Project Report
On
ANALYSIS OF URBANIZATION TENDS IN JAIPUR USING GIS AND REMOTE SENSING

Submitted
In partial fulfilment of the requirements of the degree of Bachelor of Technology
(Civil Engineering)

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CERTIFICATE

This is to certify that the Project Report entitled "**Analysis Of Urbanization Tends In Jaipur Using GIS And Remote Sensing**" which is being submitted by **Anjali Anand (2017UCE1468), Ashwini Sen Gupta (2017UCE1612) and Amit Kumar Maurya (2017UCE1317)** are for the partial fulfilment of the requirements of the degree of **B.Tech. (Civil Engineering)** to the **Department of Civil Engineering, Malaviya National Institute of Technology Jaipur**. It is a record of a student's own work carried out by him/her under my supervision and guidance. This work is approved for submission.

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ABSTRACT

Urbanisation being irreversible, rapid and coupled with fast growth of population during the last century, contributed to serious ecological and environmental consequences. This necessitates the monitoring and advance visualisation of spatial patterns of landscape dynamics for evolving appropriate management strategies towards sustainable development approaches.

Attempts were made to visualise the urbanization growth pattern of the derived watershed area which is situated in Jaipur (Rajasthan) using ArcGIS and Remote Sensing techniques for the time period 1990 to 2021.

Firstly, generation of classified land-use/cover maps of the study area (i.e., for 1990, 1995, 2000, 2010, 2018, 2020 and 2021) using LANDSAT and Sentinel data were successfully completed. Secondly, examination of the temporal pattern of urban land changes (ULCs; i.e., land changes from non-built-up to built-up) across time intervals of 5 years were performed. Finally, attempts were made to predict the future urban growth of our study area upto 2050.

The results revealed that our study area's built-up land has increased by 54.81 sq.km (261.14%) over the past 31 years (20.99 sq. km in 1990 to 75.80 sq. km in 2021), at a rate of 1.82 sq. km per year.

The analysis revealed that ULC was more intense or faster during the 1900s (8.08% annual urban growth rate) than in the 2000s (5.65% annual urban growth rate), coinciding with the trends of population and economic growth.

Most of these projected gains of built-up land will be along the transport corridors and in proximity to the growth nodes like roads and streams. These findings are important in the context of landscape and urban development planning for our study area.

Overall, this study provides valuable information on the landscape transformation of Jaipur also highlighting some important challenges facing its future sustainable urban development.

LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATION

Abbreviation		Full Form
ULC	:	Urban Land Covering
GIS	:	Geographical Information System
RS	:	Remote Sensing
LULC	:	Land Use Land Cover
LULCC	:	Land Use Land Cover Change

DEM	:	Digital Elevation Model
SRTM	:	Shuttle Radar Topography Mission
MLC	:	Maximum Likelihood Classifier
OvAc	:	Overall accuracy
FCC	:	False Colour Composite

CHAPTER 1
INTRODUCTION

1.1 OVERVIEW

The demographic transformation of human societies into the urban era has pushed the monitoring of urban areas to the forefront of environmental and developmental agendas. Due to this transformation, a higher percentage of the world's population currently resides in urban areas than ever before, and growth in urban areas is occurring at an unprecedented rate. Accordingly, Jaipur has experienced dramatic urban growth, dominated by the continuous shrinking of rural areas into urban areas.

During the past two decades, Jaipur, the largest city as well as capital of Rajasthan has experienced rapid urban growth. The concentration of increased urbanization has created environmental problems across the area that stem from extensive urban poverty, recurrent flooding, slum growth, extensive alteration of wetland ecosystems, and mismanagement of limited resources. In such a context, knowledge of the spatiotemporal pattern of urban growth is crucial in order to create sustainable urban development policies that can mitigate the adverse effects of urbanization and ensure sustainable urban development.

The emergence of land-change science, including advances in GIS and remote sensing, has provided a platform to examine landscape transformations throughout space and time.

At present, remote sensing has been recognized as a valuable technique for viewing, monitoring, analyzing, characterizing, and mapping urban growth and expansion. It has therefore been widely used in detecting and monitoring urban changes on various scales with useful results.

Obviously, satellite data, remote sensing, and Geographic Information Systems (GIS) are the most relevant technologies for meeting these needs in the most effective manner.

While several urban-related studies have been conducted in Jaipur city, there is a lack of research that provides meaningful information on the dynamics of urban growth. Hence, this study seeks to examine the spatiotemporal pattern of urban growth of Jaipur for the time interval of 1990 to 2021.

Inorder to perform our land use/ land cover analysis on Jaipur, attempts were made to fully utilize free resources available over the internet and to derive meaningful insights on the study area, in water resources planning, it is preferred to do analysis at watershed level.

In the present study, a watershed falling within Jaipur city was considered as the study area so that various methodologies could be applied to evaluate numerous water resource engineering parameters associated with the watershed.

For the delineation of the required watershed, Amanishah Nala was chosen as the outlet point for the watershed and accordingly the study area was finalised using ArcGIS. After that, generation of classified maps was successfully done using Maximum Likelihood Classification and its validation was successfully performed using Google Earth Pro. In the process of accuracy assessment for the stimulated classified map, we also compare overall accuracy and kappa coefficient for each map generated and try to analyze the trend of increase in high resolution data available.

More to this, we used various remote sensing data i.e. LANDSAT and Sentinel Images and various GIS techniques to facilitate the analysis. In order to perform land use land cover change detection, attempts were made to successfully examine change in area for five different land cover classes i.e. built up area, barren land, forest, vegetation and water body. More to this, attempts were made to perform land change intensity analysis, urban growth rate analysis and percentage increase/ decrease in area.

1.2 OBJECTIVES

The main objective of this study is to monitor and analyze urban growth patterns in order to understand them better and to support effective urban planning towards urban sustainable development. The focus is on the investigation of spatio-temporal dynamics of land cover change patterns from remote sensing images; assessment of the underlying cause-effect relationships in urban growth process; simulation of urban growth. The specific objectives are as follows:

- To use free high resolution available resources i.e. multi-temporal LANDSAT and Sentinel data from USGS Earth Explorer, Bhuvan - Indian Geoportal of ISRO and Copernicus Open Source Hub

- To delineate watershed falling within Jaipur city and perform various GIS techniques to extract meaningful water resources engineering parameters and insights on the study area using ArcGIS

- To extract and compare the historical land cover information for the study area through the interpretation of remote sensing images and the using of quantitative measures

- To examine the underlying cause-effect relationships in the urban growth process to provide insight into how driving factors contribute to urban growth

- To understand and implement various image processing and classification techniques in generation of classified maps

- To study the principles and applications of Geographic Information Systems (GIS), aims to develop the skill of using software and other tools of GIS in ArcGIS and Erdas.

- To understand the future scenarios by taking into account the current urban development strategies of state government and to provide various recommendations to resolve the problems faced by Jaipur city

1.3 CHALLENGES

Some of the challenges that were faced during this study of urbanization trends of Jaipur using remote sensing and GIS techniques for the time interval of 1990 to 2021 are discussed in detail as below.

- **Complex data structures**: The data collected and stored in the GIS system is usually complex with plenty of definition and restructuring required. This means that special skills are required to understand and interpret the data collected in a GIS system.

- **Large amounts of data**: A GIS system stores extremely large amounts of data at any given time. This may create problems when it comes to analysis due to the complexity of the data and the risk of generalization. It also creates problems when it comes to interpretation.

- **Large storage**: GIS data requires extremely large storage space due to the large data sizes and data types used. This also increases the cost of storage and the manpower required to manipulate the data to make sense.

- **Time consuming**: The process of collecting, storing and analyzing information using a GIS system is long and tedious and therefore time consuming. It may take a long time to get complete information regarding a particular set of data due to the vastness of the data available.

- **Interpolation of missing data:** As the project has planned to collect the data at the interval of 5-years, but some of the data were missing so interpolation needs to be done to obtain missing data.

- **Low resolution LANDSAT data of early 1990s:** Back in 1990s, remote sensing techniques were not so advanced as of now to take high resolution satellite imagery and hence we have used various image preprocessing in order to retrieve relevant data from these low resolution satellite images.

- **Distorted LANDSAT data:** Images acquired by Landsat sensors are subject to distortion as a result of sensor, solar, atmospheric, and topographic effects. Preprocessing attempts to minimize these effects to the extent desired for a particular application.

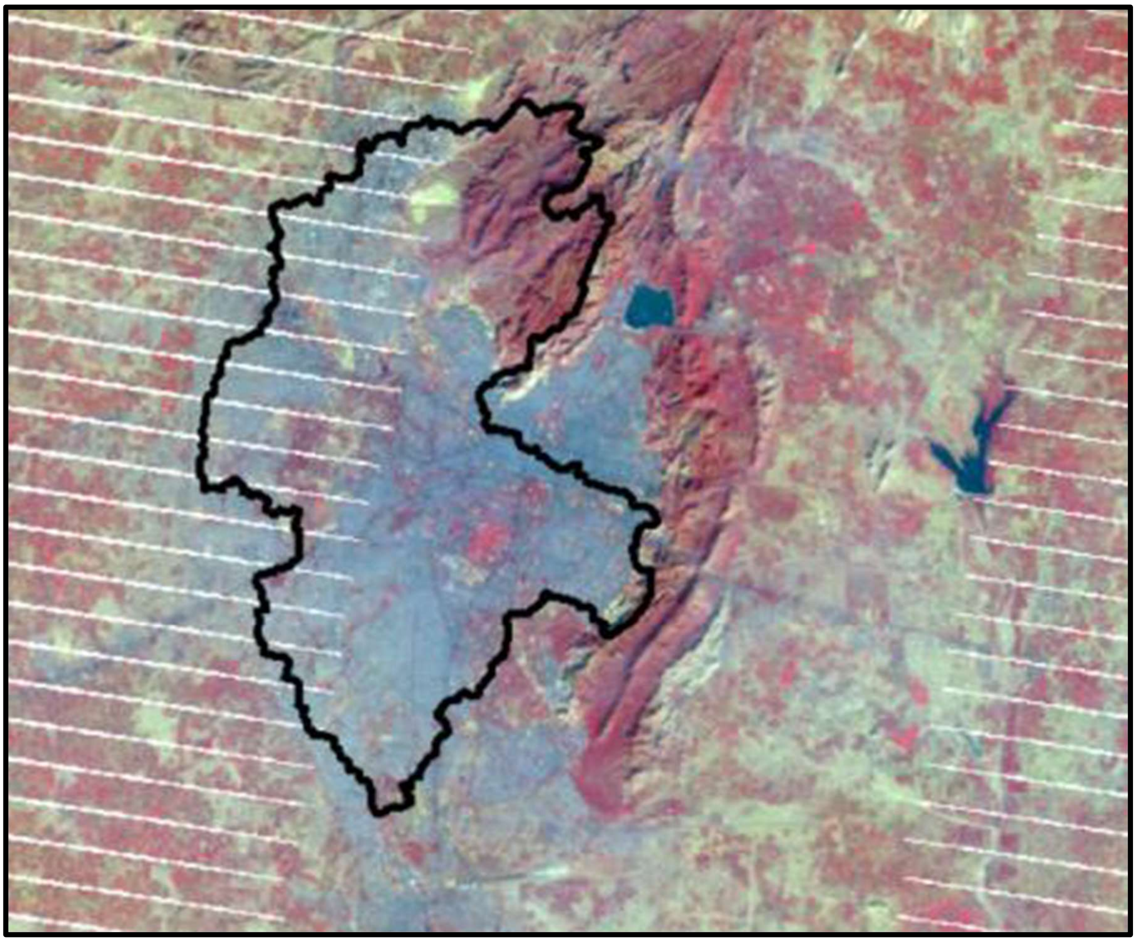


Fig 1. Distorted LANDSAT data of year 2005

1.4 SCOPE OF WORK

Some of the practical applications of the study are discussed below in detail which could be helpful in deriving further meaningful water resources related insights on the study area as well as its applicability in different fields.

- Analysis of urbanization trends could be used in different ranges of disciplines including urban planning, geography, sociology, architecture, economics and public health.

- In civil engineering perspective, with the help of urbanization trend analysis of Jaipur city and hydrological data evaluated in the study, there is possibility of designing the drainage system, rainfall per annum, discharge of a particular point to construction of a dam.

- With the help of freely available resources, furthermore, water resource management and planning which includes discharge, storage of water, flood and drainage system could be estimated in order to reduce water scarcity of Jaipur with the help of algorithms or software.

- Urbanization trends could also be used in forecasting the intensity of climate change as well as in study of disaster management.

- The accurate analysis of urban growth has become increasingly important not only to better understand the environmental impacts but also to support the sustainable urban development strategy.

- Urbanisation trends could be further used in order to develop and replace existing water supply & sanitation systems with more effective one.

- Moreover, these trends could be utilized by different governmental as well as non-governmental institutions in order to solve the problem of housing by developing effective city planning strategies.

- Furthermore, designing of road systems, waste disposal and pollution control measures could be effectively implemented when we take into consideration the growing urban population of Jaipur.

1.5 SOFTWARE USED

- ArcGIS 10.4
- ERDAS IMAGINE
- SNAP
- QGIS 2.18
- Google Earth Pro
- Google Sheets

CHAPTER 2

LITERATURE REVIEW

Since the emphasis of this project is the integration of RS and GIS for monitoring and analyzing the urban growth process, this chapter provides a brief outline of the theoretical fundamentals associated with the project. The key concepts related to urban growth are explained.

Furthermore, Jaipur’s water resource management problems have been discussed thoroughly and the land cover classes that were taken into consideration are explained in detail.

Over the past few decades, the field of water resource engineering has advanced to better understand some of the impacts of urban development on natural hydrological processes. Despite this, the impact of the built environment on natural hydrological dynamics is complex and our collective understanding remains limited.

2.1 URBAN HYDROLOGY

Urban hydrology is the scientific application of hydrologic principles and knowledge to the planning and management of urban areas and their surroundings. It embraces all aspects of the interactions of man and water in occupancy of land. It includes the special hydrologic studies needed to accomplish these ends and deals with minimizing the adverse effects of man's use of land and water and with maximizing the effective use of the available water resources.

2.1.1 URBAN IMPACTS ON HYDROLOGICAL CYCLE

As urban space continues to expand to accommodate a growing global population, there remains a real need to quantify and qualify the impacts of urban space on natural processes. The expansion of global urban areas has resulted in marked alterations to natural processes, environmental quality and natural resource consumption.

The urban landscape influences infiltration and evapotranspiration, complicating our capacity to quantify their dynamics across a heterogeneous landscape at contrasting scales.

Increased impervious cover associated with urbanization alters the natural cycling of water. Changes in the shape and size of urban streams, followed by decreased water quality, are the most visible effects of increased imperviousness. Greater frequency and severity of flooding, channel erosion, and destruction of aquatic habitat commonly follow watershed urbanization. Alterations in the aquatic environment associated with these hydrological changes greatly compromise the normal functioning of our waterways.

Urban landscapes are host to a suite of contaminants that impact on water quality, where novel contaminants continue to pose new challenges to monitoring and treatment regimes.

2.1.2 URBAN IMPACTS ON RAINFALL

The concentration of heat-absorbing materials, heat-generating processes and lack of cooling vegetation contribute to increased temperatures in urban areas (urban heat island (UHI) effect), impacting rainfall proliferation in downwind areas. This is further impacted by the presence of natural and anthropogenic aerosols, which contribute to thermal insulation and act as condensation nuclei for cloud-microphysical processes. These resultant changes to the surrounding atmosphere can have a profound impact on precipitation intensity and variability within the city.

2.1.3 URBAN IMPACTS ON LOCAL RAINFALL–RUNOFF TRANSFORMATIONS

Increasingly, urban hydrologists and engineers are assessing the local responses of urban areas to precipitation, assessing the fate of rainfall at the building and street scale.

Buildings with predominantly brick or concrete compositions have porous spaces where water can seep into the building and be considered as a hydrological loss, particularly in older buildings with load-bearing and cavity walls. The impacts of these dynamics on the wider catchment water balance remain uncertain; however, localised pluvial flood risk can be exacerbated by buildings of particular material and inefficient supporting drainage infrastructure.

As building density increases and larger neighbourhood areas emerge, greater impervious surface area modifies the way rainfall is translated into runoff at the surface and near-surface levels.

2.2 JAIPUR’S WATER RESOURCE RELATED PROBLEMS

Jaipur depended on the Ramgarh Dam as its surface water source throughout the 1900s, but this became a non-viable source leading to a shift to complete dependence on groundwater & thus a rapidly depleting aquifer. Jaipur is currently experiencing growing water scarcity and diminishing drinking water sources.

Jaipur relies extensively on groundwater and a single surface water source, the Bisalpur Dam, which is located 120 km southwest of Jaipur & is shared with Ajmer and Tonk District villages. In addition to water scarcity, degradation in quality of both surface and Groundwater sources is of great concern. Jaipur is located in the semi-arid zone of India, which is characterized by high temperatures, low rainfall, and a mild winter. The average annual rainfall of Jaipur is about 650 mm.

Following are the problems that are associated with Jaipur's water resources planning which were discussed and hence the study area was finalised to solve these underlying problems.

2.2.1 Problems related to Hydrology

- There are as many as 518 rivulets originating from the Aravalli Hills: 398 1st order streams, 92 2nd order streams, 25 3rd order streams, & 3 4th order streams. Many natural streams began to be used for dumping garbage.

- Due to expansion, 150 streams with 113 of 1 st order, 37 of 2nd order, and 10 of 3rd order are blocked or have been filled for construction purposes.

2.2.2 Problems related to Surface Waters

- Degradation in Water Quality Industrial processes in and around the city have greatly and negatively affected the quality of surface waters in Jaipur.

- Amanishah Nala has become unsightly and foul smelling due to the discharge of industrial wastewater to its storm water drainage network.

- Decreased water quality causes increased health risks and increased spending on health care.

- These conditions also allow for an increased risk of pollution of shallow aquifers.

2.2.3 Problems related to Groundwater

- Jaipur's groundwater supply has diminished to a critical limit, with more than 500% overexploitation in some areas & severe degradation in quality.

- Lack of regulation of tube wells has also compounded the problem.

- With an estimated 20,000 private tube wells within the city, compared to approximately 2,000 Public Health Engineering Department controlled tube wells, the regulation and monitoring of groundwater extraction are nearly unachievable.

- Depletion With increasing population, increasing dependence on groundwater Loss of forest lands, agricultural fields, pasturelands, & open wasteland due to urbanization, building of roads, houses, and commercial complexes has reduced recharge areas around Jaipur.

- Degradation: The overexploitation of groundwater concentrates the inherent salts, fluorides, chlorides, and other chemicals already found in the water.

- The seepage of sewage water into surface water sources has further degraded the water.

2.2.4 Problems related to Natural Gradient and Flood Area

- Rapid urbanization of Jaipur, increase in paved area and decrease in open, recharge areas land has resulted in an increase in local urban flooding.

- During rapid urbanization, the drainage system of Jaipur was given little attention.

- New development and residential colonies developed over the bed of the drainage patterns. As well, construction often involves flattening of the land disrupting the natural topography and thus drainage of the area.

