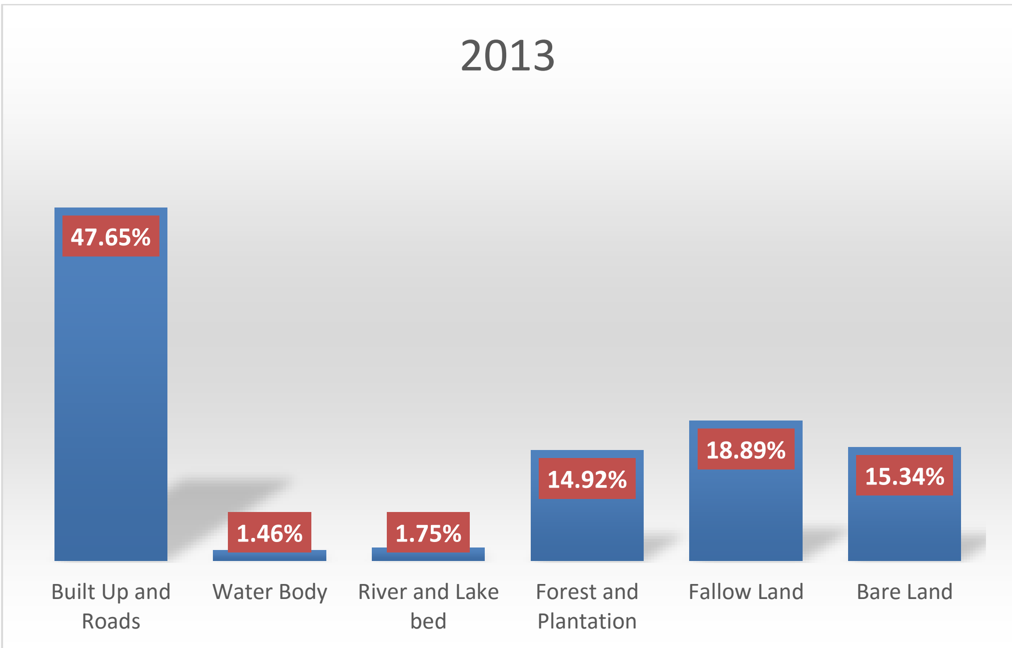


Fig. – 5.1.9: Land use/Land cover map for Chandigarh 2015

5.2 Image Classification Accuracy

The accuracy report obtained for the classified images for both the study areas by using the accuracy assessment tool in ERDAS Imagine has been tabulated below.

Year	Overall Classification Accuracy	Overall Kappa Coefficient
2003	87.50%	0.84
2009	87.50	0.84
2015	90%	0.87

*Table 5.2.1***:** *Accuracy report for Chandigarh Metropolitan*

Year	Overall Classification Accuracy	Overall Kappa Coefficient
2003	88.33%	0.86
2008	86%	0.82
2013	82.5%	0.78

*Table 5.2.2***:** *Accuracy report for Ahmedabad City*

The overall accuracy for both the study areas is shown above in the tables. For Chandigarh, the maximum accuracy obtained is 90% for the year 2015 and the minimum accuracy obtained is 87.50%. The maximum accuracy of 90% is obtained because of the data used is much clear and different pixels are clearly visible and can be distinguished easily. This is because the data is of Landsat 8 which is the latest satellite of RS. The FCC of the classified image of 2015 for Chandigarh city has been shown earlier in this chapter. And most importantly the accuracy report for the images before the year 2000 cannot be obtained since there is no availability of the reference data for the same. According to Rahman, *et al,* (2006) kappa values have been characterized into 3 categories: a value which is greater than 0.80 (80%) represents strong agreement, a value which is between

0.40 and 0.80 (40 to 80%) denotes moderate agreement, and a value below 0.40 (40%) represents poor agreement. Since the kappa coefficient values obtained is above 0.80, hence it shows a strong agreement between the classified map and the reference information obtained for the ground.

Similarly the overall accuracy obtained for the Ahmedabad city is maximum for the year 2003 and minimum for the year 2013. This has happened because of the pixel mixing between the pixels of river bed and built up. Even after continuous trials of classifying the image again and again, the pixel mixing couldn't be avoided. There is only a minor pixel mixing happening between the both classes hence it has been ignored. The kappa coefficient values for the year 2003 and 20008 is above 0.80 which showing strong agreement and for the year 2013, it is below 0.8 which means the agreement is moderate.

5.3 Land Use/Land Cover Change Analysis

5.3.1 Chandigarh Metropolitan

In this section, the LULC classes with their respective areas for the different year has been tabulated below for both the cities. The changes between the years have been obtained by subtracting the particular class area for the former year from the later one. The changes obtained has been analyzed in the later part of this section.