2.3 CLASSIFICATION OF LAND COVER CLASSES

Five separable land cover classes were identified by taking into consideration the spectral characteristics of LANDSAT and Sentinel data, existing knowledge of land cover categories within the study areas and the objectives of the study which are as follows:

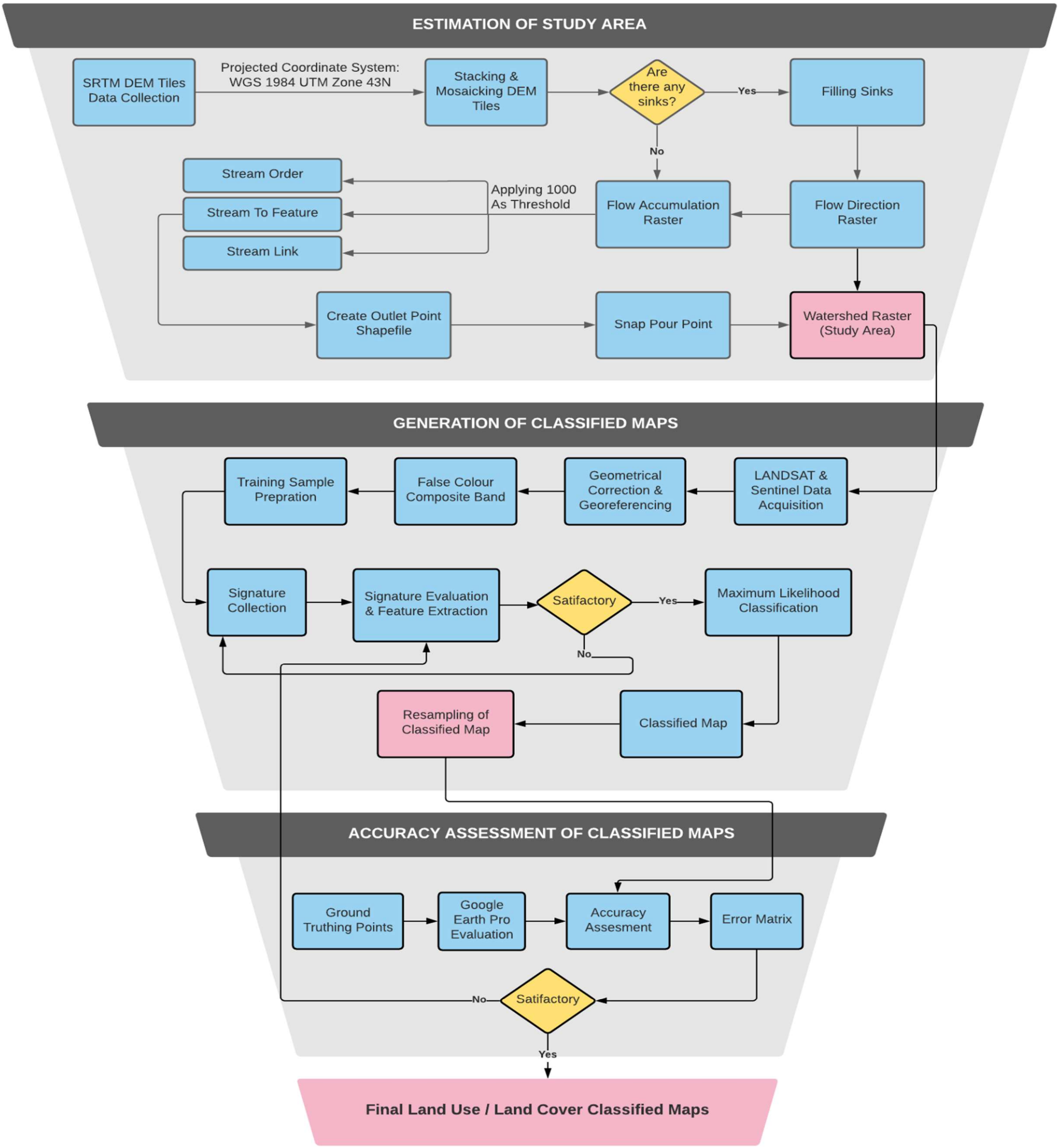
- Built Up Area
- Vegetation
- Forest
- Barren Land
- Water Body

Detailed description of these five categories of land use/cover are summarized in table below:

S. No.	**Feature Classes**	**Description**
1	Built Up Area	Residential, commercial services, industrial, transportation, communications, mixed urban or build-up land, other urban or built-up land
2	Vegetation	Field crops, pasture, trees (mainly olives and fruit trees), deciduous and evergreen oaks and coniferous trees and open shrub and herbaceous rangeland
3	Forrest	Deciduous forest land, evergreen forest land, mixed forest land, forest over mountains
4	Barren Land	bare fields, deserts, dry salt flats, beaches, sand dunes, exposed rock, strip mines, and gravel pits
5	Water Body	Permanent open water, lakes, reservoirs, streams

Table 1. Land use and land cover classes & their description

2.4 PROCEDURE FLOWCHART



CHAPTER 3
STUDY AREA

The study area that was considered for land cover change detection analysis is the watershed generated with help of ArcGIS which is located in the central part of Jaipur with a total area of 118.91 km^2. It lies between the latitudes 26 48’43”N and 27 0’54”N and longitudes 75 42’7”E and 75 53’6”E. Areas of high population density tend to be located in the core of the city and this is an integral part of study area which is basically derived from delineation of watershed where the outlet point was specified as Amanishah Nala having latitude 26.84N and longitude 75.78E.

The study area is located in the semi-arid zone of India, which is characterized by high temperatures, low rainfall, and a mild winter. Its economy is primarily based on trading, administration, tourism activities, & local handicrafts industries. The study area which is situated in Jaipur relies extensively on groundwater and a single surface water source, the Bisalpur Dam, which is located 120 km southwest of Jaipur & is shared with Ajmer and Tonk District villages.

Jaipur is the largest city in Rajasthan and was built in the eighteenth century by Sawai Jai Singh as India's first planned city. It hosts several attractions like the City Palace, Govind Dev ji Temple, Birla Temple, several massive Rajput forts and so on. However, the project is limited to the surrounding Dravyavati River area only.

The Amanishah Nala Drain which is the outlet point of the study area is on the northwest of Jaipur city. It is critical to the water and sewage management of Jaipur as it connects the upward stream from the Aravalli Hills to the downward stream of the Dravyavati River. Due to Jaipur’s severe seasonal fluctuations of monsoons, the drain collects an annual average of 6 million cubic meters of water from the mountain as well as approximately 1 million cubic meters per hour of street stormwater during the monsoon season.

SPECIFICATION

- Area: 118.91 km^2
- Elevation: 431 m
- Population Density :6,500/km 2
- Weather: 17 °C, Wind N at 2 km/h, 53% Humidity
- Coordinate of outlet point (Amanishah Nala) 26.84N ,75.78E
- Average annual temperature 25.1 °C
- Annual precipitation : 536 mm

3.1 TOPOLOGICAL VIEW

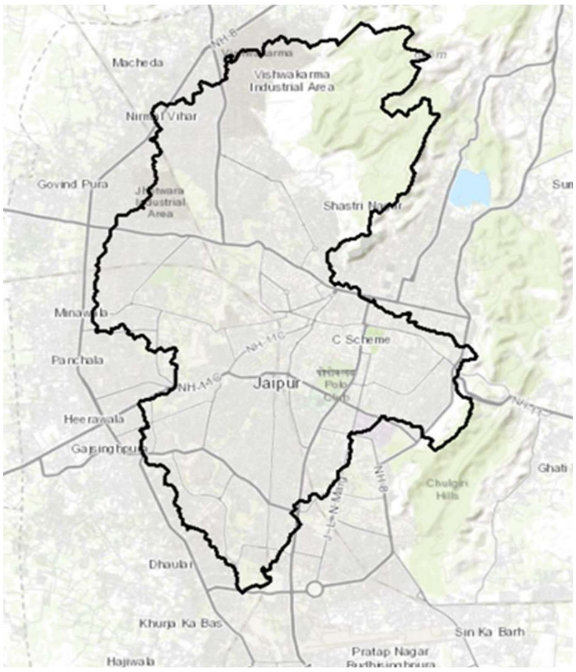


Fig.2 Topographical View Of Study Area

3.2 SATELLITE VIEW

Fig.3 Satellite View Of Study Area

CHAPTER 4
DATA SOURCES

4.1 SATELLITE IMAGERY

Although most developed countries have comprehensive land cover information, the relative lack of geospatial data is a serious situation in developing countries,particularly in India.

In addition to the common advantages of remote sensing images, LANDSAT images with medium spatial resolution and multiple spectrals provide an appropriate data source for land cover study because they are free of charge and maximize the possible temporal monitoring period.LANDSAT data is available free of cost and is usually sufficient to derive useful information. In the present project, attempts are made to identify free LANDSAT sources and to download the same for the study area and analyze the data.

Table lists the acquisition dates and sensors for the satellite images selected. The cloud free remote sensing images as the primary data source for mapping land cover in the study areas were obtained from the **USGS Earth Explorer**.

Numerous studies in satellite image based land cover mapping have demonstrated that improved accuracy of the results can be obtained by using more than one date of imagery rather than using single temporal imagery as a basis for classification, because it can increase the potential for spectral differentiation among land cover types.

In order to assess the accuracy of classification results, a set of reference data were necessary, which included topographic maps, high-resolution aerial photography, and field survey data.

The images were resampled to a pixel size of 30 m × 30 m using the nearest neighbor algorithm to maintain the spatial resolution and radiometric properties of the original data.

Year	Date	Data Sources	Band	Path	Row
1990	31/12/1990	LANDSAT 5 (TM C1 Level-1)	2,3,4	147	41
1995	29/12/1995	LANDSAT 5 (TM C1 Level-1)	2,3,4	147	41
2000	02/12/2000	LANDSAT 7 (ETM+ C1 Level 1)	2,3,4	147	41
2008	18/10/2008	LANDSAT 7 (ETM+ C1 Level 1)	2,3,4	147	41
2010	14/12/2010	LANDSAT 7 (ETM+ C1 Level 1)	2,3,4	147	41
2015	04/12/2015	LANDSAT8 (OLI/TIRS C1 Level 1)	3,4,5	147	41
2018	26/12/2018	SENTINEL 2B	8,4,3	----	----
2020	01/12/2020	SENTINEL 2B	8,4,3	----	----
2021	07/03/2021	SENTINEL 2B	8,4,3	----	----

Table 2. List of remote sensing images for study area

4.2 GIS DATA

Urban growth is a complex process which involves the interaction of various factors. A DEM at a spatial resolution of 30 m of the study areas was used to represent topography. Slope gradient was derived from the elevation surface.

The growth of urban population and economy create urban land demand. More urban land will be required to satisfy further growth of urban population and economy in the future. Any water resources planning is preferably done at the watershed level. In the present study a watershed falling within the Jaipur city was considered as a study area so that methodology to correctly evaluate watershed is understood as one of the objectives of the project.

The DEM tiles have been downloaded from **30m SRTM TILE DOWNLOADER.**

Dem Tiles	Coordinate	Dem Tiles	Coordinate
1.	N026E075	3.	N026E076
2.	N025E075	4.	N025E076

Table 3. 30m SRTM DEM

CHAPTER 5

METHODOLOGY

5.1 MAXIMUM LIKELIHOOD CLASSIFICATION

The Maximum Likelihood Classifier (MLC) is the most commonly used supervised classification method, which creates decision surfaces based on the mean and covariance of each class. However, MLC presents less successes because the MLC assumption that the data follow Gaussian distribution may not always be held in complex areas. Artificial Neural Networks (ANN) and Support Vector Machine (SVM) originally proposed by Vapnik and Chervonenkis (1971) are recent additions to the existing image classification methods,which received increasing attention in remote sensing applications.

Maximum likelihood classification assumes that the statistics for each class in each band are normally distributed and calculates the probability that a given pixel belongs to a specific class. Unless you select a probability threshold, all pixels are classified. Each pixel is assigned to the class that has the highest probability (that is, the maximum likelihood). If the highest probability is smaller than a threshold you specify, the pixel remains unclassified.

ENVI implements maximum likelihood classification by calculating the following discriminant functions for each pixel in the image

$$g_i(x) = 1\text{n}\, p(\omega_i) - {}^1\!/_2\, 1\text{n}\, |\Sigma_i| - {}^1\!/_2 (x - m_i)^T \Sigma_i^{-1} (x - m_i)$$

Where:

i = class

x = n-dimensional data (where n is the number of bands)

$p(\omega_i)$ = probability that class ω_i occurs in the image and is assumed the same for all classes

$|\Sigma_i|$ = determinant of the covariance matrix of the data in class ω_i

Σ_i^{-1} = its inverse matrix

m_i = mean vectors

5.2 RESAMPLING OF CLASSIFIED MAPS

Nearest neighbor is a resampling method used in remote sensing. The approach assigns a value to each "corrected" pixel from the nearest "uncorrected" pixel. The advantages of the nearest neighbor include simplicity and the ability to preserve original values in the unaltered scene. The disadvantages include noticeable position errors, especially along linear features where the realignment of pixels is obvious.

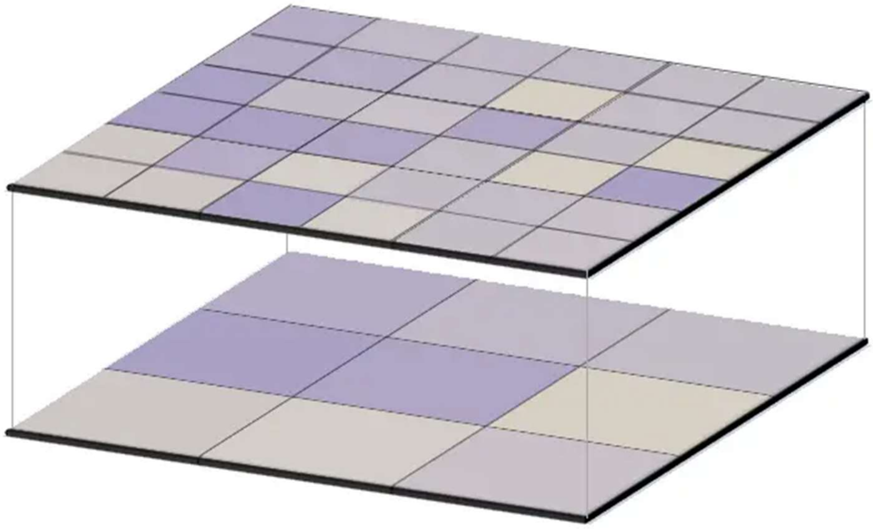


Fig.4. Raster Resampling for Discrete and Continuous Data

Resampling assigns the digital number (DN) of the closest input pixel (in terms of coordinate location) to the corresponding output pixel.

5.3 ACCURACY ASSESSMENT BY ERROR MATRIX

METHOD

A confusion matrix (or error matrix) is usually used as the quantitative method of characterising image classification accuracy. It is a table that shows correspondence between the classification result and a reference image. To create the confusion matrix the ground truth data is needed, such as cartographic information, results of manually digitizing an image, field work/ground survey results recorded with a GPS-receiver. Firstly, pay attention to the diagonal elements of the matrix. Diagonal cells contain the number of correctly identified pixels.Divide the sum of these pixels by the total number of pixels and get classification's overall accuracy (**OvAc**).

Another accuracy indicator is the kappa coefficient. It is a measure of how the classification results compare to values assigned by chance. It can take values from 0 to 1. If kappa coefficient equals 0, there is no agreement between the classified image and the reference image. If kappa coefficient equals to 1, then the classified image and the ground truth image are totally identical. So, the higher the kappa coefficient, the more accurate the classification is.

- **Overall Accuracy**

$$\frac{\text{Number of correctly classified pixels}}{\text{Total number of reference pixels}} \times 100$$

- **User Accuracy**

$$\frac{\text{Number of correctly classified pixels in each category}}{\text{Total number of classified pixels in that category}} \times 100$$

- **Producer Accuracy**

$$\frac{\text{Number of correctly classified pixels in each category}}{\text{Total number of classified pixels in that category}} \times 100$$

- **Kappa Coefficient**

$$\frac{TS \times TCS - \sum \text{Column Total} \times \text{Row Total}}{TS^2 - \sum \text{Column Total} \times \text{Row Total}}$$

Here, TS=Total Sample, TCS= Total Corrected Sample

5.4 LAND CHANGE INTENSITY ANALYSIS

Change detection was carried out by post-classification comparison, and creation of contingency tables for the time intervals 1990–1995, 1995–2000, 2000–2005 ,2005–2010,2010-2015 , 2015-2020 and 2020-2021. We performed three levels of Intensity Analysis: time interval, category, and transition . The time interval level examines how the size and rate of change varies across time intervals. For any particular time interval, the category level examines how the size and intensity of gross losses and gross gains in each category vary across categories. For any particular category, the transition level examines how the size and intensity of the category's transitions vary across the other categories that are available for that transition. At each level, Intensity Analysis compares the observed changes to hypothetical uniform change, as a uniform line indicates.

CHAPTER 6

PROCEDURES

6.1 COLLECTION OF SRTM DEM

Firstly download the DEM tile .A DEM at a spatial resolution of 30 m of the study areas was used to represent topography.USGS Digital elevation models (DEMs) are arrays of regularly spaced elevation values referenced horizontally either to a Universal Transverse Mercator (UTM) projection or to a geographic coordinate system. The grid cells are spaced at regular intervals along south to north profiles that are ordered from west to east. The USGS acquires bare-earth elevation source data through the 3D Elevation Program (3DEP) and resamples the data to several National Map DEM products for the U.S. and territories.

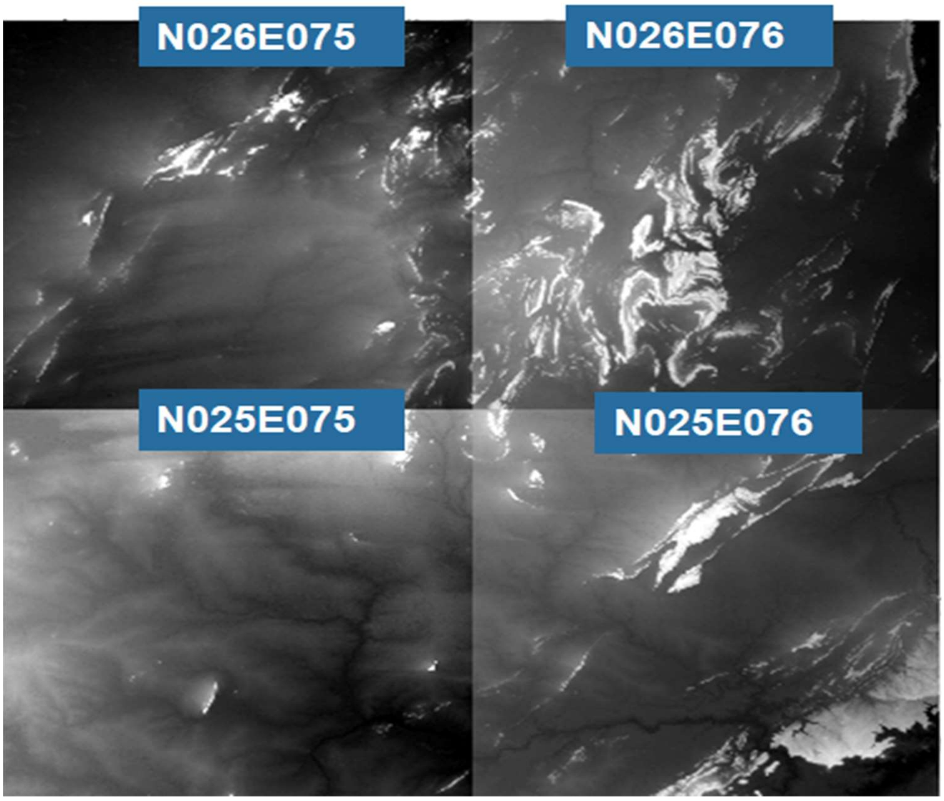


Fig.5.SRTM DEM

6.2 STACKING AND MOSAICKING THE SRTM DEM

After that do the mosaicing.Mosaicing is the process to combine multiple images of a raster dataset .Mosaicing is one of the techniques of image processing which is useful for tiling digital images. Mosaicing is blending together several arbitrarily shaped images to form one large radiometrically balanced image so that the boundaries between the original images are not seen. Any number of geocoded images can be blended together along user-specified cut lines (polygons).

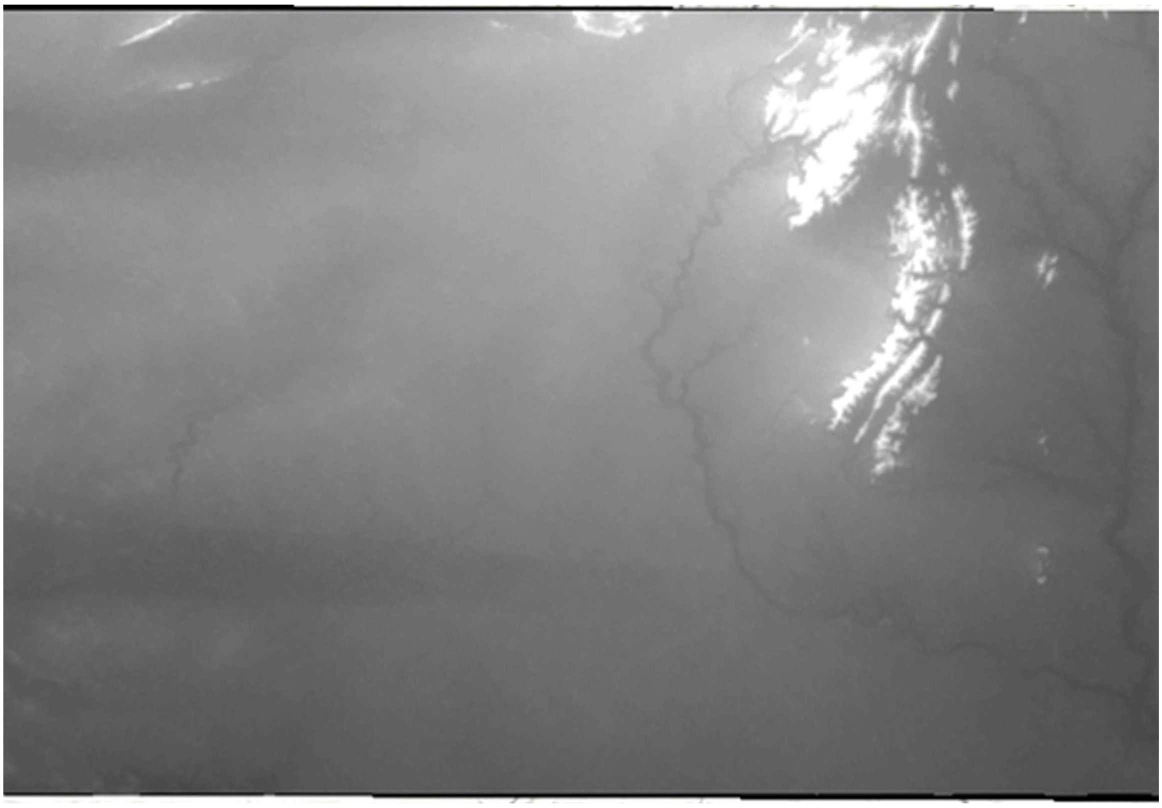


Fig.6. Mosaic DEM

6.3 FILLING THE MOSAIC SRTM DEM

After mosaicing filling needs to be done . Filling is a process which helps to remove imperfection/sinks of the raster dataset.And if any void is present in DEM tiles then it will also help to fill that void.

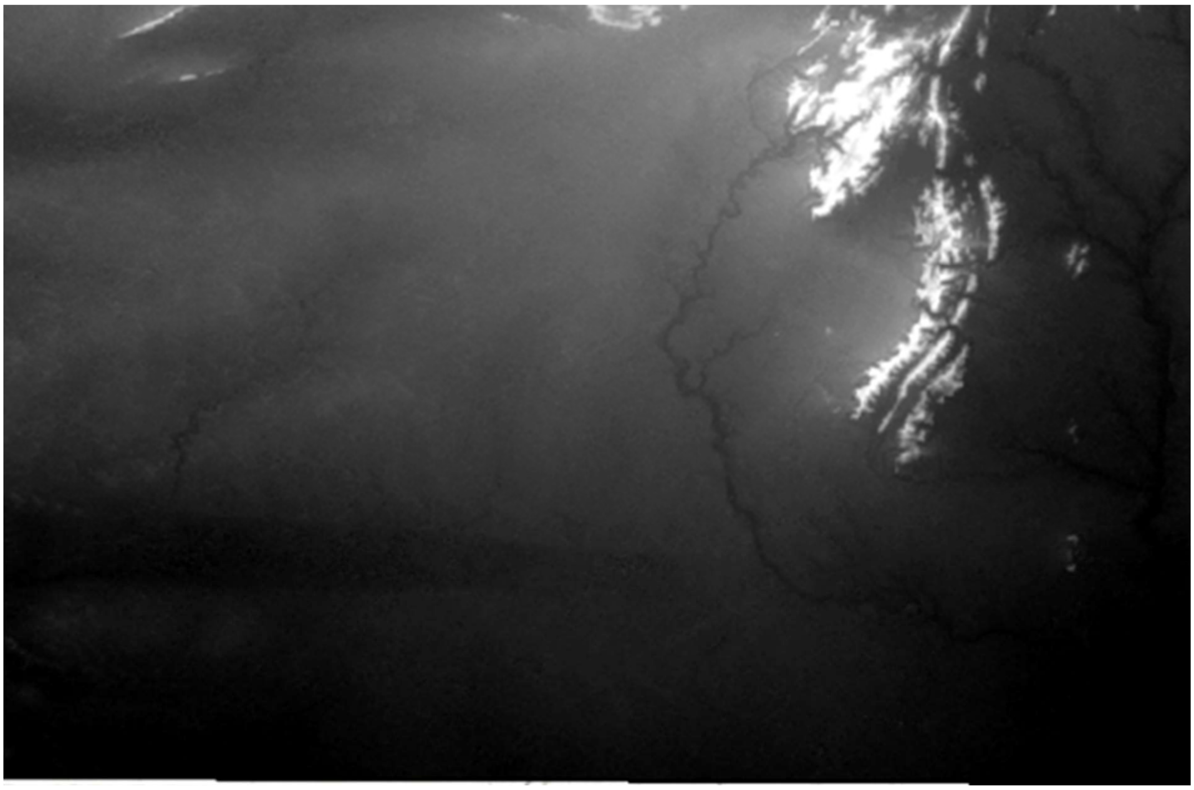
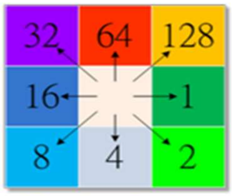


Fig.7. Filled Mosaic SRTM DEM

6.4 GENERATION OF FLOW DIRECTION RASTER

Flow direction is a process which helps to determine the direction in which water would flow out of each cell .Flow direction means the direction the stream flows in each cell. The figure below the direction coding; it is called eight-direction flow direction coding. That a steam flows from the center cell to its eight neighboring cells is considered that it flows to eight different directions, and the eight neighboring cells will be assigned a number; if the water flows from center to the right side(the flow direction is identified by the steepest slope or the direction with the greatest height difference), the flow direction value will be 1. If "Force edge cells to flow outward" is checked, the cells on the edge of DEM will be treated as flowing outward across the elevation surface.



Direction Coding

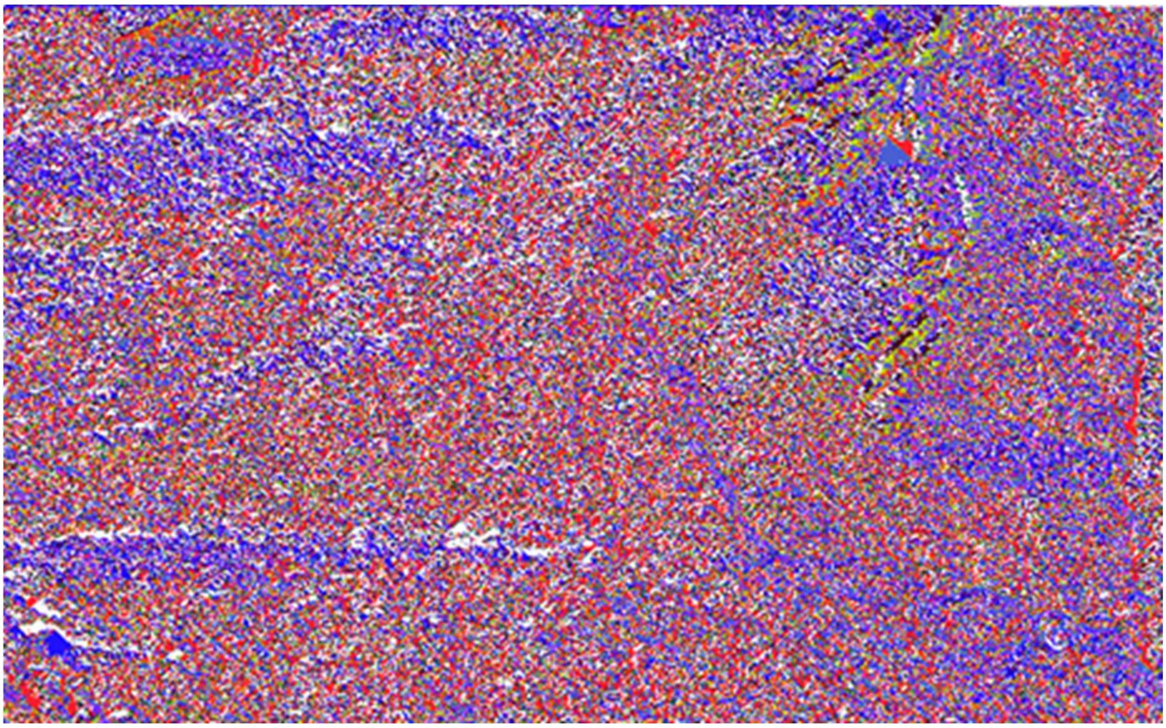


Fig.8. Flow direction raster

6.5 DELINEATION OF FLOW BASIN RASTER

It is a raster delineating all the drainage basins with the help of a basin tool.The drainage basins are delineated within the analysis window by identifying ridge lines between basins. The input flow direction raster is analyzed to find all sets of connected cells that belong to the same drainage basin. The drainage basins are created by locating the pour points at the edges of the analysis window (where water would pour out of the raster), as well as sinks, then identifying the contributing area above each pour point. This results in a raster of drainage basins.

Fig.9. Flow Basin Raster

6.6 CONVERSION OF RASTER BASIN TO VECTOR POLYGON

Convert the raster basin to vector polygon. With the help of pour point select the watershed. Converting between raster and vector formats makes use of both raster and vector data when solving a GIS problem, as well as using the various analysis methods unique to these two forms of geographic data. This increases the flexibility .To combine a raster and vector analysis, you need to convert one type of data to the other.

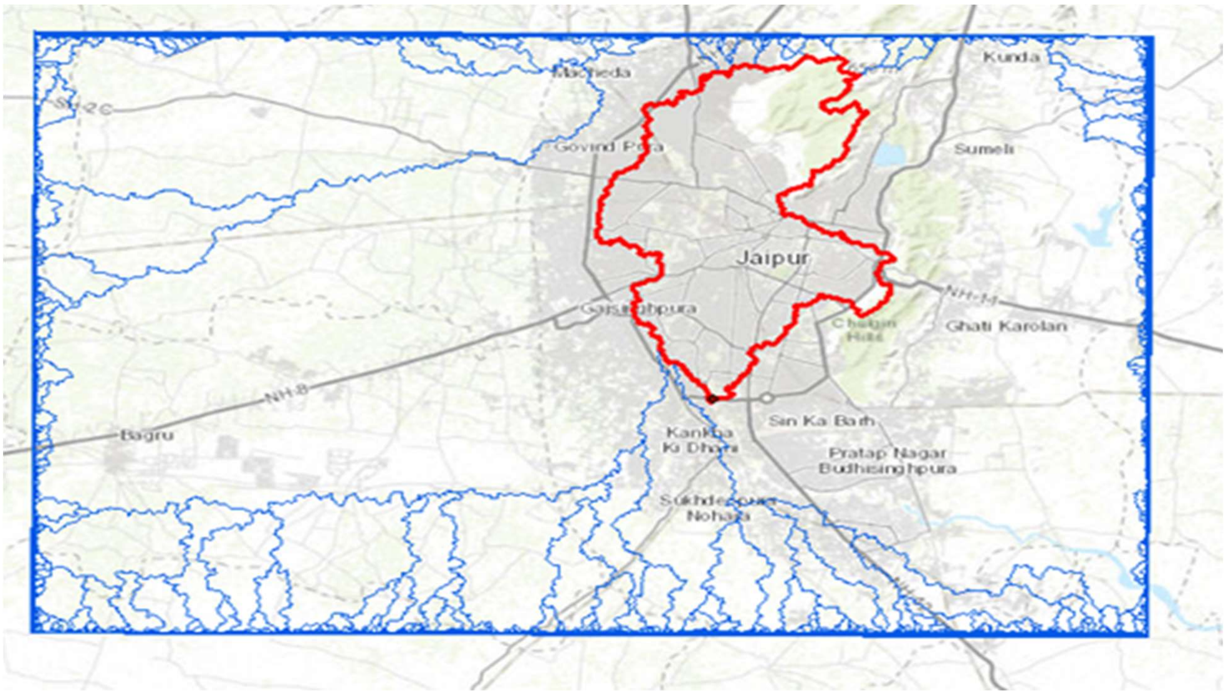


Fig.10. Catchment polygons created by raster to vector conversion of catchment grid

6.7 EXTRACTION OF WATERSHED

Inorder to perform land use/ land cover analysis on Jaipur, attempts were made to fully utilize free resources available over the internet and to derive meaningful insights on the study area, in water resources planning, it is preferred to do analysis at watershed level. A watershed embraces physical-biological features as well as socio-economic and political features which have to be integrated into the planning and management process. Coordinate of outlet point is 26.84N ,75.78E so from the vector polygon the watershed has been extracted.

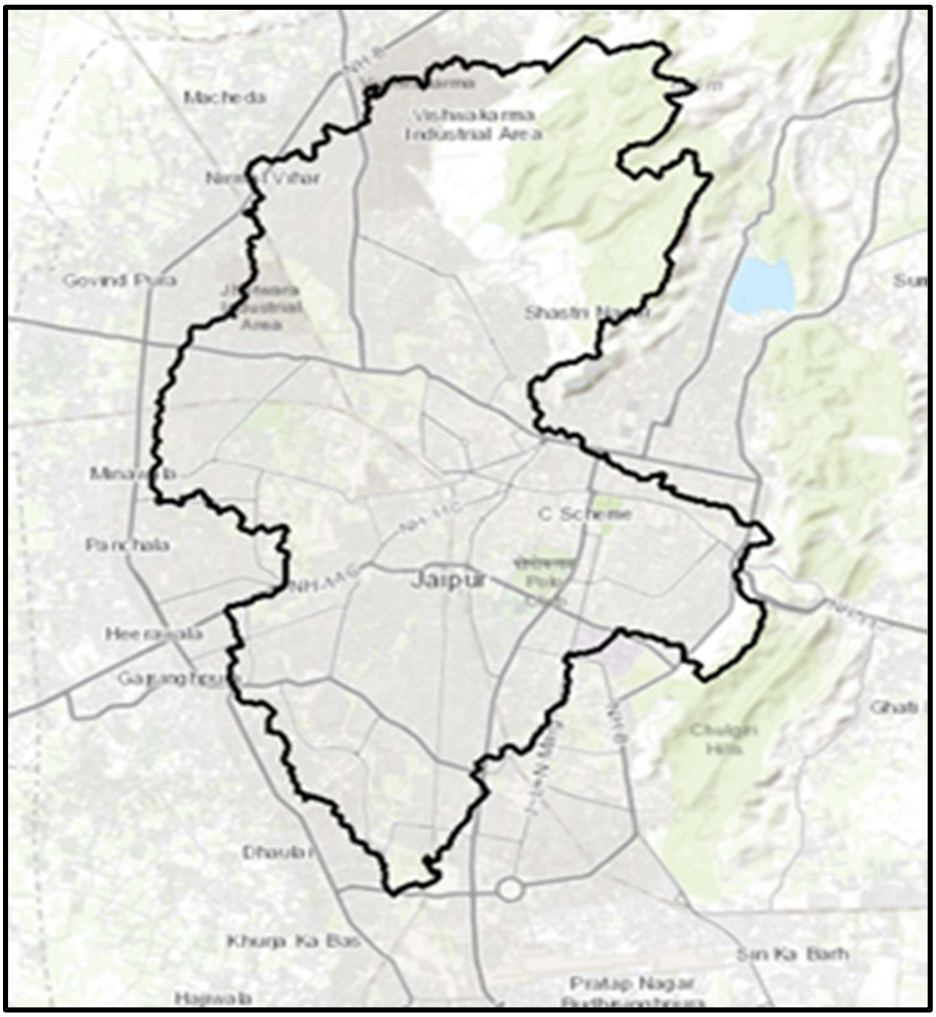


Fig.11. Extracted Watershed

6.8 ASSIGNING ORDER TO THE STREAM NETWORK

Stream ordering is a method of assigning a numeric order to links in a stream network. This order is a method for identifying and classifying types of streams based on their numbers of tributaries. Some characteristics of streams can be inferred by simply knowing their order.

The Stream Order tool has two methods to assign orders. These are the methods proposed by Strahler (1957) and Shreve (1966).

1. **Strahler Method**

In the Strahler method, all links without any tributaries are assigned an order of 1 and are referred to as first order.The stream order increases when streams of the same order intersect. Therefore, the intersection of two first-order links will create a second-order link, the intersection of two second-order links will create a third-order link, and so on. The intersection of two links of different orders, however, will not result in an increase in order. The Strahler method is the most common stream ordering method. However, because this method only increases in order at intersections of the same order, it does not account for all links and can be sensitive to the addition or removal of links.

2. **Shreve Method**

The Shreve method accounts for all links in the network. As with the Strahler method, all exterior links are assigned an order of 1. For all interior links in the Shreve method, however, the orders are additive. For example, the intersection of two first-order links creates a second-order link, the intersection of a first-order and second-order link creates a third-order link, and the intersection of a second-order and third-order link creates a fifth-order link.Because the orders are additive, the numbers from the Shreve method are sometimes referred to as magnitudes instead of orders. The magnitude of a link in the Shreve method is the number of upstream links.