Class Name	1991	1997	2003	2009	2015
Built up and Roads	4306.86	6643.44	8408.16	10936.5	11123.7
Water Body	163.44	197.01	171.45	135.45	322.02
Forest and Plantation	9066.06	5229.99	5414.85	6817.77	5512.14
Bare Land	5911.47	8142.12	3348	2231.01	3030.93
Fallow Land	3393	2628.27	5498.37	2720.07	2852.01
Total	22840.8	22840.8	22840.8	22840.8	22840.8

Table 5.3.1: Area for each class in each study year for Chandigarh

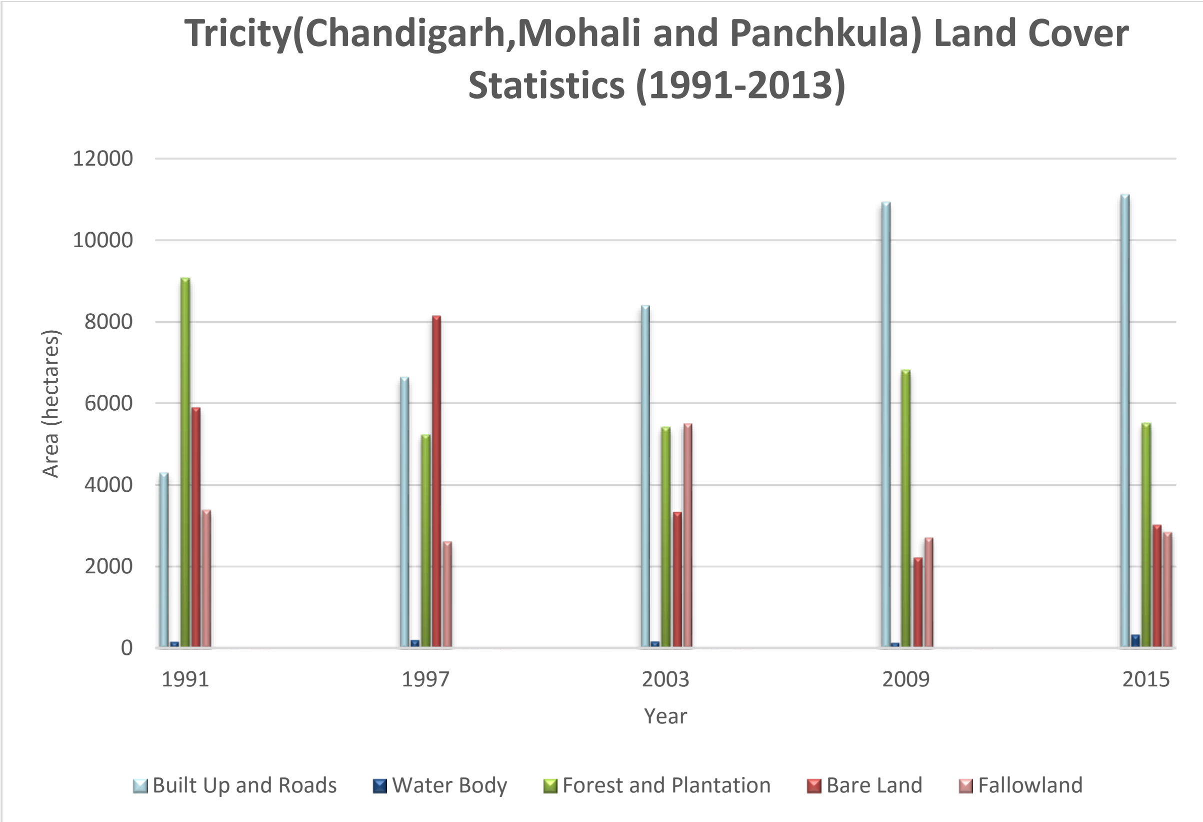


Fig. – 5.3.1: Land use/Land bar graph for Chandigarh (1991-2015)

Built Up and Roads			**Water Body**		
Year	**Area**	**Change**	**Year**	**Area**	**Change**
1991	4306.86		1991	163.44	
1997	6643.44	54.25%	1997	197.01	20.54%
2003	8408.16	26.56%	2003	171.45	-12.97%
2009	10936.5	30.07%	2009	135.45	-21.00%
2015	11123.7	1.71%	2015	322.02	137.74%

*Table 5.3.2**:** Change in Built up and Water body for all years for Chandigarh*