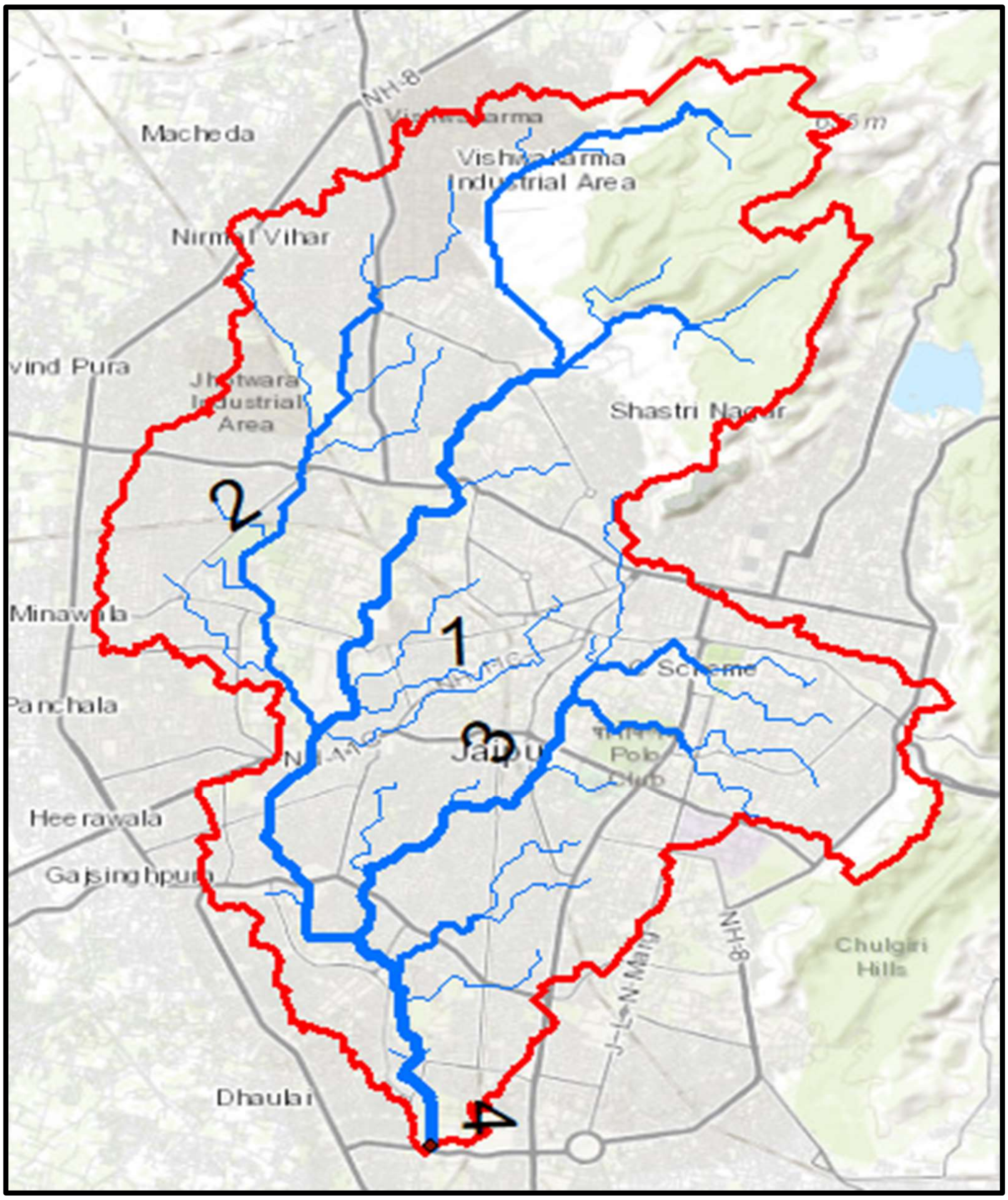


Fig12. Stream order

6.9 CALCULATION OF LENGTH OF STREAM NETWORK

The graph below represents the length of the stream network of order 1,2,3 and 4 .

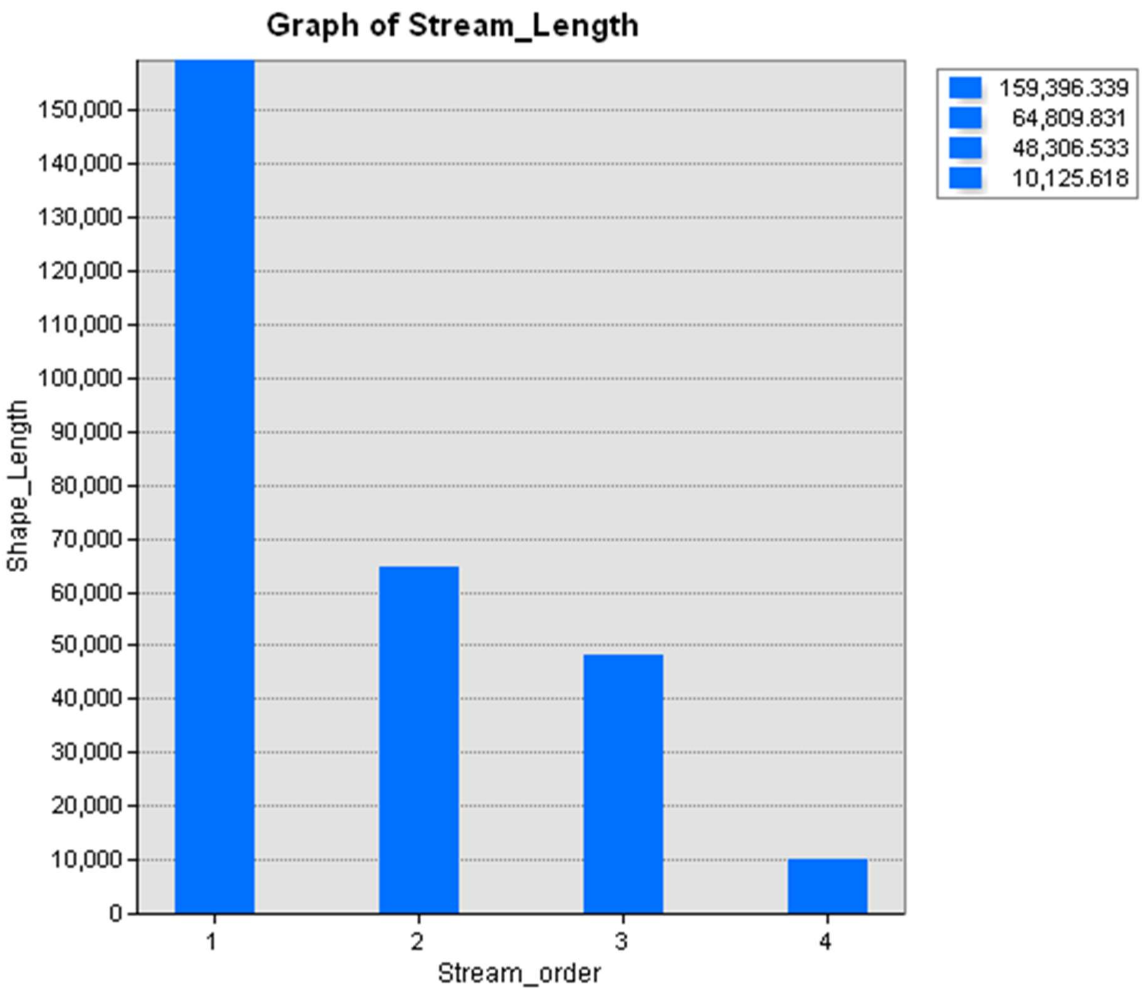


Fig.13 Length of Stream Network

6.10 LANDSAT & SENTINEL DATA ACQUISITION

The LANDSAT and SENTINEL images surrounding the watershed have been downloaded from USGS Earth Explorer at the interval of 5years.

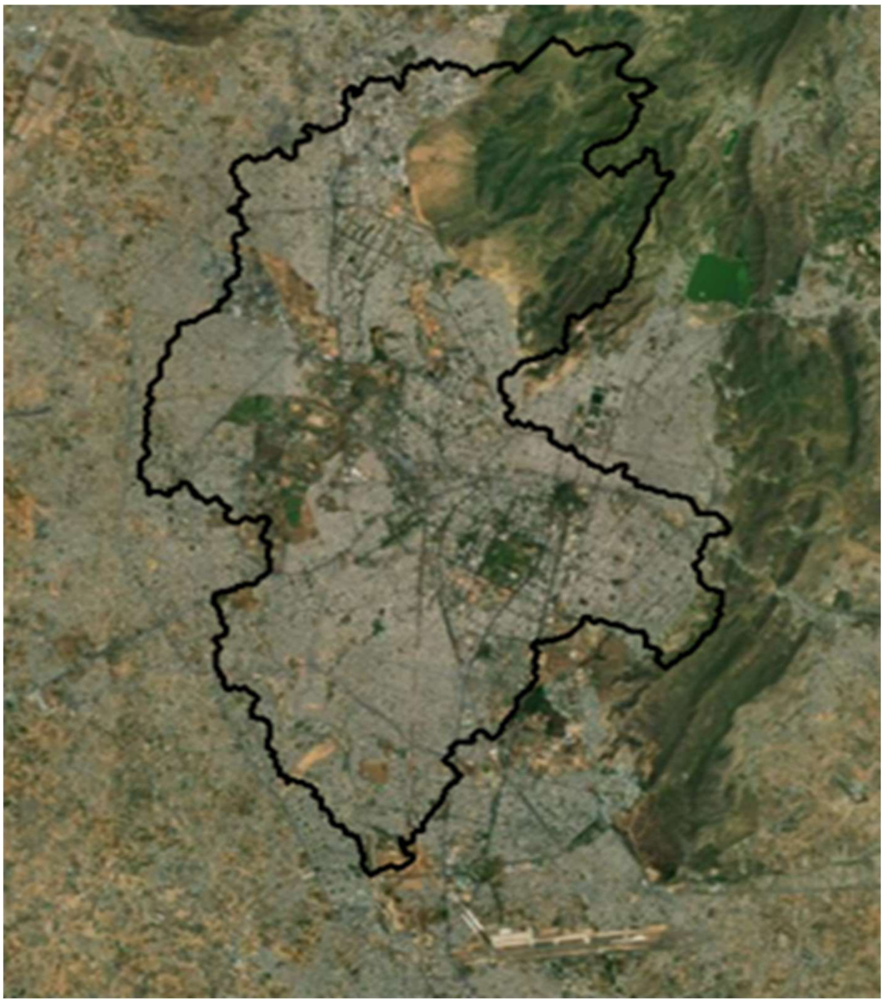


Fig.14. LANDSAT Image

6.11 GENERATION OF FALSE COLOR COMPOSITE

False color images are a representation of a multispectral image produced using any bands other than visible red, green and blue as the red, green and blue components of the display. False color composites allow us to visualize wavelengths that the human eye can not see (i.e. near-infrared and beyond). Using bands such as near infrared highlights the spectral differences and often increases the interpretability of the data. There are many different false colored composites that can be used to highlight different features. To make false colour composite bands 2,4,3 are used of older LANDSAT and 3,4,5 of LANDSAT 8 and 8,4,3 of Sentinel 2.

False Colour Composite of year 2021 has shown below.

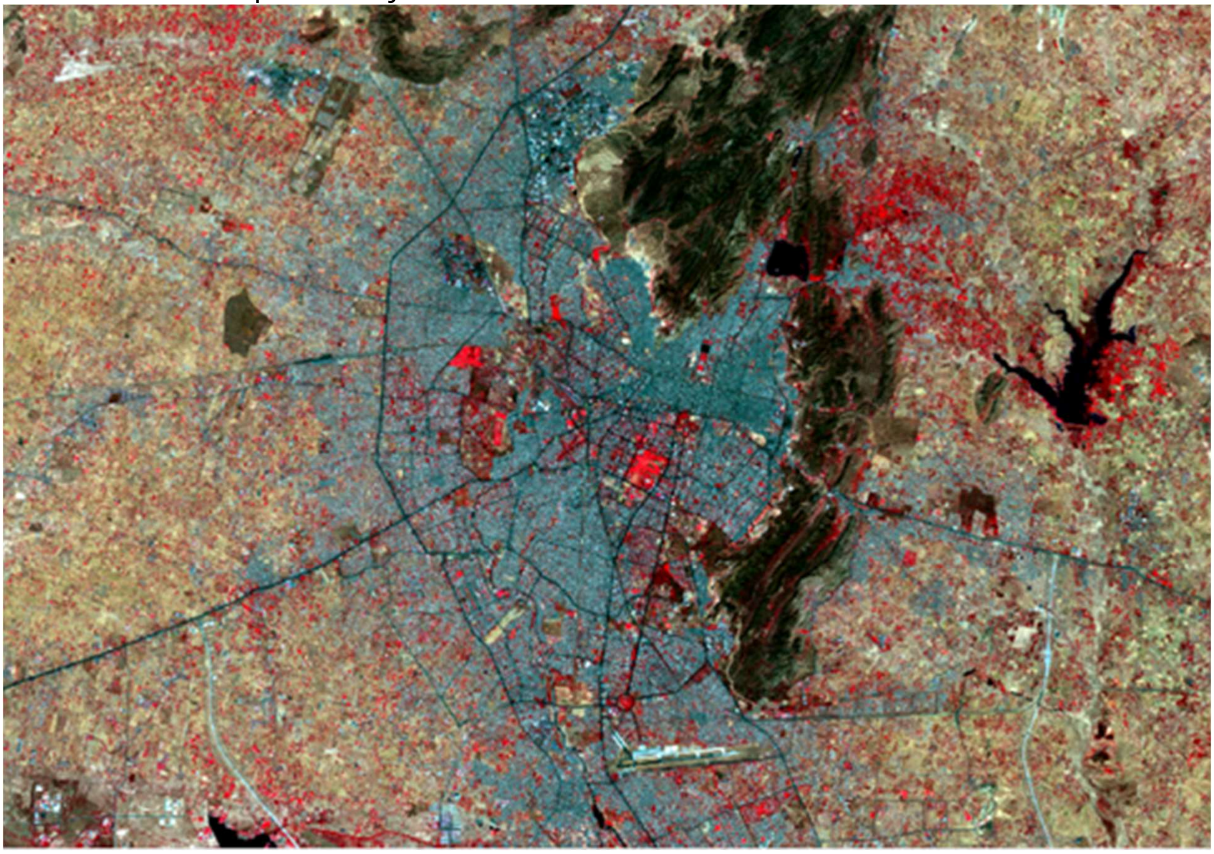


Fig.15 False Colour Composite

6.12 EXTRACTION OF STUDY AREA

From the raster image of False Colour Composite we extracted the area surrounding the watershed.

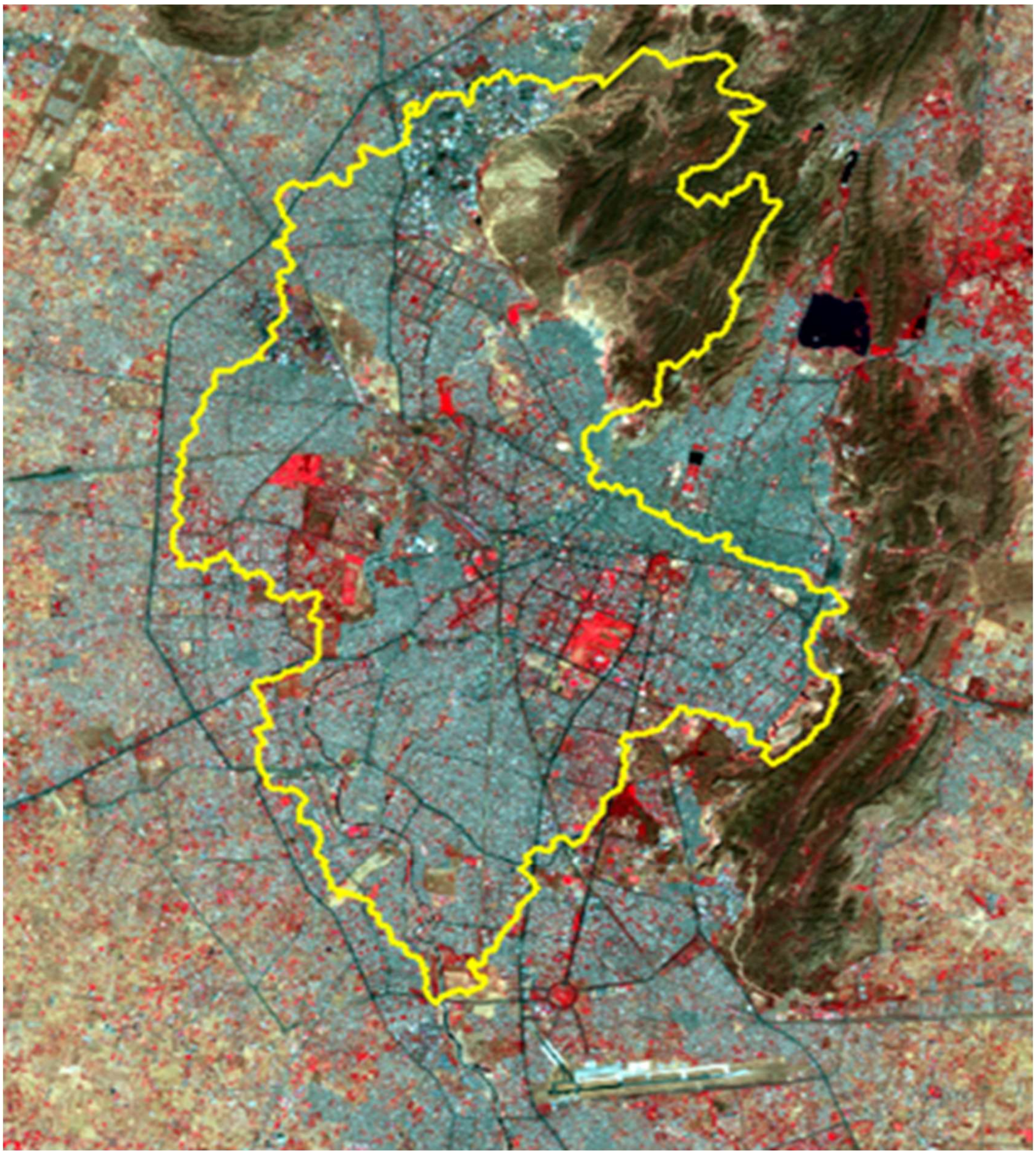


Fig.16. Extracted Study Area

6.13 MAXIMUM LIKELIHOOD CLASSIFICATION

Maximum likelihood classification assumes that the statistics for each class in each band are normally distributed and calculates the probability that a given pixel belongs to a specific class. Unless you select a probability threshold, all pixels are classified. Each pixel is assigned to the class that has the highest probability (that is, the maximum likelihood). If the highest probability is smaller than a threshold you specify, the pixel remains unclassified.

Take 30-45 training samples of each to do the classification of Water Body,Built Up Area ,Barren Land ,Forest and Vegetation.

Figure shows the MAXIMUM LIKELIHOOD CLASSIFICATION of year 2021

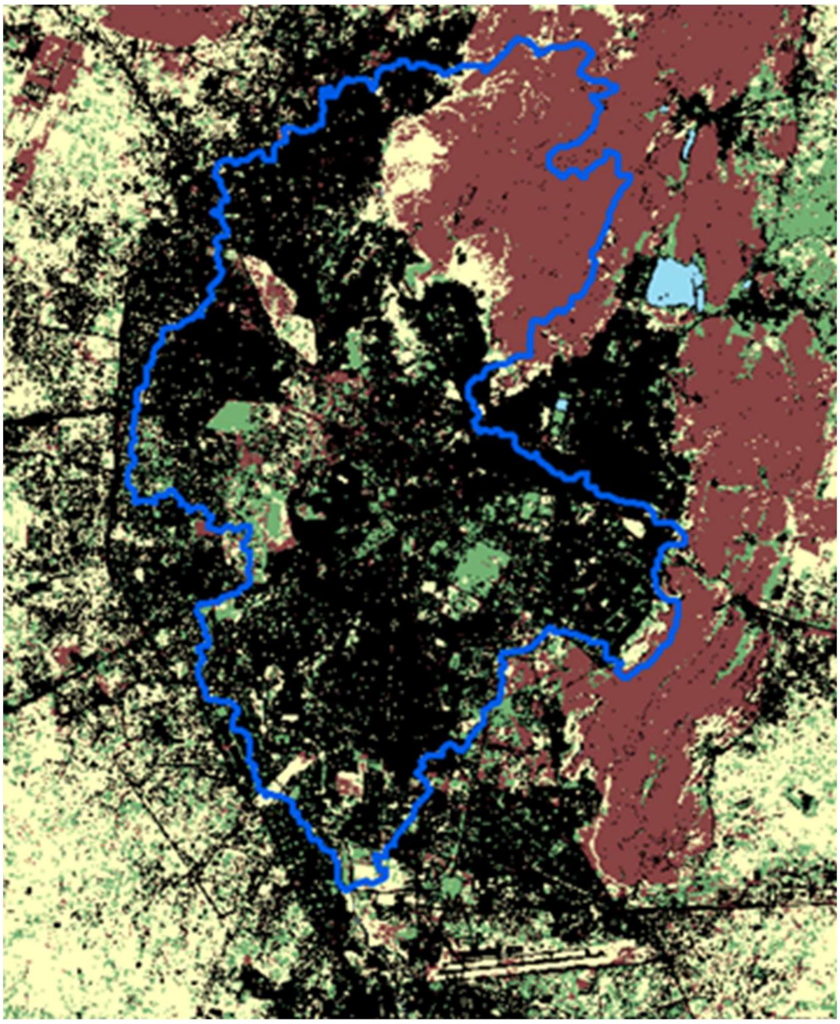


Fig.17 Classified Image

6.14 RESAMPLING OF CLASSIFIED IMAGE

Resampling of all the classified images has been done to bring the classified image of each year to the same pixel value.And we extracted the Land Use Land Cover of each year surrounding the watershed.

Figure shows the Resampled Land Use Land Cover watershed of the year 2021.

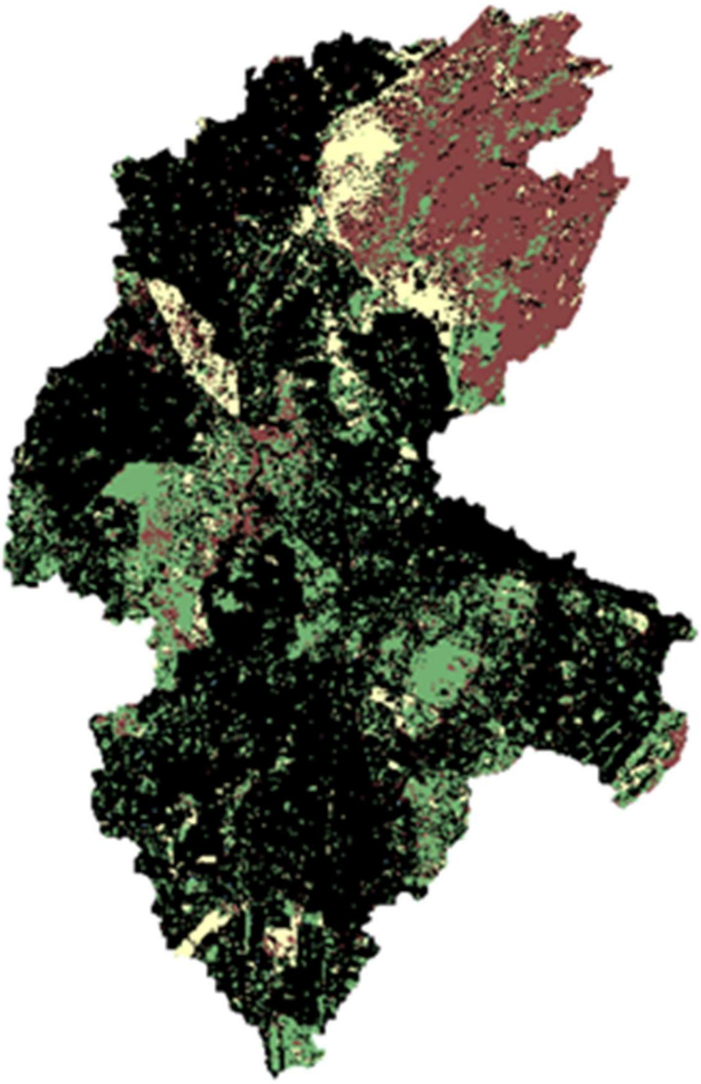


Fig.18 Resampled Classified Image raster

6.15 CONVERSION OF CLASSIFIED MAP TO VECTOR

Convert the Raster Image of LULC into a Vector polygon.From here calculate the area of Water Body ,Built Up ,Barren Land ,Forest and Vegetation.

Figure shows the vector image of LULC of the year 2021.Also calculated the change in area of Water Body ,Built Up ,Barren Land ,Forest and Vegetation.

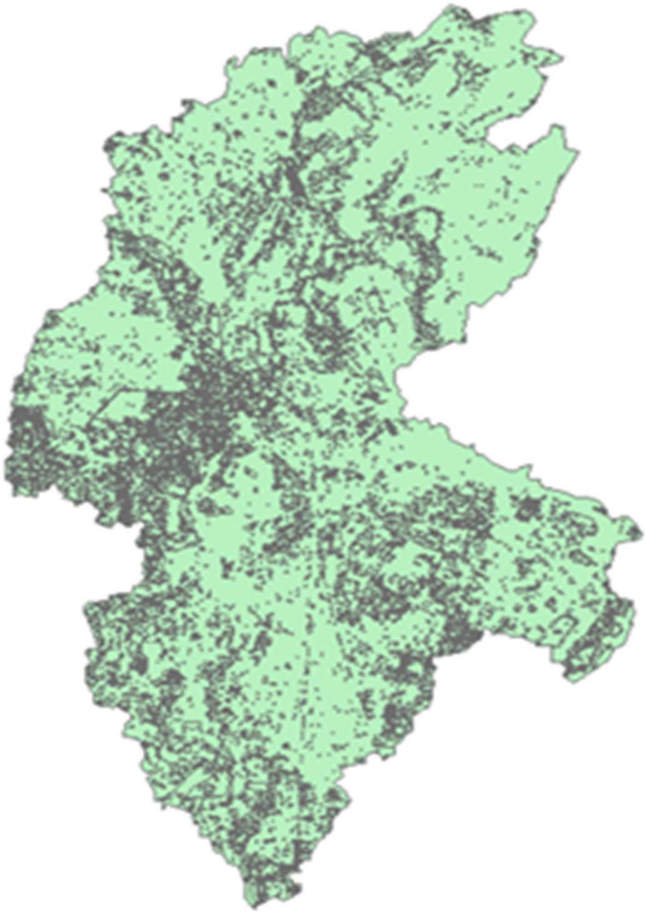


Fig.19 Classified Image Vector

6.16 ACCURACY ASSESSMENT

The accuracy assessment has been done by taking 100 random points and then verifying it from Google Earth Pro.Accuracy assessment is the procedure used to quantify the reliability of a classified image. The standard accuracy assessment procedure is to construct an "error matrix." This is a square matrix in which the rows and columns represent the land cover classes from the classified image.

Accuracy assessment is an important part of any classification project. It compares the classified image to another data source that is considered to be accurate or ground truth data. Ground truth can be collected in the field; however, this is time consuming and expensive. Ground truth data can also be derived from interpreting high-resolution imagery, existing classified imagery, or GIS data layers.The most common way to assess the accuracy of a classified map is to create a set of random points from the ground truth data and compare that to the classified data in a confusion matrix.

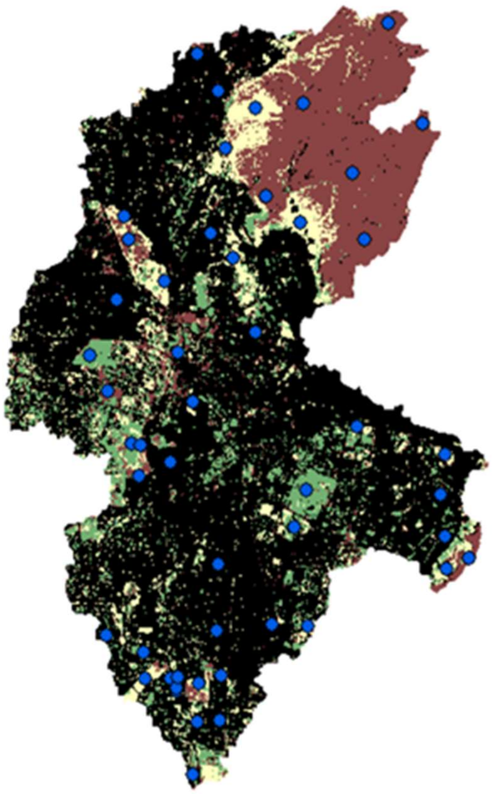


Fig.20 Accuracy Assessment Sample

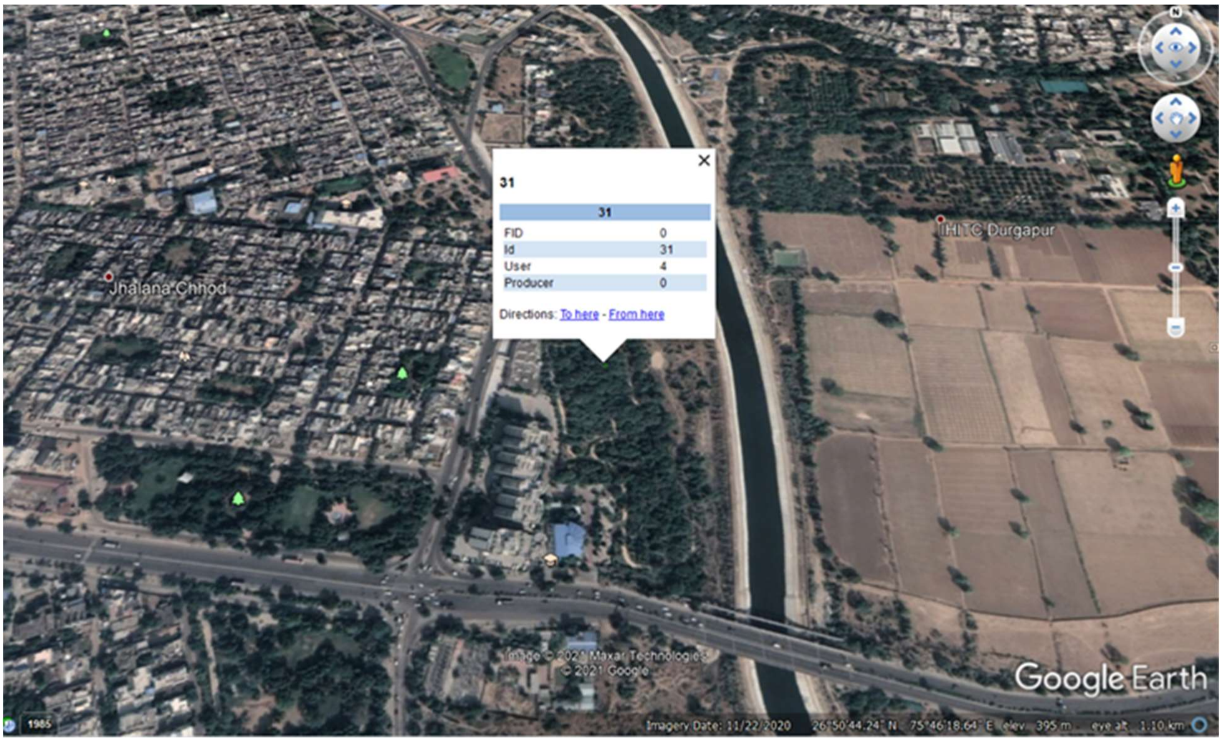


Fig.21 Point Relocation In Google Earth Pro

CHAPTER 7
RESULTS AND DISCUSSIONS

Detailed accuracy assessment of all the classification maps was carried out for the period of 1900–2021 using error matrix / confusion matrix method for study area situated in Jaipur of Rajasthan State. Along with that, attempts were made to calculate overall accuracy, user accuracy, producer accuracy and kappa coefficient to verify the relevance of generated maps.

The accuracy assessment results revealed that the classified land-use/cover maps had an overall accuracy of 88%(1990), 87%(1995), 85% (2000), 92%(2010), 90%(2015), 93%(2018), 96%(2020), 94.95%(2021).

The overall accuracy results revealed that all of the classified maps' accuracies were more than 85%, which indicates that the image processing approaches adopted in this study was effective in producing compatible land use/cover data over time.

A detailed analysis of urbanisation trend of the study area which is situated in Jaipur, Rajasthan has been presented below which covers deep analysis of land cover classification maps, area comparison on yearly basis, percentage breakdown of land cover classes from 1990-2021, percentage increase/decrease in the area since 1990.

Furthermore, land change intensity analysis, annual change intensity, uniform intensity and urban growth rate analysis were also performed using Google Sheets.

7.1 LAND COVER CLASSIFICATION MAPS (1990 -2021)

Attempts were made to generate classification maps from the time interval of 1990 to 2021 for the study area using Maximum Likelihood Classification algorithm (i.e. pixel based supervised classification technique) using ArcGIS 10.2 software.

As the LANDSAT data downloaded in 2005 from USGS Earth Explorer was distorted and hence we were unable to generate classification maps for the same. Following are the generated classification maps from the time interval of 1990 to 2021 :

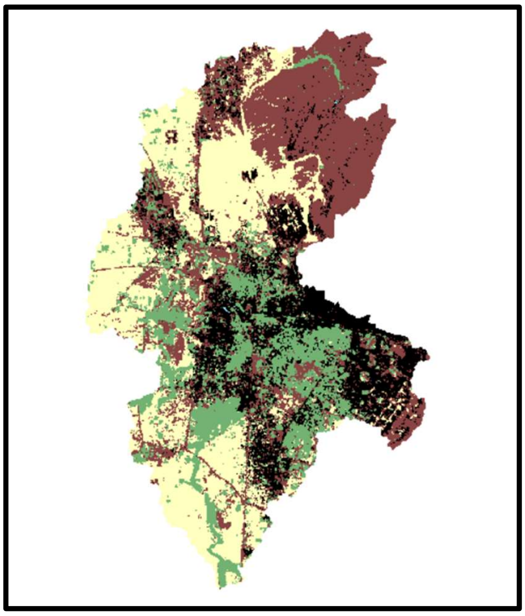


Fig.22. Classification map of 1990

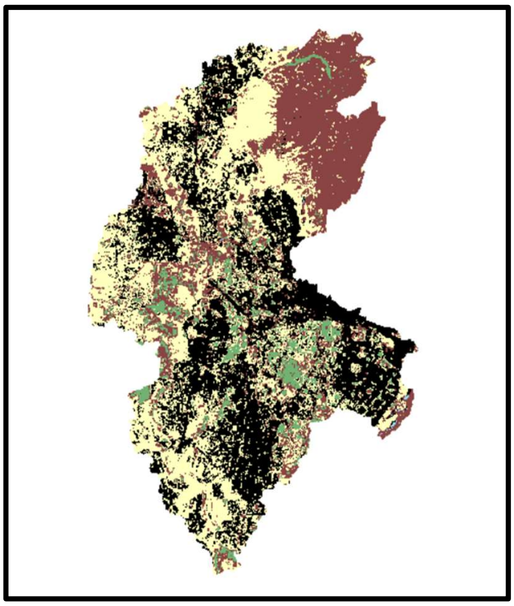


Fig.23. Classification map of 1995

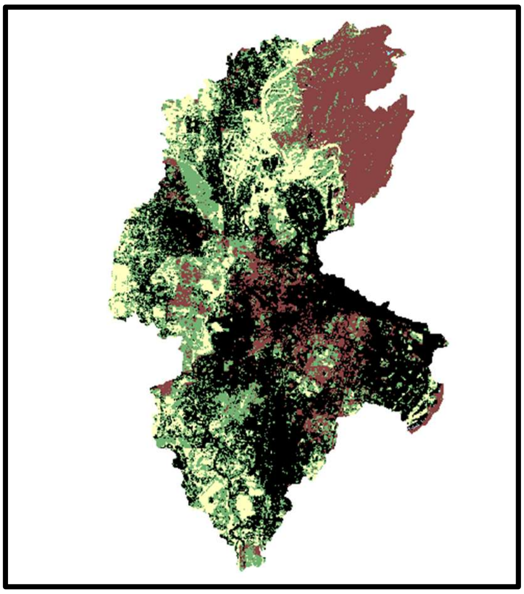


Fig.24. Classification map of 2000

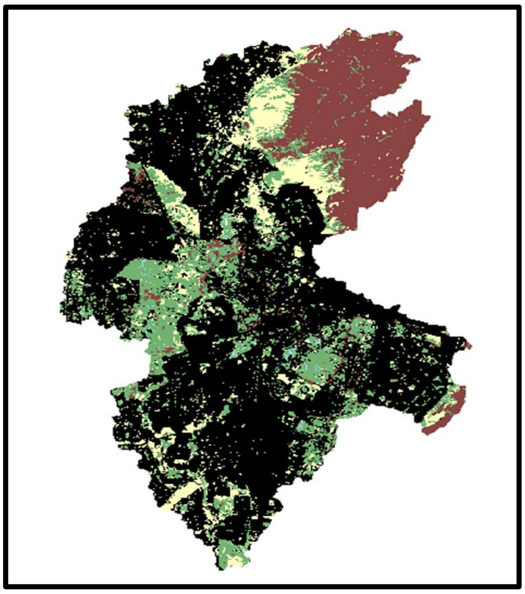


Fig.25. Classification map of 2010

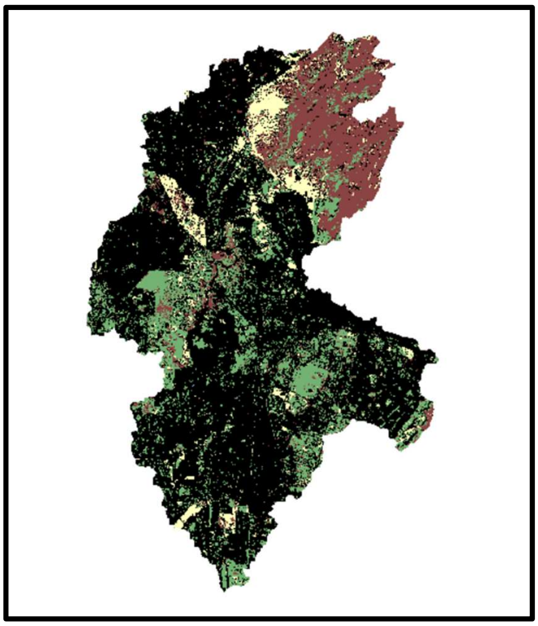


Fig.26. Classification map of 2015

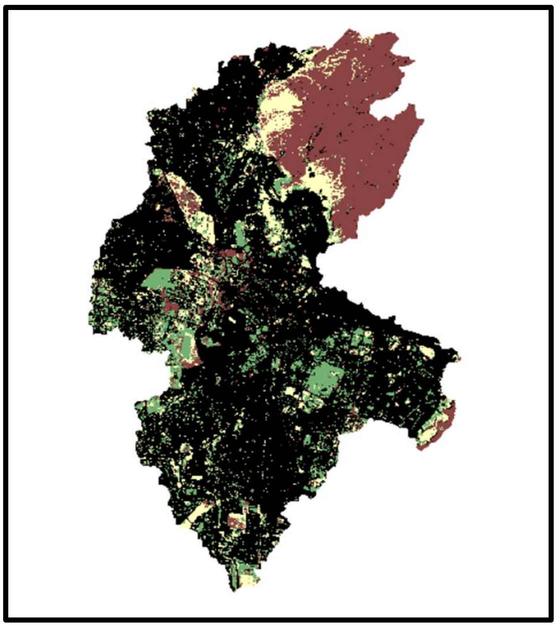


Fig.27. Classification map of 2020

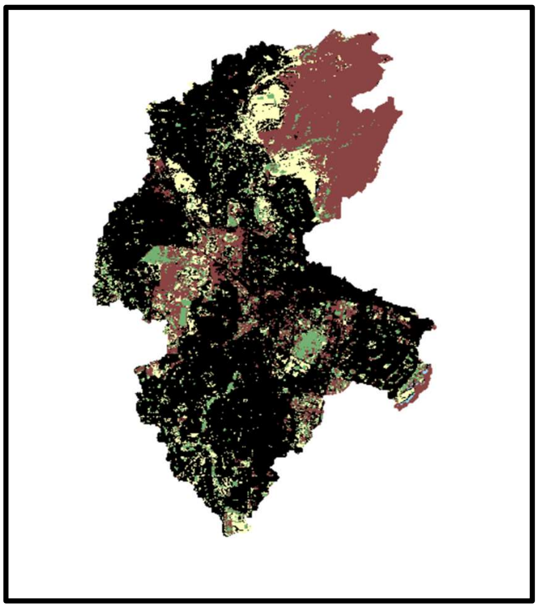
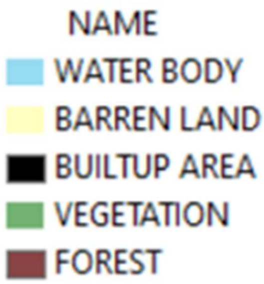


Fig.28. Classification map of 2021



7.2 ACCURACY ASSESSMENT OF CLASSIFIED MAPS

For the quantitative accuracy assessment of land-use/cover mapping, a total of 100 randomly selected sample points in shapefile format were used. Google Earth Pro images and topographical maps were used as reference in verifying the land-use /cover of these points.