Forest and Plantation			Bare Land		Fallow Land	
Year	**Area**	**Change**	**Area**	**Change**	**Area**	**Change**
1991	9066.06		5911.47		3393	
1997	5229.99	-42.31%	8142.12	37.73%	2628.27	-22.54%
2003	5414.85	3.53%	3348	-58.88%	5498.37	109.20%
2009	6817.77	25.91%	2231.01	-33.36%	2720.07	-50.53%
2015	5512.14	-19.15%	3030.93	35.85%	2852.01	4.85%

Table 5.3.3: Change in Plantation, Bare Land and Fallow Land for Chandigarh

The LULC changes for the study years have been shown in tables above for the Chandigarh Metropolitan area. Since Chandigarh has always been a priority among the people to live and construct houses there, hence it is obvious that the built up and roads area are bound to increase due to the construction of new buildings and transportation medium. With the increase in the population, there is need of infrastructure, transportation facilities, water supply, etc. Hence the built up area has shown a remarkable increase from 1991 to 2015. There is significant increase in the built up from 1991 to 2009 but a very minor increase it there from 2009-2015 due to the increase of land cost, cost of construction, etc. There is an increase of 158.28 % in built up from 1991-2015. As the time passes the area is bound to undergo certain changes. Hence, there are certain changes in LULC map of Chandigarh since 1991. The water body has shown a gradual increase from 1991 to 2015. The water body has increased by 97%. The main area of water body in Chandigarh city is covered by Sukhna Lake. The water in Sukhna lake has a shallow depth. The reason behind the increase in the water body area is the formation of new ponds in public gardens, swimming pools, water treatment plants, water in the dried channels around the city, etc. The forest and plantation class which includes forest area of Dariya reserved forest, Lake reserved forest and the agriculture area with vegetation on it. The vegetation cover has shown a decrease of 39.20% due to the growth in the built up area, acquisition of land by cutting of trees to make construction sites. The city expansion has led to conversion of bare and fallow land to construction sites. The bare land has decreased by 48.73% and the fallow land has decreased by 15.94 %. The fallow land is the land left by farmers as uncultivated. It is discussed earlier that the expansion of the city on large scale has led to the decrease of areas under these classes. In a nutshell, it can be said that there is an overall decrease in the area under each class except built up and the water body. This is because the development has led to the formation of many new constructed buildings for living and several new man-made water accumulated structures. Even in the classified images one can see that the small pockets of water have shown up in the later image of 2015 as compared to the image of 1991.