The sample points verified using the topographical maps were first overlaid with the georeferenced topographic maps using ArcGIS software. The sample points verified using Google Earth images were first converted into kml file format and uploaded to Google Earth Pro for a careful and rigorous visual inspection.

For the year of 1990, images retrieved from Google Earth Pro were not clear enough as the image resolution at that time was not satisfactory. Hence, low overall accuracy of the 1990 year i.e. 85% as compared to the year of 2021 with overall accuracy of 92% was noted.

Classification process is said to be completed once its accuracy is tested. Accuracy can be obtained by preparation of error matrix or confusion matrix. User accuracy, producer accuracy, overall accuracy and kappa statistics were calculated from the error matrix. Overall accuracy considers only diagonal elements of reference map and classified map whereas kappa statistic takes off diagonal elements also into account.

The accuracy assessment results revealed that the classified land-use/cover maps had an overall accuracy of 88%(1990), 87%(1995), 85% (2000), 92%(2010), 90%(2015), 93%(2018), 96%(2020), 94.95%(2021).

Furthermore, kappa coefficients for the classification maps are 0.85(1990), 0.83(1995), 0.81 (2000), 0.90(2010), 0.87(2015), 0.91(2018), 0.05(2020), 0.92(2021).

The overall accuracy results revealed that all of the classified maps' accuracies were more than 85%, which indicate that the image processing approach adopted in this study was effective in producing compatible land use/cover data over time.

ERROR MATRIX / CONFUSION MATRIX (1990-2021)

Class	Barren Land	Built Up Area	Forest	Vegetation	Water Body	Total (User)	User's Accuracy(%)
Barren Land	18	0	0	2	0	20	**90.00**
Built Up Area	1	29	0	0	0	30	**96.67**
Forest	3	1	15	1	0	20	**75.00**
Vegetation	0	0	1	19	0	20	**95.00**
Water Body	0	0	1	2	7	10	**70.00**
Total (Producer)	22	30	17	24	7	100	
Producer's Accuracy(%)	**81.82**	**96.67**	**88.24**	**79.17**	**100.00**		

Overall Accuracy(%)	Kappa Coefficient(T)
88.00	0.85

Table 4 : Error Matrix for classified 1990 land use/cover map

Class	Barren Land	Built Up Area	Forest	Vegetation	Water Body	Total (User)	User's Accuracy(%)
Barren Land	15	2	0	3	0	20	**75.00**
Built Up Area	0	30	0	0	0	30	**100.00**
Forest	1	0	18	1	0	20	**90.00**
Vegetation	0	0	2	17	1	20	**85.00**
Water Body	0	0	2	1	7	10	**70.00**
Total (Producer)	16	32	22	22	8	100	
Producer's Accuracy(%)	**93.75**	**93.75**	**81.82**	**77.27**	**87.50**		

Overall Accuracy(%)	Kappa Coefficient(T)
87.00	0.83

Table 5 : Error Matrix for classified 1995 land use/cover map

Class	Barren Land	Built Up Area	Forest	Vegetation	Water Body	Total (User)	User's Accuracy(%)

Barren Land	16	1	0	3	0	20	80.00
Built Up Area	0	28	2	0	0	30	93.33
Forest	1	0	17	2	0	20	85.00
Vegetation	0	0	3	17	0	20	85.00
Water Body	0	0	2	1	7	10	70.00
Total (Producer)	17	29	24	23	7	100	
Producer's Accuracy(%)	94.12	96.55	70.83	73.91	100.00		

Overall Accuracy(%)	**Kappa Coefficient(T)**
85.00	0.81

Table 6 : Error Matrix for classified 2000 land use/cover map

Class	**Barren Land**	**Built Up Area**	**Forest**	**Vegetation**	**Water Body**	**Total (User)**	**User's Accuracy(%)**
Barren Land	19	0	0	1	0	20	**95.00**
Built Up Area	0	30	0	0	0	30	**100.00**
Forest	0	0	16	4	0	20	**80.00**
Vegetation	0	0	2	18	0	20	**90.00**
Water Body	0	0	1	0	9	10	**90.00**
Total (Producer)	19	30	19	23	9	100	
Producer's Accuracy(%)	**100.00**	**100.00**	**84.21**	**78.26**	**100.00**		

Overall Accuracy(%)	**Kappa Coefficient(T)**
92.00	0.90

Table 7 : Error Matrix for classified 2010 land use/cover map

Class	**Barren Land**	**Built Up Area**	**Forest**	**Vegetatio n**	**Water Body**	**Total (User)**	**User's Accuracy(%)**
Barren Land	18	0	1	1	0	20	**90.00**

Built Up Area	0	29	0	1	0	30	**96.67**
Forest	0	0	18	2	0	20	**90.00**
Vegetation	0	0	3	17	0	20	**85.00**
Water Body	0	0	2	0	8	10	**80.00**
Total (Producer)	18	29	24	21	8	100	
Producer's Accuracy(%)	**100.00**	**100.00**	**75.00**	**80.95**	**100.00**		

Overall Accuracy(%)	**Kappa Coefficient(T)**
90.00	0.87

Table 8 : Error Matrix for classified 2015 land use/cover map

Class	**Barren Land**	**Built Up Area**	**Forest**	**Vegetation**	**Water Body**	**Total (User)**	**User's Accuracy(%)**
Barren Land	19	0	0	1	0	20	**95.00**
Built Up Area	0	28	0	2	0	30	**93.33**
Forest	0	0	17	3	0	20	**85.00**
Vegetation	1	0	0	19	0	20	**95.00**
Water Body	0	0	0	0	10	10	**100.00**
Total (Producer)	20	28	17	25	10	100	
Producer's Accuracy(%)	**95.00**	**100.00**	**100.00**	**76.00**	**100.00**		

Overall Accuracy(%)	**Kappa Coefficient(T)**
93.00	0.91

Table 9 : Error Matrix for classified 2018 land use/cover map

Class	**Barren Land**	**Built Up Area**	**Forest**	**Vegetation**	**Water Body**	**Total (User)**	**User's Accuracy(%)**
Barren Land	18	0	0	2	0	20	**90.00**
Built Up Area	0	30	0	0	0	30	**100.00**
Forest	0	0	19	1	0	20	**95.00**

Vegetation	1	0	0	19	0	20	**95.00**
Water Body	0	0	0	0	10	10	**100.00**
Total (Producer)	19	30	19	22	10	100	
Producer's Accuracy(%)	**94.74**	**100.00**	**100.00**	**86.36**	**100.00**		

Overall Accuracy(%)	Kappa Coefficient(T)
96.00	0.95

Table 10 : Error Matrix for classified 2020 land use/cover map

Class	Barren Land	Built Up Area	Forest	Vegetation	Water Body	Total (User)	User's Accuracy(%)
Barren Land	20	0	0	0	0	20	**100.00**
Built Up Area	0	30	0	0	0	30	**100.00**
Forest	0	0	18	2	0	20	**90.00**
Vegetation	0	0	2	17	0	19	**89.47**
Water Body	0	0	0	1	9	10	**90.00**
Total (Producer)	20	30	20	20	9	99	
Producer's Accuracy(%)	**100.00**	**100.00**	**90.00**	**85.00**	**100.00**		

Overall Accuracy(%)	Kappa Coefficient(T)
94.95	0.92

Table 11: Error Matrix for classified 2021 land use/cover map

7.3 COMPARISON OF OVERALL ACCURACY

Here, in this section, comparisons have been made between different data sources that were used throughout the study and its corresponding overall accuracy and kappa coefficient that was achieved.

Year	Data Source	Overall Accuracy(%)	Kappa Coefficient(T)
1990	LANDSAT 5 (TM C1 Level-1)	88.00	0.85
1995	LANDSAT 5 (TM C1 Level-1)	87.00	0.83
2000	LANDSAT 7 (ETM+ C1 Level 1)	85.00	0.81
2010	LANDSAT 7 (ETM+ C1 Level 1)	92.00	0.90
2015	LANDSAT8 (OLI/TIRS C1 Level 1)	90.00	0.87
2018	SENTINEL 2B	93.00	0.91
2020	SENTINEL 2B	96.00	0.95
2021	SENTINEL 2B	94.95	0.92

Table12 : Overall Accuracy & Kappa Coefficient for time interval 1990-2021

When comparison were made between different data sources used ie LANDSAT 5, LANDSAT 7, LANDSAT 8 and SENTINEL 2B throughout the study, observation were made that as there was shift from LANDSAT to Sentinel data, a significant increase in overall accuracy recorded which have been graphically depicted here. Similarly, Kappa Coefficient also shows a similar trend.

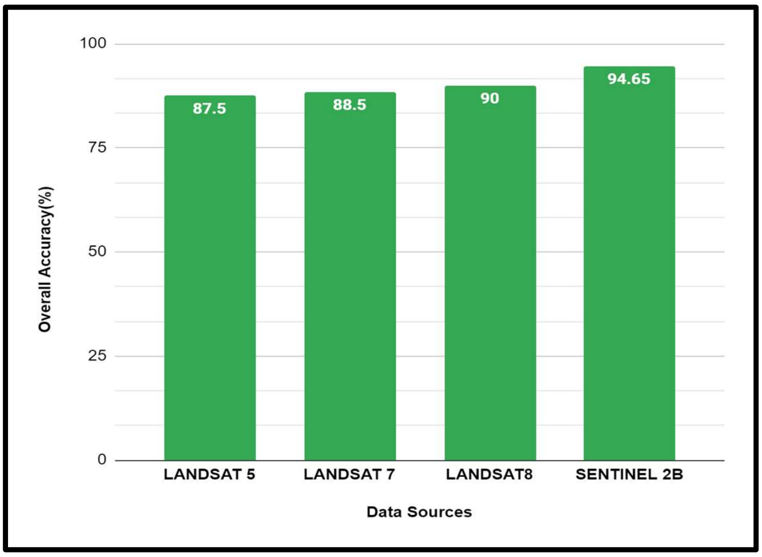


Fig.29 : Data Sources v/s Average Overall Accuracy

7.4 LAND COVER CHANGE DETECTION ANALYSIS

Mapping and monitoring land cover have been widely recognized as an important step to better understand and provide solutions for social, economic, and environmental problems (Adb El-Kawy et al., 2011; Dewan & Yamaguchi, 2009; Foody, 2002). And hence, attempts were made to perform land cover change detection analysis by area comparison for time interval of 1990 to 2021, percentage breakdown of land cover classes for each year that were considered in the project and percentage increase/decrease in area since 1990 which is further discussed in detail.

7.4.1 AREA COMPARISON (1990-2021)

In order to analyze land use land cover detection, attempts were made to compare land cover classes areas for the time interval of 1990 to 2021 and found significant increases in the percentage increase of built up area and other classes i.e. barren land, forest, vegetation, water body to be in declining phase. This could be explained by observing the table below.

Class	1990 Area (km^2)	1995 Area (km^2)	2000 Area (km^2)	2010 Area (km^2)	2015 Area (km^2)	2018 Area (km^2)	2020 Area (km^2)	2021 Area (km^2)
Barren Land	30.78	27.39	23.05	11.14	12.01	9.69	9.27	10.98
Built Up Area	20.99	29.47	39.95	62.53	69.18	73.32	75.47	75.81
Forest	38.55	32.05	28.33	22.10	18.27	17.42	16.98	15.77
Vegetation	28.37	29.74	27.40	23.06	19.39	18.42	17.14	16.33
Water Body	0.24	0.26	0.17	0.10	0.09	0.08	0.06	0.04

Table 13: Land cover change for the study area as extracted from digital images

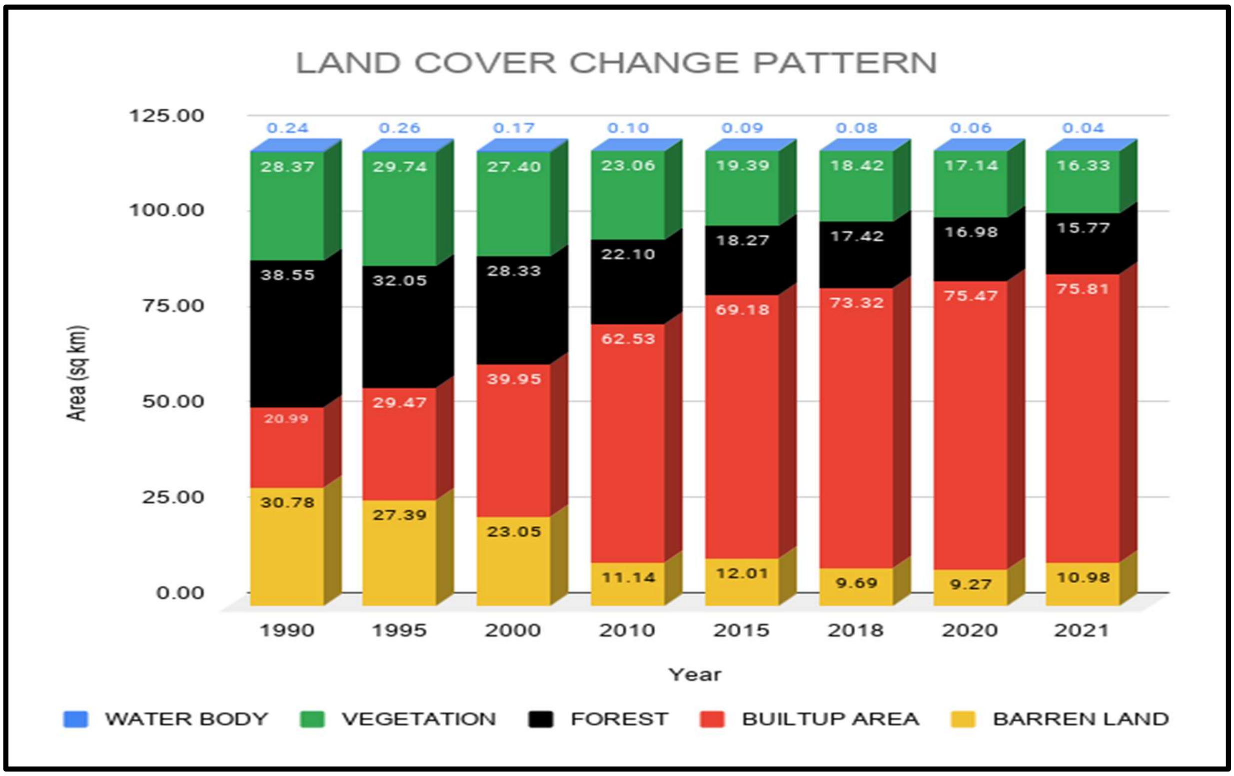


Fig.30. Land Cover/Land Use Change Pattern

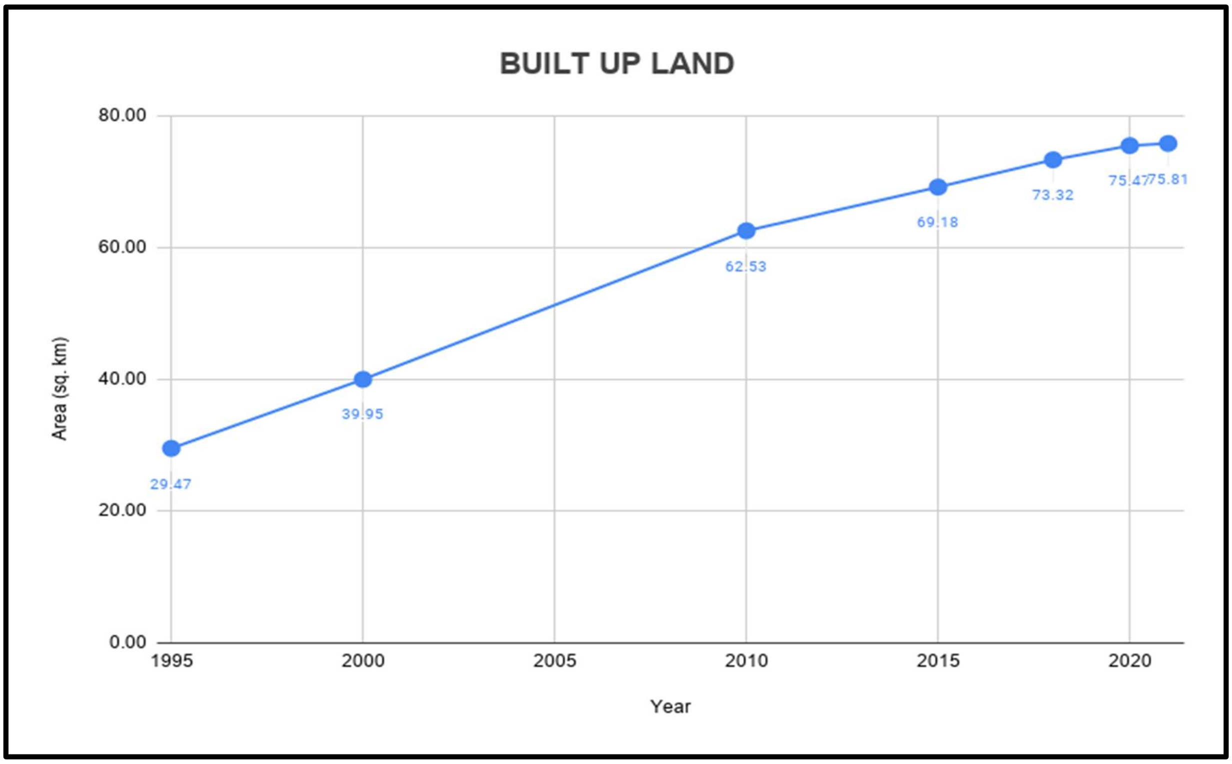


Fig.31. Built Up Land Area Over Time Interval (1990-2021)