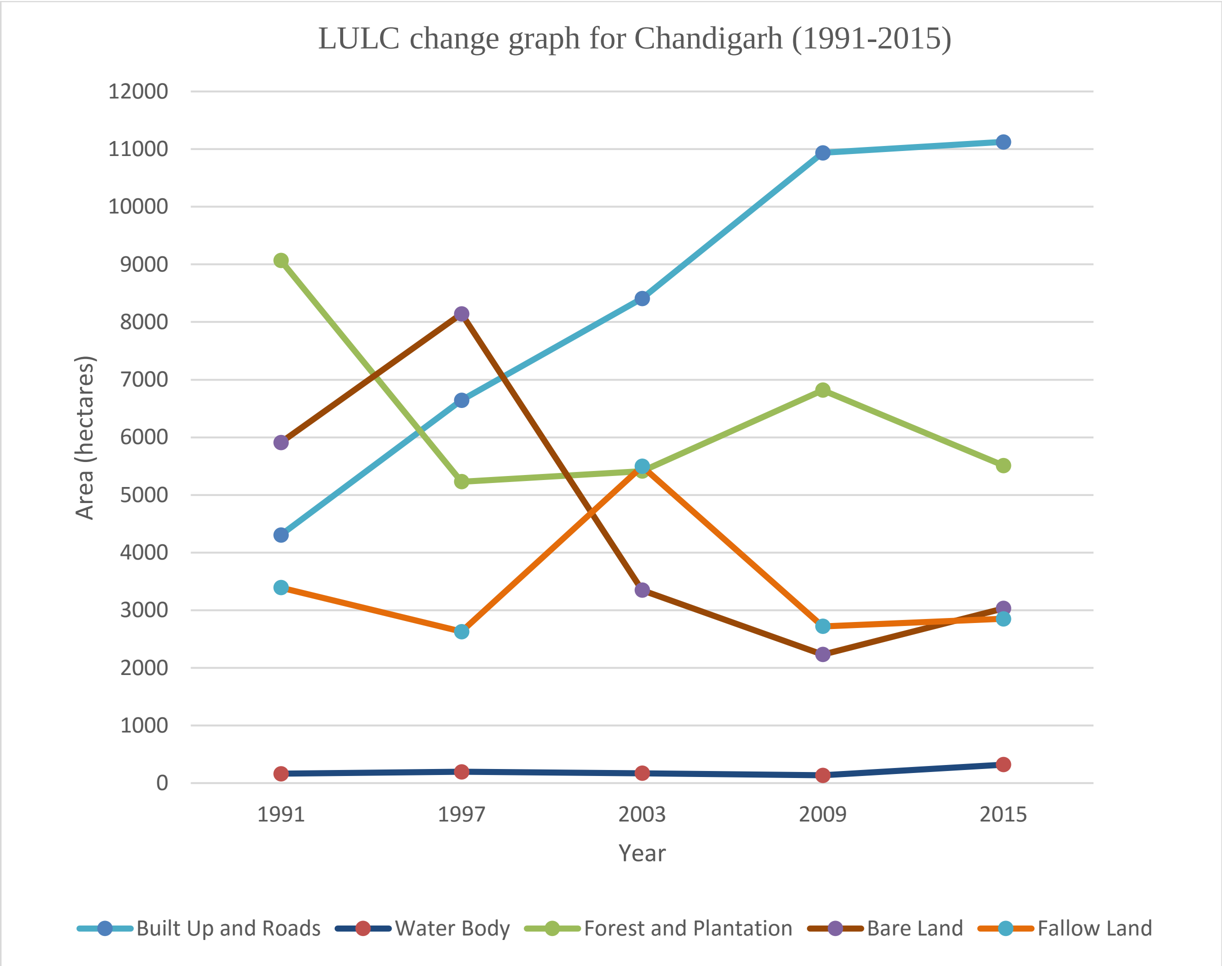


Fig. – 5.3.2: Land use/Land cover change graph for Chandigarh (1991-2015)

5.3.2 Ahmedabad City

The areas for LULC for each class type has been tabulated for Ahmedabad city in the table below along with the tables showing LULC changes happening during the years.

Class Name	1998	2003	2008	2013
Built up and Roads	17662	18253.1	19476.1	22522.9
Water Body	365.22	653.85	345.96	688.59
River and Lake Bed	968.48	819.81	907.6	826.25
Forest and Plantation	7093.98	8623.44	9440.55	7050.78
Bare Land	10819	5227.56	6847.74	7249.16
Fallow Land	10258.1	13686.7	10148.8	8926.74
Total	47264.46	47264.46	47264.46	47264.46

*Table 5.3.4**:** Area for each class in each study year for Ahmedabad City*

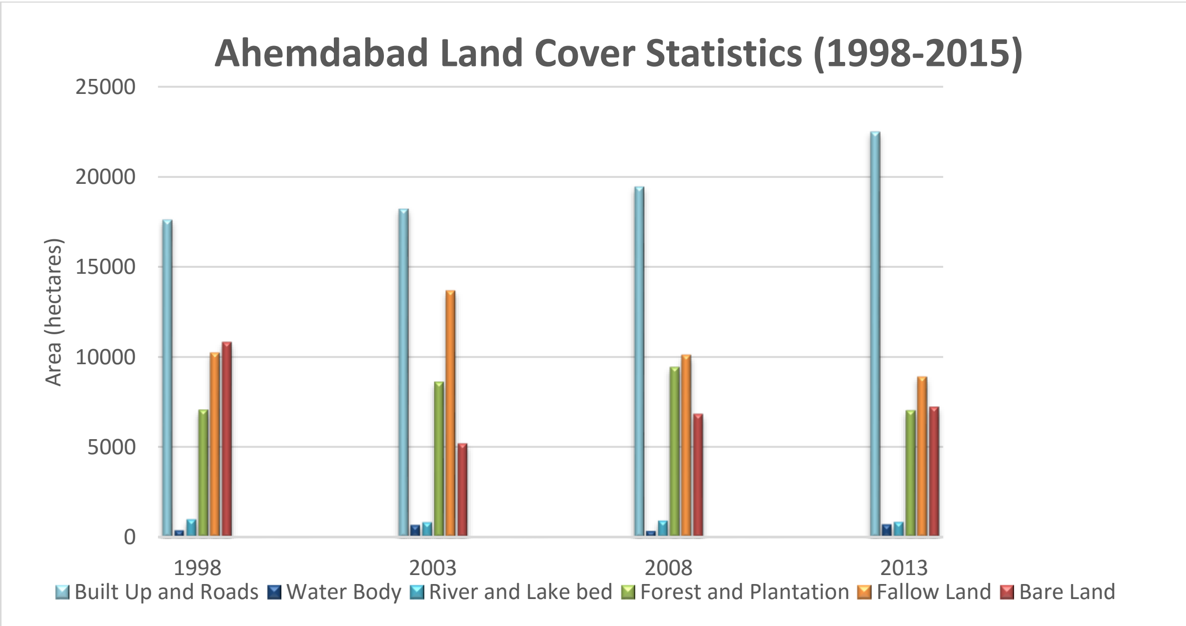


Fig. – 5.3.3: Land use/Land cover change graph for Ahmedabad City (1998-2013)

Built Up and Roads			Water Body		River and Lake bed	
Year	Area	Change (%)	Area	Change (%)	Area	Change (%)
1998	17662		365.22		968.48	
2003	18253.1	3.35%	653.85	79.03%	819.81	-15.35%
2008	19476.1	6.70%	345.96	-47.09%	907.6	10.71%
2013	22522.9	15.64%	688.59	99.04%	826.25	-8.96%

Table 5.3.5: Change in Built up, Water Body and River Bed for Ahmedabad City

Forest and Plantation			Fallow Land		Bare Land	
Year	Area	Change (%)	Area	Change (%)	Area	Change (%)
1998	7093.98		10258.1		10819	
2003	8623.44	21.56%	13686.7	33.42%	5227.56	-51.68%
2008	9440.55	9.48%	10148.8	-25.85%	6847.74	30.99%
2013	7050.78	-25.31%	8926.74	-12.04%	7249.16	5.86%

Table 5.3.6: Change in Plantation, Fallow Land and Bare Land for Ahmedabad City

The classes adopted for the study area number 2 which is Ahmedabad city is similar to that of Chandigarh except one extra class that has been added that is River and Lake Bed. The River and Lake bed class has been added to the LULC map of Ahmedabad city because of the presence of the river named Sabarmati and a lot many lake bodies in the city. The city has showed a mix trend of change for the water bodies in the period of 1998 to 2013. This has happened because of the drying up of the river and lakes at certain times in the given period. Now starting from the urban growth, Ahmedabad city is the largest city of the state Gujarat and hence it has expanded in a remarkable way around all the corners of the city. The built area has shown a moderate increase of 27.52% from 1998-2013. Although the increase is quite significant as the period is short as compared to the Chandigarh city. As it is known that the civilization develops across the river or sources with huge amount of water. Hence, the density of construction is more around the bank of the river Sabarmati. There is no forest area in the Ahmedabad city, hence most of the vegetation consists of vegetation near the river bank and agricultural vegetation. The water body has shown an increase from 1998 to 2003 and then a decrease from 2003 to 2008 and then further increase from 2008 to 2013. The overall increase in the water body is of about 88.54%. The cause of this kind of variation is sudden water loss from the lakes leaving them dry and then sudden increase in the water in lakes. There is an increase in the lakes in the Ahmedabad city from 2008-2013. The name of the main lakes in the city are Chandola Lake, Kankaria Lake, Malek Saban Lake and many more small lagoons are there. The most part of the river Sabarmati river has remained dry till 2008 but in 2013 the river has gained good amount of water in it. There is an overall decrease of 14.69% in the river and lake bed area due to the increase in water body. The plantation area has remained more or less same in this city although there is an overall decrease of 0.61% from 1998 to 2013. The plantation area hasn't shown any variable trends due to variations in the growth of the plant/trees on the river banks and many more such factors accounts for the same. Since it has been discussed earlier that the city has expanded around all the corners, therefore there is a decreasing trend in the fallow and bare land area by 12.98% and 33% respectively. Again in this city also, there is an overall decrease in all classes except the built up and water body. The population of the Ahmedabad city is growing at a good pace, hence there are sufficient chances of built up area to increase in the future. The relationship between the population and the urban built up area has been correlated in the further sections of the thesis.