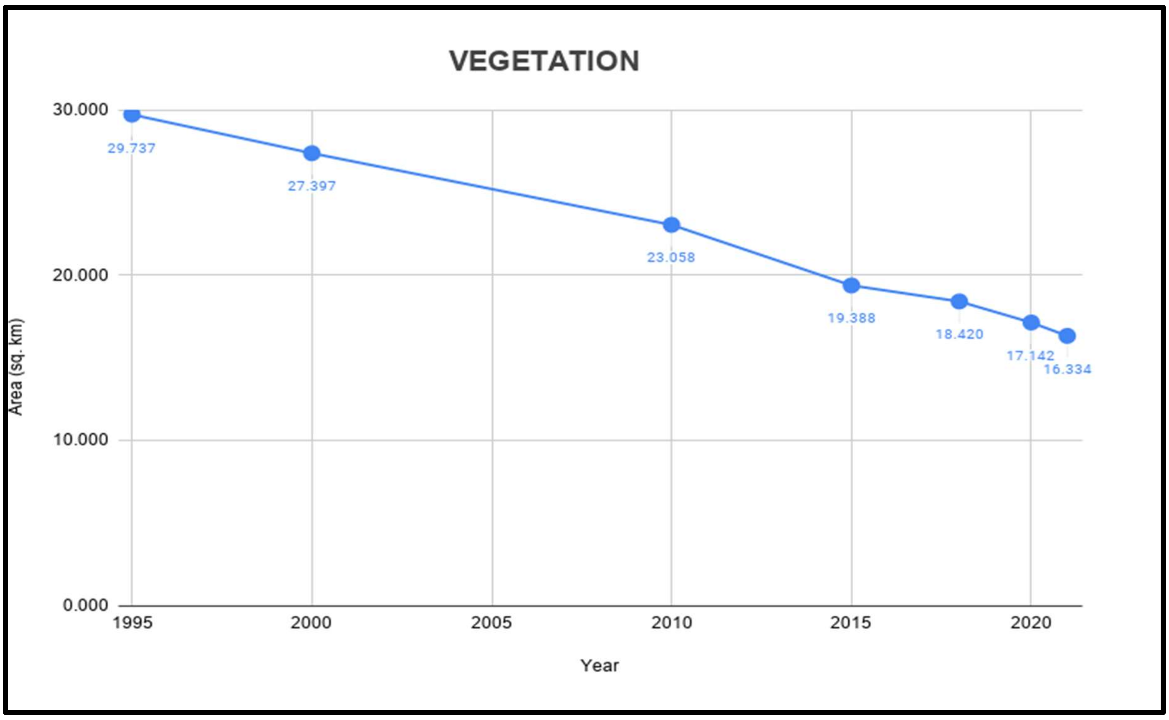
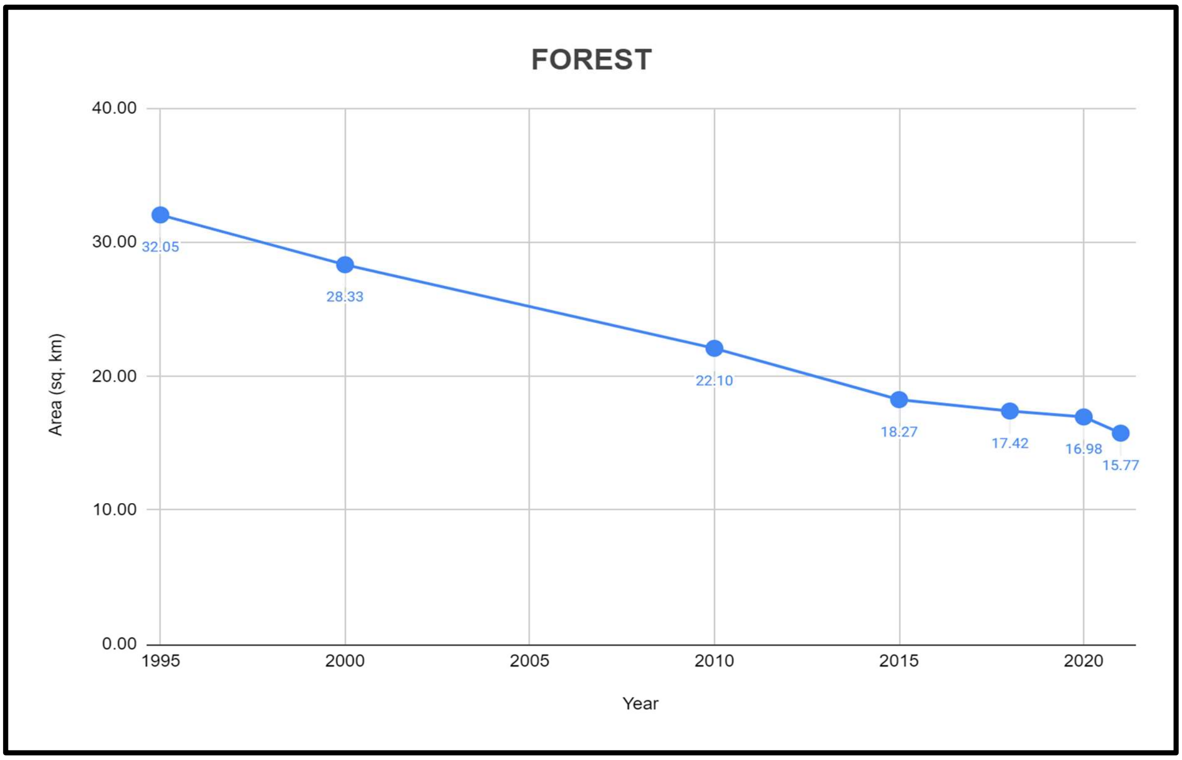


Fig.32. Vegetation Area Over Time Interval (1990-2021)



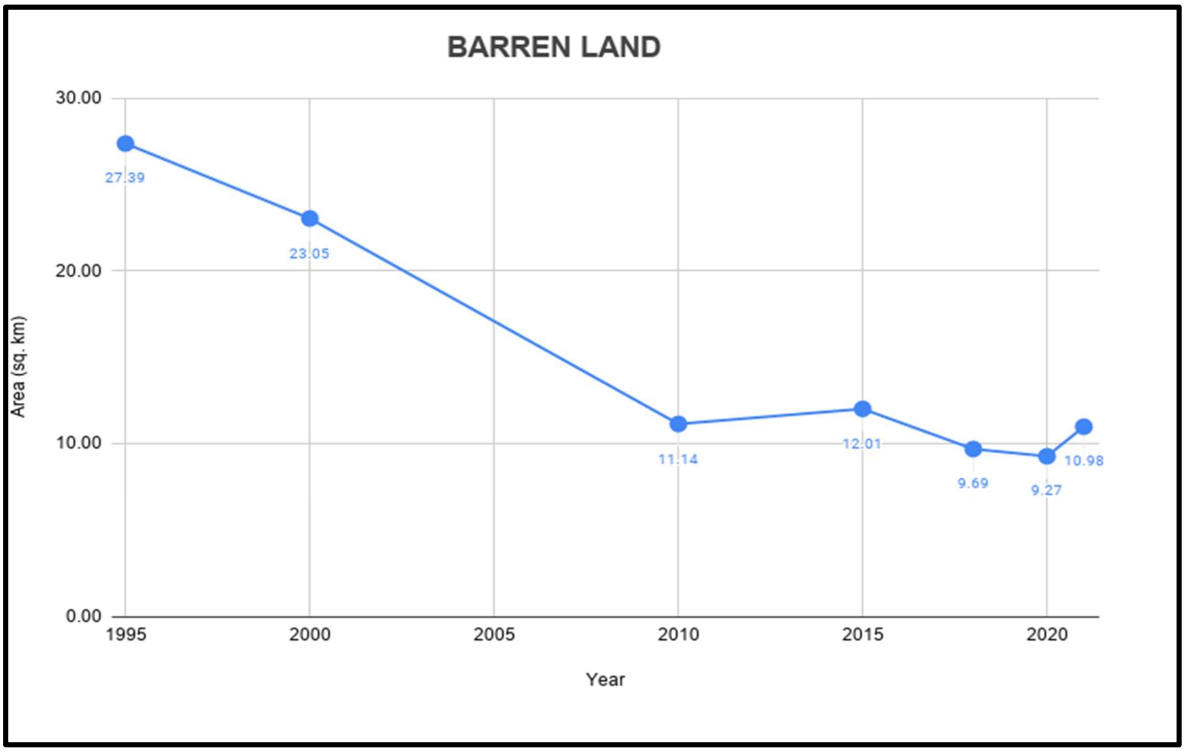


Fig.33. Forest Area Over Time Interval (1990-2021)
Fig.34. Barren Land Area Over Time Interval (1990-2021)

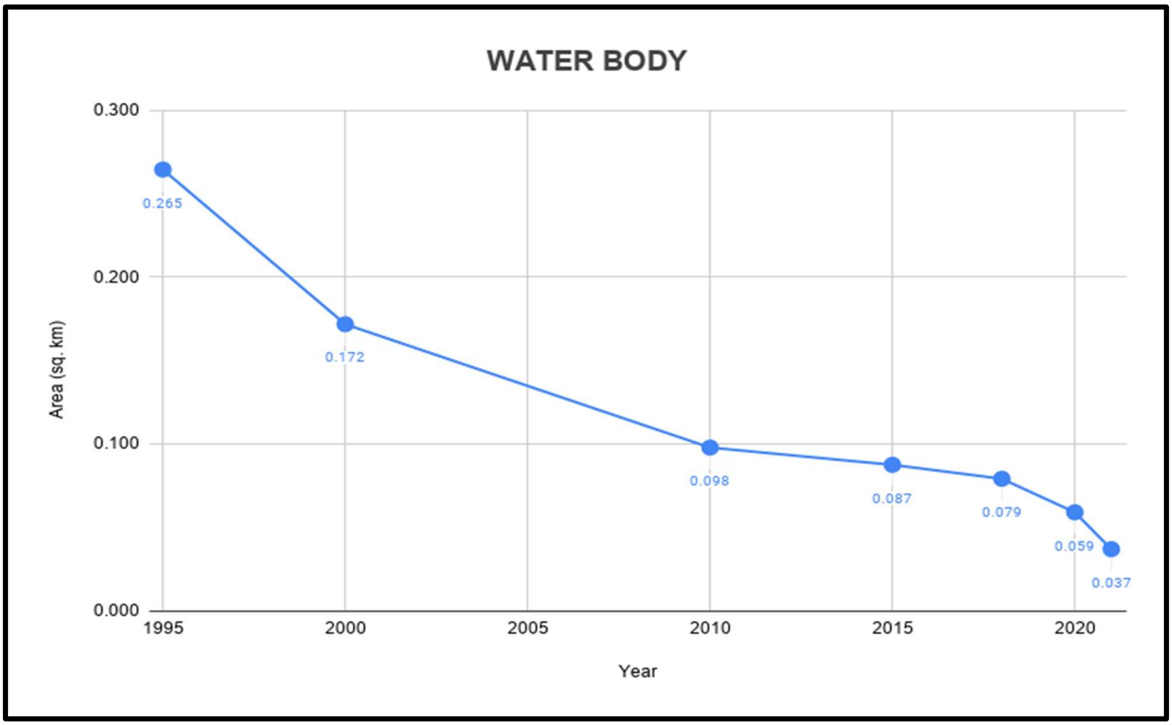


Fig.35. Water Body Over Time Interval (1990-2021)

7.4.2 PERCENTAGE BREAKDOWN OF LAND COVER CLASSES(1990-2021)

In order to understand land use land change detection analysis, attempts were made to analysis percentage breakdown of area of different land cover classes ie barren land, built up area, forest, vegetation, water body for all the year that were considered for the analysis purpose in time interval of 1990 to 2021 for the study area in Jaipur, Rajasthan.

7.4.2.1 Percentage breakdown for land cover classes of year 1990

Class Name	1990 Area(km^2)	(%)
Barren Land	30.78	25.88
Built Up Area	20.99	17.65
Forest	38.55	32.41
Vegetation	28.37	23.85
Water Body	0.24	0.20

Table 14 : Area Distribution for year 1990

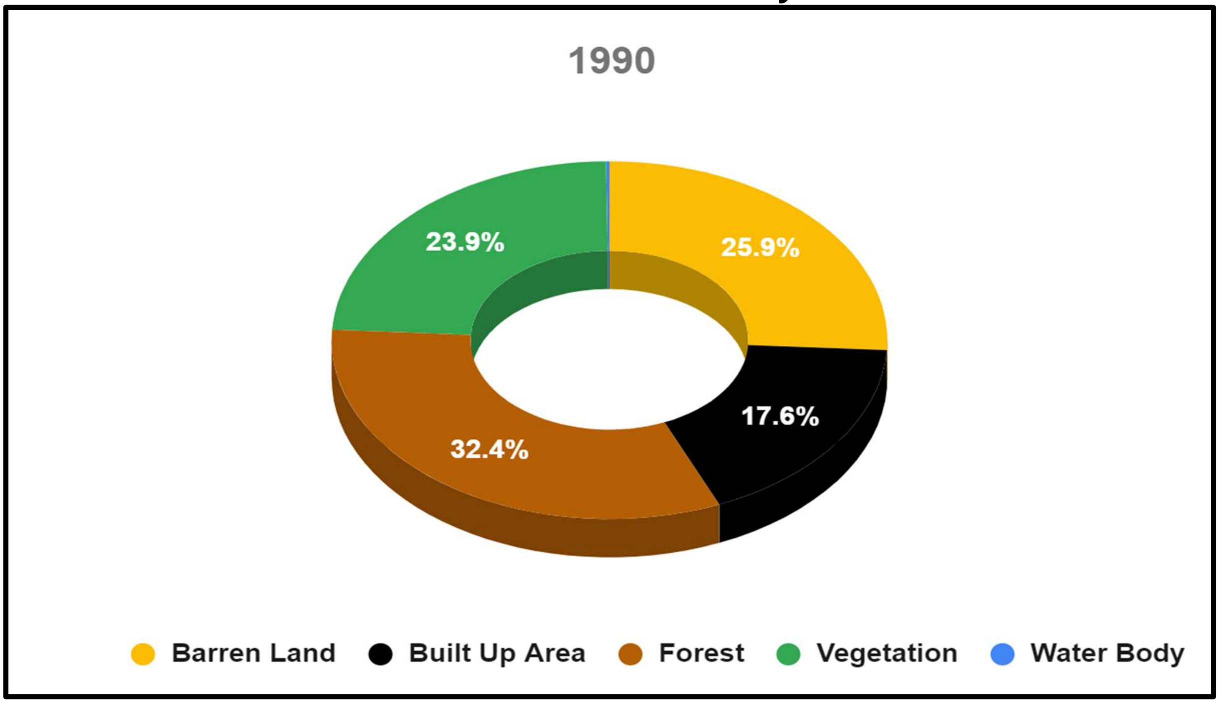


Fig.36. Pie Chart for Area Distribution for year 1990

7.4.2.1 Percentage breakdown for land cover classes of year 1995

Class Name	1995Area(km^2)	(%)
Barren Land	27.39	23.03
Built Up Area	29.47	24.79
Forest	32.05	26.95
Vegetation	29.74	25.01
Water Body	0.26	0.22
Total	118.91	100.00

Table 15 : Area Distribution for year 1995

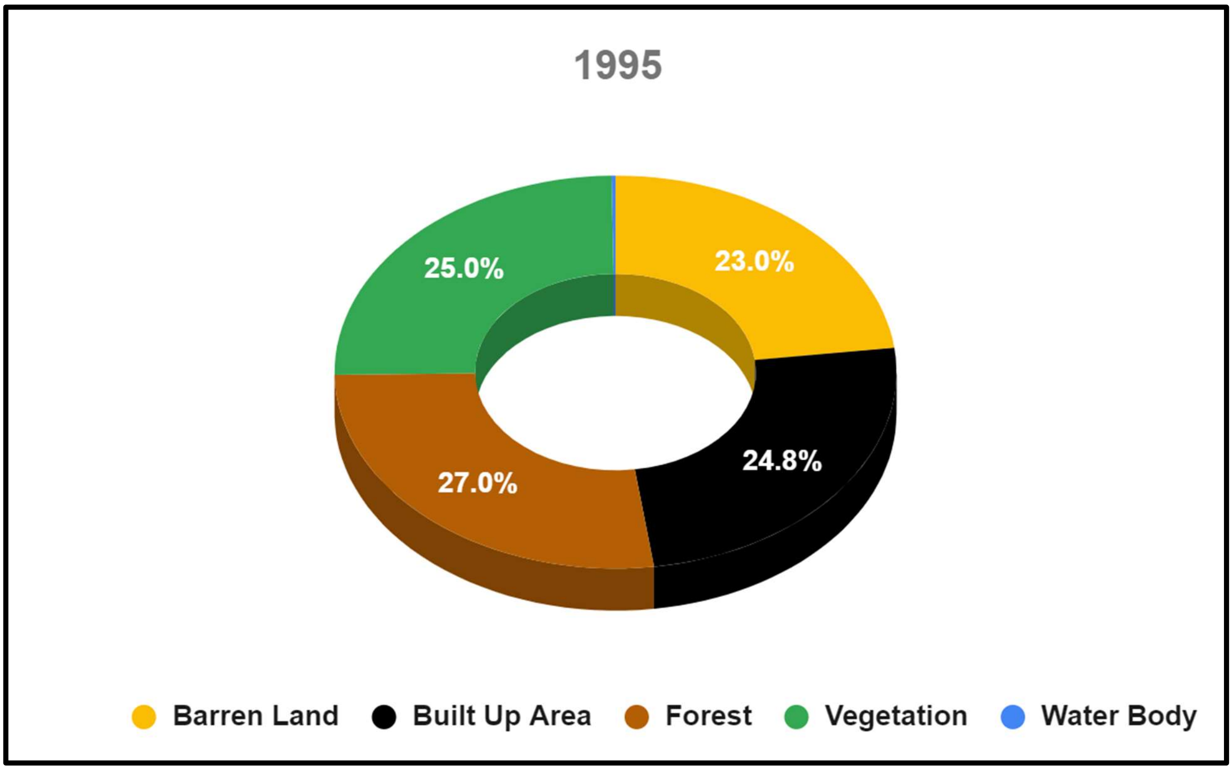


Fig.37. Pie Chart for Area Distribution for year 1995

7.4.2.2. Percentage breakdown for land cover classes year 2000

Class Name	2000 Area(km^2)	(%)
Barren Land	23.05	19.38
Built Up Area	39.95	33.60
Forest	28.33	23.83
Vegetation	27.40	23.04
Water Body	0.17	0.14
Total	118.90	100.00