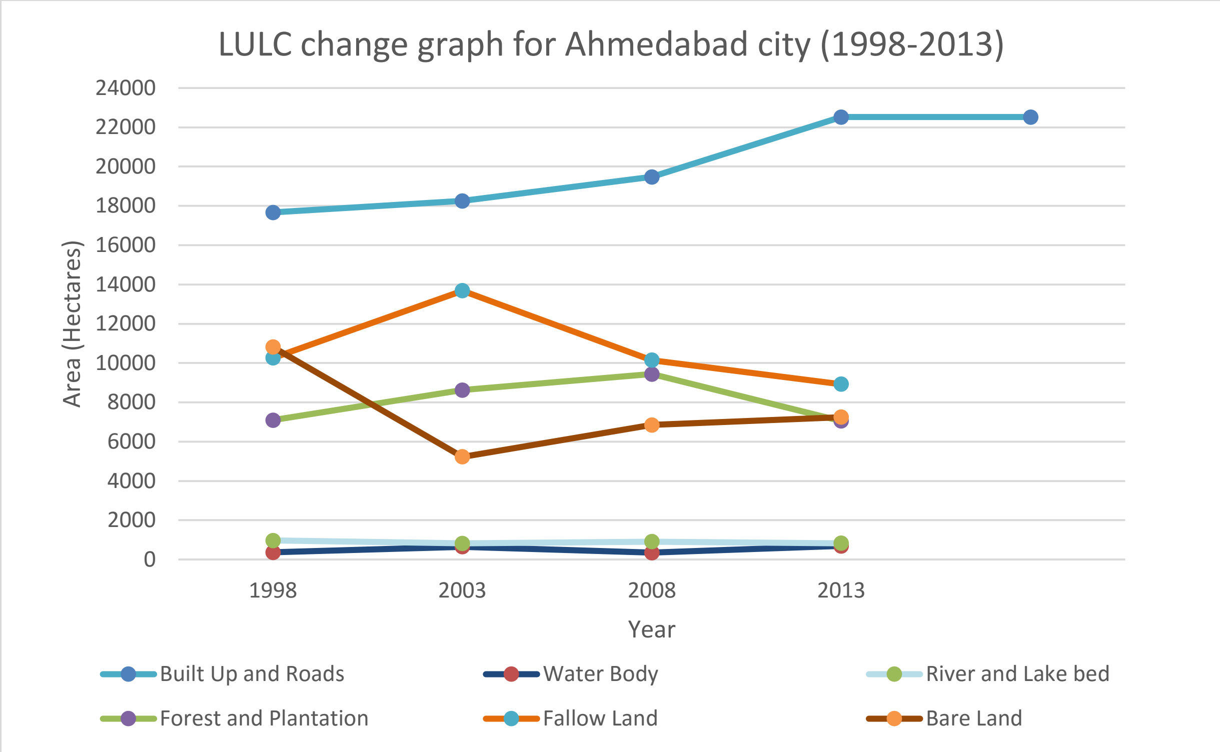


Fig. – 5.3.4: Land use/Land cover change graph for Ahmedabad City (1998-2013)

5.4 Population Growth and its Correlation with Built Up Area

5.4.1 Chandigarh Metropolitan Area

The population data for this area has already been tabulated in chapter number 3. In this chapter a relationship between the population of the city corresponding to the year of Landsat data has been obtained by comparing the built up and population of the same year. It is obvious that the population and the built up will show a linear variation but still an effort has been made to obtain the correlation graph between the two. Firstly, the area of each city i.e. Chandigarh, Mohali and Panchkula has been obtained from the sources noted in the chapter number 3 and then the total area of the Metropolitan region has been calculated by adding the individual area of each city from census year 1991, 2001 and 2011. Now, after obtaining the total area for the census years, a graph has been plotted between the year and the population of the city. After the graphs has been obtained, the population of the Landsat image years has been derived by using curve fitting equation which includes Bessel spline function and Flex Spline function.

Population of Chandigarh Metropolitan Area (1991-2011)	
Year	Population
1991	790,847
2001	1,165,044
2011	1,412,254

*Table 5.4.1**:** Total population of the area for census years*

Metropolitan Population for each year corresponding to the Landsat data year		
Year	Population	Percentage change
1991	790,847	
1997	1,030,604	30%
2003	1,224,645	19%
2009	1,372,971	12%
2015	1,485,741	8%

*Table 5.4.2**:** Total population of the area for census years*

Built Up vs Population for the area (1991-2015)		
Year	Built Up	Population
1991	4306.86	790,847
1997	6643.44	1030603.64
2003	8408.16	1224644.96
2009	10936.5	1372970.96
2015	11123.7	1485740.6

*Table 5.4.3**:** Built up and Population for the same study year*

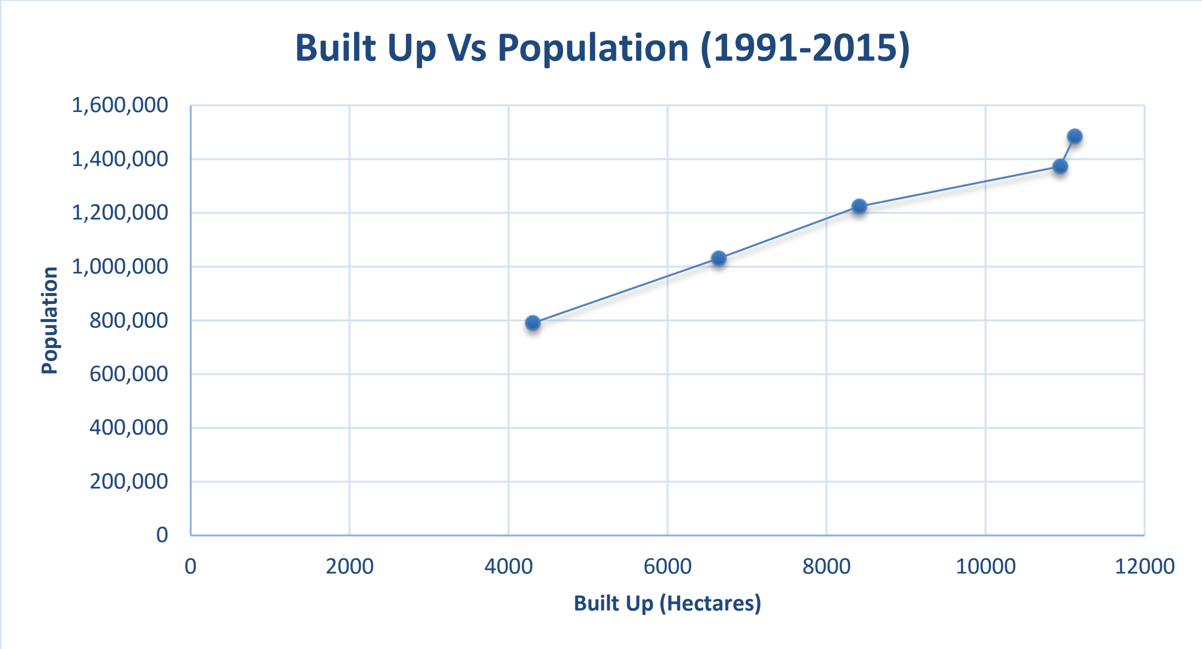


Fig. – 5.3.5: Population vs Built Up graph for Chandigarh city (1991-2015)

The graph above shows the population growth of the city with the built up increase in the city. The graph between the two given parameters has shown a linear trend as we can see and there is a sharp increase in the graph from 2009 to 2015. This has happened because of the rapid increase in the population in this period. The rapid urbanization and the city infrastructure maybe the reason behind the increase in the population. As the city is well connected by means of road, rail and air transport, hence the chances of the population to rise are quite possible. It is the influence of the Chandigarh city only that the towns like Mohali and Panchkula have turned into cities. The city's planning, rapid development, infrastructure, good connectivity, etc. has attracted a lot of population to settle down in the city. Hence, the city expansion is not going to stop according to the study and the population growth is going to affect the built up effectively in future also.

5.4.2 Ahmedabad City

The Ahmedabad city of Gujarat is a much larger city when compared to the Chandigarh Metropolitan area. Hence, it is obvious that the built up area and the population for this study area has larger numbers when compared to the study area of Chandigarh. Secondly, due to huge source of water provided by river Sabarmati and a large number of lakes in the city has also accounted for the increase in the population for the area. In this section, the relation between the area and population for the study years have been investigated for this study area. The details of the population data has already been showed in the previous chapter number 3. Hence, no repletion of the same data has been done in this section and directly the relationship between the two parameters has been obtained for this study area. Again, same methodology has been adopted to obtain the population of the study year by using Microsoft Excel and using curve fitting functions discussed above.

Ahmedabad Population for each year corresponding to Landsat data		
Year	Population	Percentage change
1998	3228576.935	
2003	3822502	18.40%
2008	4830458.313	26.37%
2013	6129215.6	26.89%
2015	6727059.4	9.75%
2016	7043444.375	4.70%

*Table 5.4.4**:** Ahmedabad Population for each year corresponding to Landsat data*

Built Up vs Population for the area (1998-2013)		
Year	Built Up	Population
1998	17662	3228576.935
2003	18253.1	3822502
2008	19476.1	4830458.313
2013	22522.9	6129215.6

*Table 5.4.5**:** Population and Built Up for each study year for Ahmedabad city*

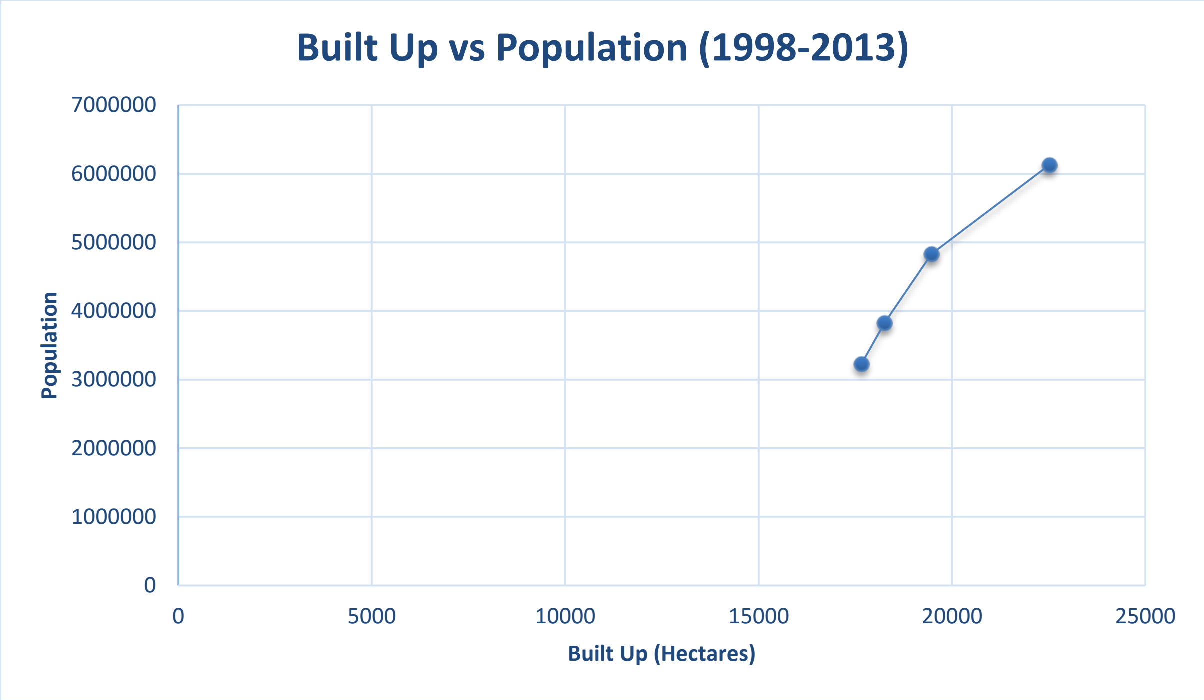


Fig. – 5.3.6: Population vs Built Up graph for Ahmedabad city (1998-2013)

As the figure 5.3.6 shows, the slope of the graph is quite steep. The steepness in the slope shows that the population has increased at a more rate as compared to the built up area of the city. The reason behind this can be the migration of people from the nearby towns to the city as the city is a hub of rive Sabarmati and many lakes discussed previously in the study. There is an expected increase of 89.84% in the population from 1998 to 2013 whereas the overall increase in the built up area has been calculated as 27.52%. The increase in the population is almost 3.5 times the increase in the built up area, hence the chances of the city to get over crowded by the population in future is more. Hence, there is a need to increase the built up area to cater to the demands of poplation increasing at a rapid rate.

Chapter 6

Conclusion and Future Work Recommendation

6.1 Conclusion

After observing the results and outputs of each study area, the following conclusions have been drawn.

1. The main theme behind the study is the change detection analysis of both the areas, hence the LULC changes occurring in both the cities have shown a significant growth of water body which is quite uncommon nowadays where scarcity of water is a crucial issue around the world.
2. The study has also suggested that there is significant area in the cities which is covered by fallow land which can be due to the lack of farming practices or due to lack of availability of farming materials.
3. The Built up area in both the cities has expanded gradually and hence it can be expected that in future times, there can be very less percentage of vegetation, cultivated land, etc. which an alarming issue.
4. The FCC image part of Sukhna lake in Chandigarh city has showed that there can be a shallow depth of water in the lake or there is a silting problem in the lake.
5. The Built up area in the Chandigarh Metropolitan is growing accordingly with the population but in case of Ahmedabad the Built up area has increases by 1.5 from 1998-2013 but the population has just become twice from 1998 to 2013. Hence, there are chances of people living without homes in future in the city.
6. The Sabarmati river in the Ahmedabad city has been facing the scarcity of water and hence there is still certain part of the river which is dry.

6.2 Future Work Recommendation

After obtaining the results and conclusion from the study, the following recommendations have been suggested.

1. The rapid land use/land cover change that has happened during the last ten years requires suitable attentions.
2. For the classification of the images the supervised classification method has been adopted. Hence, other methods like object oriented classification can also be used and the results can be compared.

3. The future prediction of the LULC of the study areas can be made using Markov Chain model.
4. The classification of the images has been done by taking only limited classes, hence the classes for classification can be increased to get more specific results.

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