Table 16 : Area Distribution for year 2000

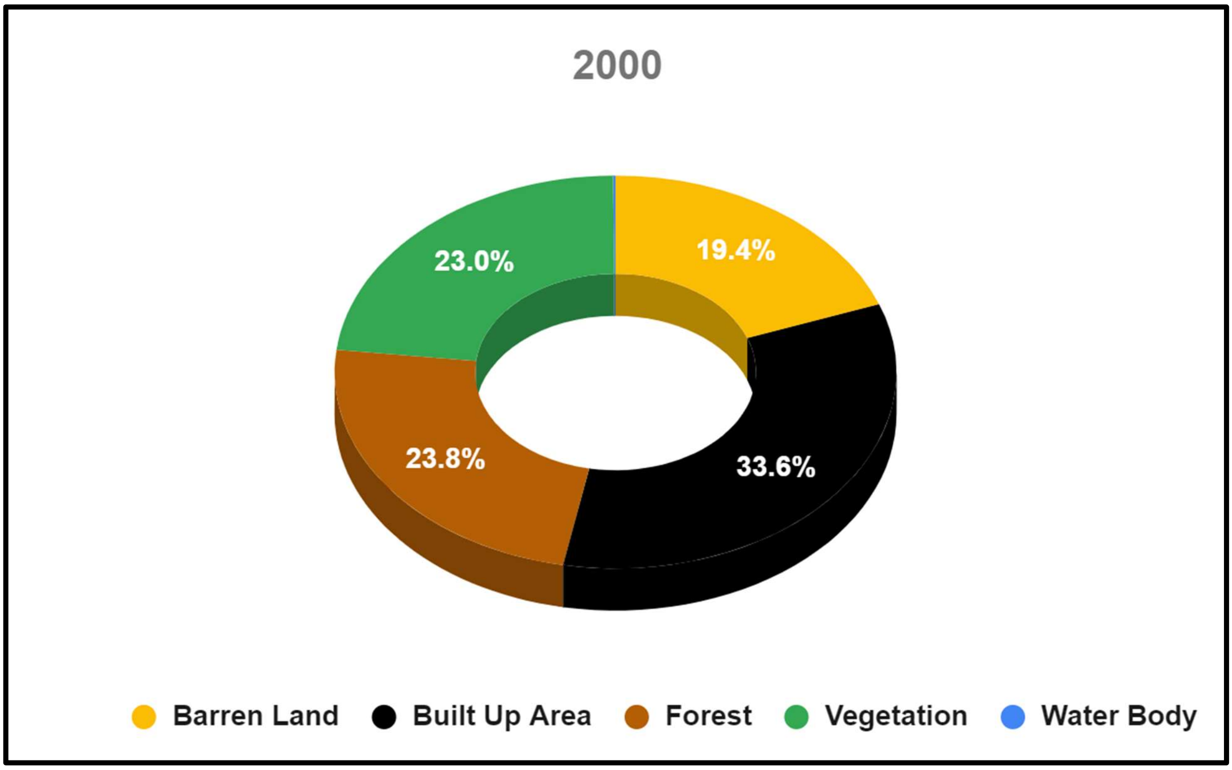


Fig.38. Pie Chart for Area Distribution for year 2000

7.4.2.3. Percentage breakdown for land cover classes year 2010

Class Name	2010 Area(km^2)	(%)
Barren Land	11.14	9.36
Built Up Area	62.53	52.58
Forest	22.10	18.58
Vegetation	23.06	19.39
Water Body	0.10	0.08
Total	118.92	100.00

Table 17 : Area Distribution for year 2010

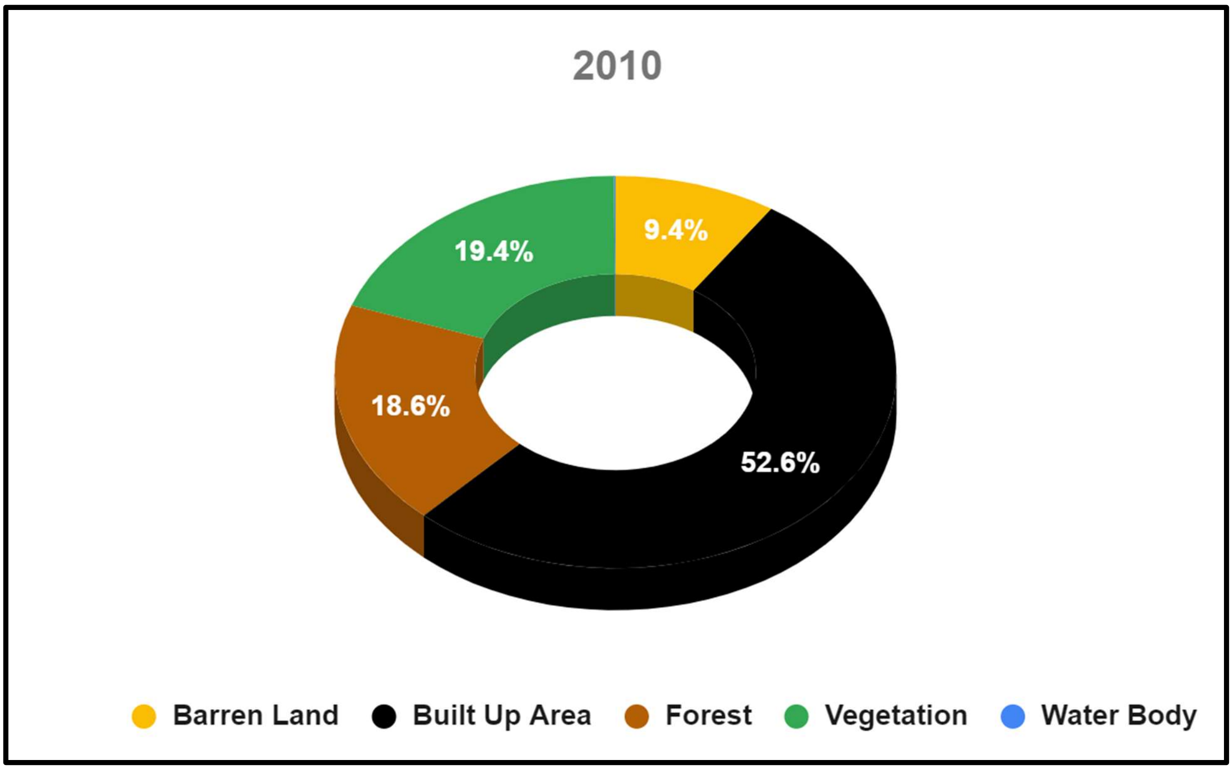


Fig.39. Pie Chart for Area Distribution for year 2010

7.4.2.4. Percentage breakdown for land cover classes year 2015

Class Name	2015 Area(km^2)	(%)
Barren Land	12.01	10.10
Built Up Area	69.18	58.17
Forest	18.27	15.36
Vegetation	19.39	16.30
Water Body	0.09	0.07
Total	118.93	100.00

Table 18 : Area Distribution for year 2015

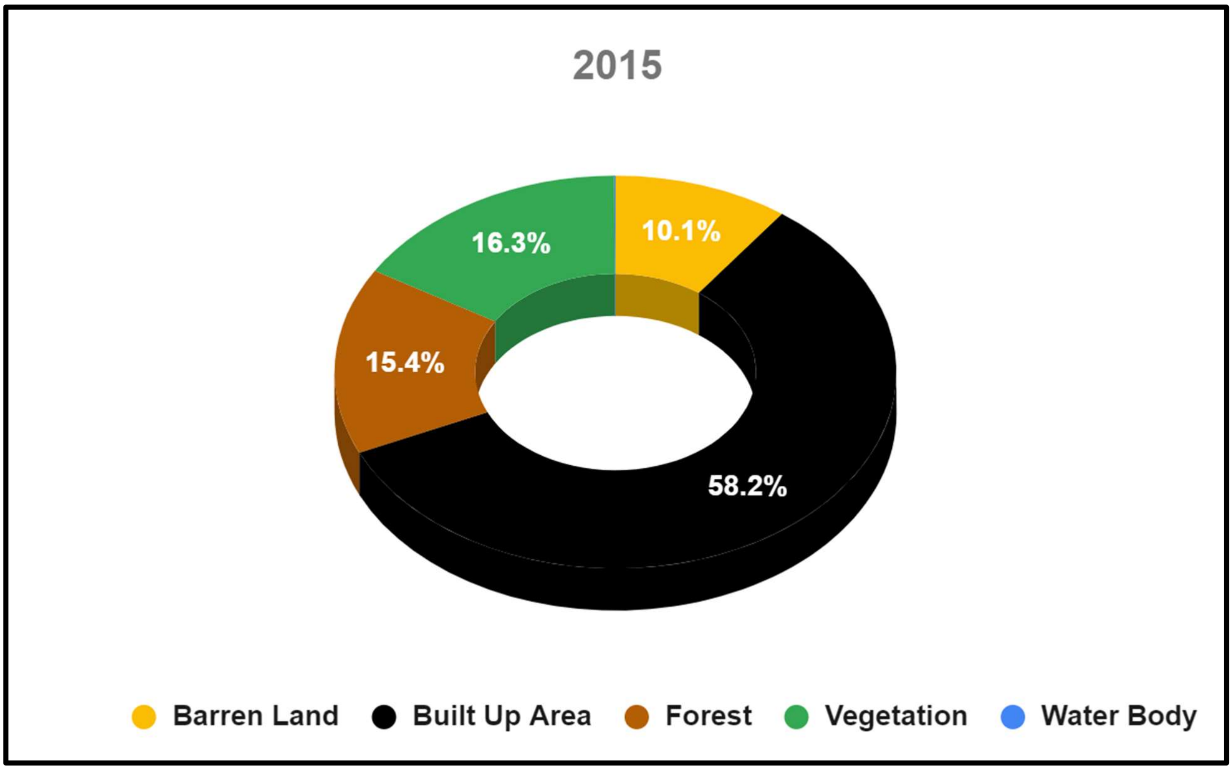


Fig.40. Pie Chart for Area Distribution for year 2015

7.4.2.5. Percentage breakdown for land cover classes year 2018

Class Name	2018 Area(km^2)	(%)
Barren Land	9.69	8.14
Built Up Area	73.32	61.66
Forest	17.42	14.64
Vegetation	18.42	15.49
Water Body	0.08	0.07
Total	118.92	100.00

Table 19 : Area Distribution for year 2018

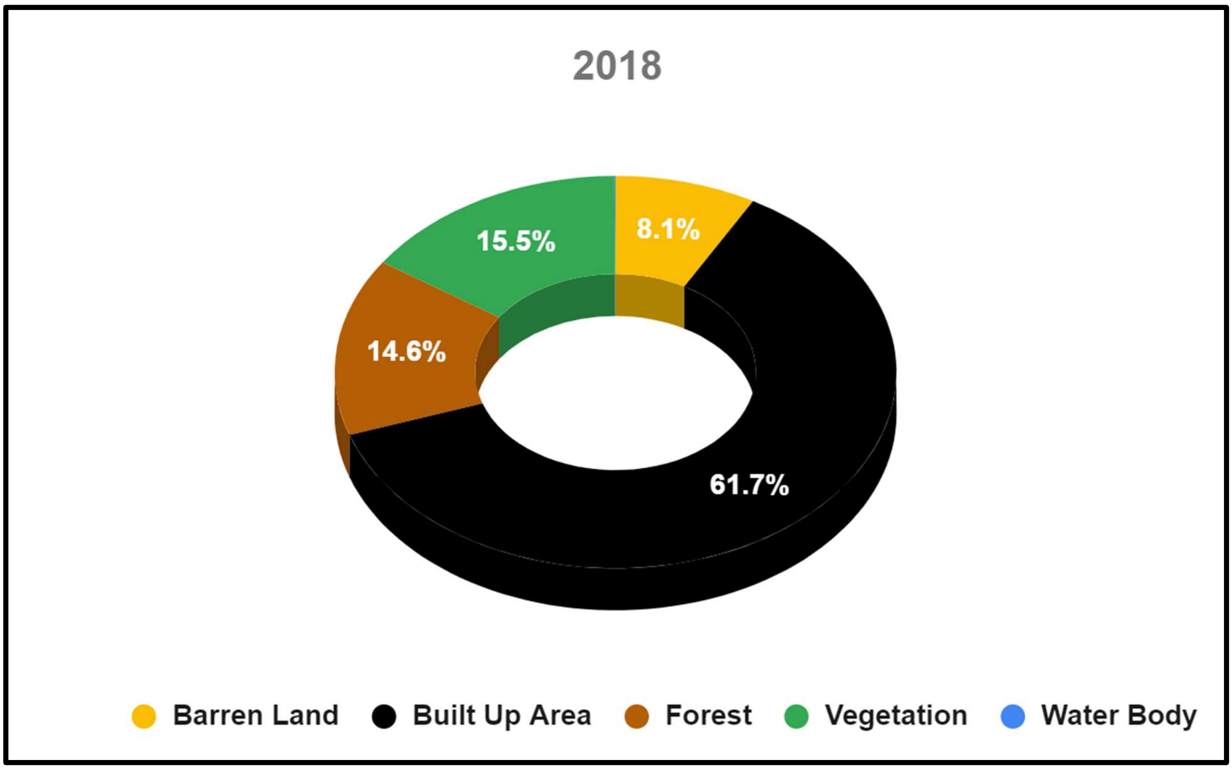


Fig.41. Pie Chart for Area Distribution for year 2018

7.4.2.6 Percentage breakdown for land cover classes year 2020

Class Name	2020 Area(km^2)	(%)
Barren Land	9.27	7.79
Built Up Area	75.47	63.47
Forest	16.98	14.28
Vegetation	17.14	14.42
Water Body	0.06	0.05
Total	118.91	100.00

Table 20 : Area Distribution for year 2020

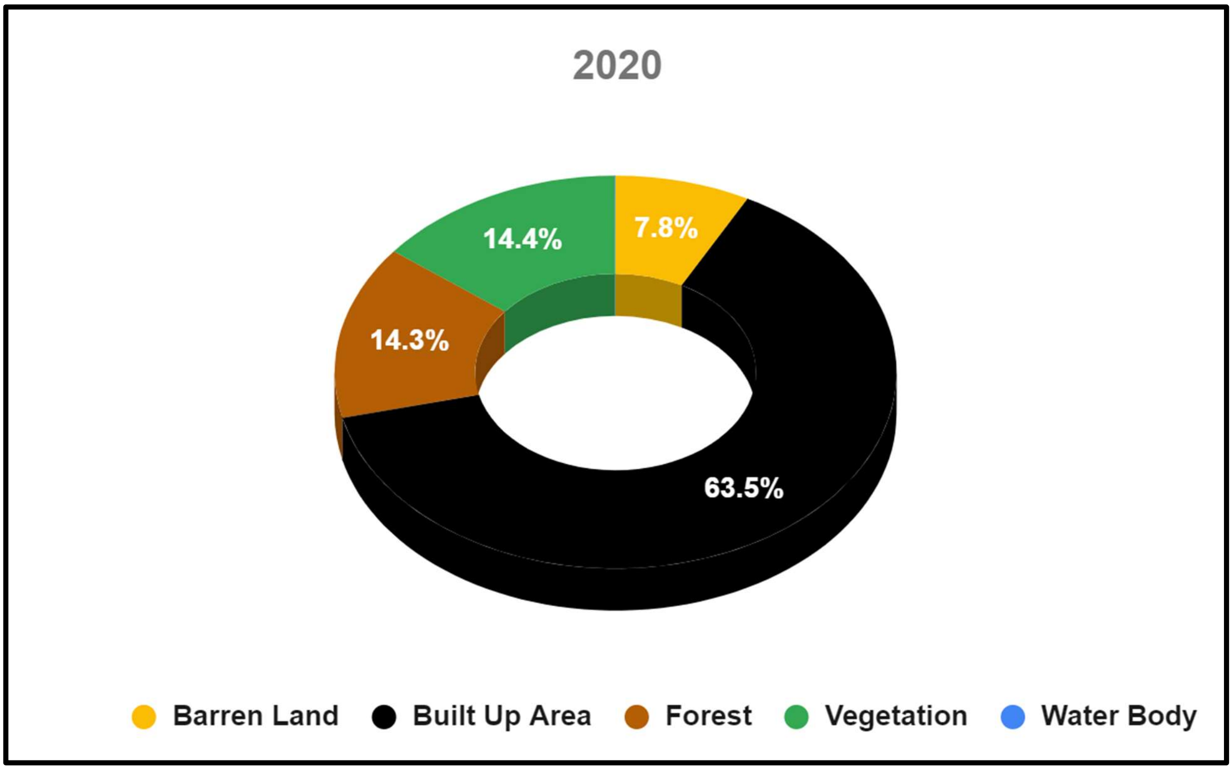


Fig.42. Pie Chart for Area Distribution for year 2020

7.4.2.7. Percentage breakdown for land cover classes year 2021

Class Name	2021 Area(km^2)	(%)
Barren Land	10.98	9.23
Built Up Area	75.81	63.75
Forest	15.77	13.26
Vegetation	16.33	13.73
Water Body	0.04	0.03
Total	118.92	100.00

Table 21 : Area Distribution for Year 2021

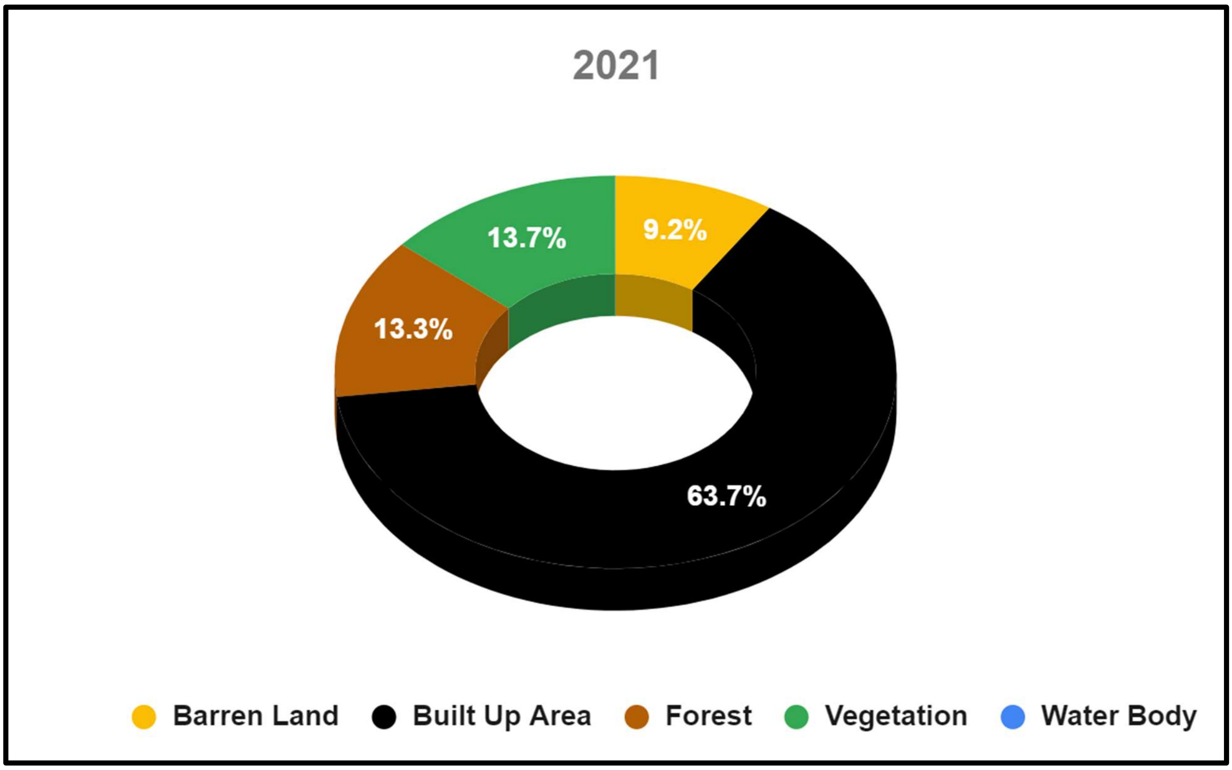


Fig.43. Pie Chart for Area Distribution for year 2021

7.4.3 Percentage increase/decrease in area since 1990

Percentage increase/decrease in the area of our study area which is situated in Jaipur, Rajasthan since 1990 is depicted below in detail. As observed, since 1990 built up area has increased at tremendous rate and 261.14% increase in area observed for year 2021. More to this, observations were made which consist of a percentage decrease of barren land(-62.34%), forest(-59.10%), vegetation(-42.42%) and water bodies(-84.47%).

Class Name	% of Increase or Decrease Area Since 1990
Barren Land	-62.34%
Built Up Area	261.14%
Forest	-59.10%
Vegetation	-42.42%
Water Body	-84.47%

Table 22 :Percentage Increase or Decrease of Area Since 1990

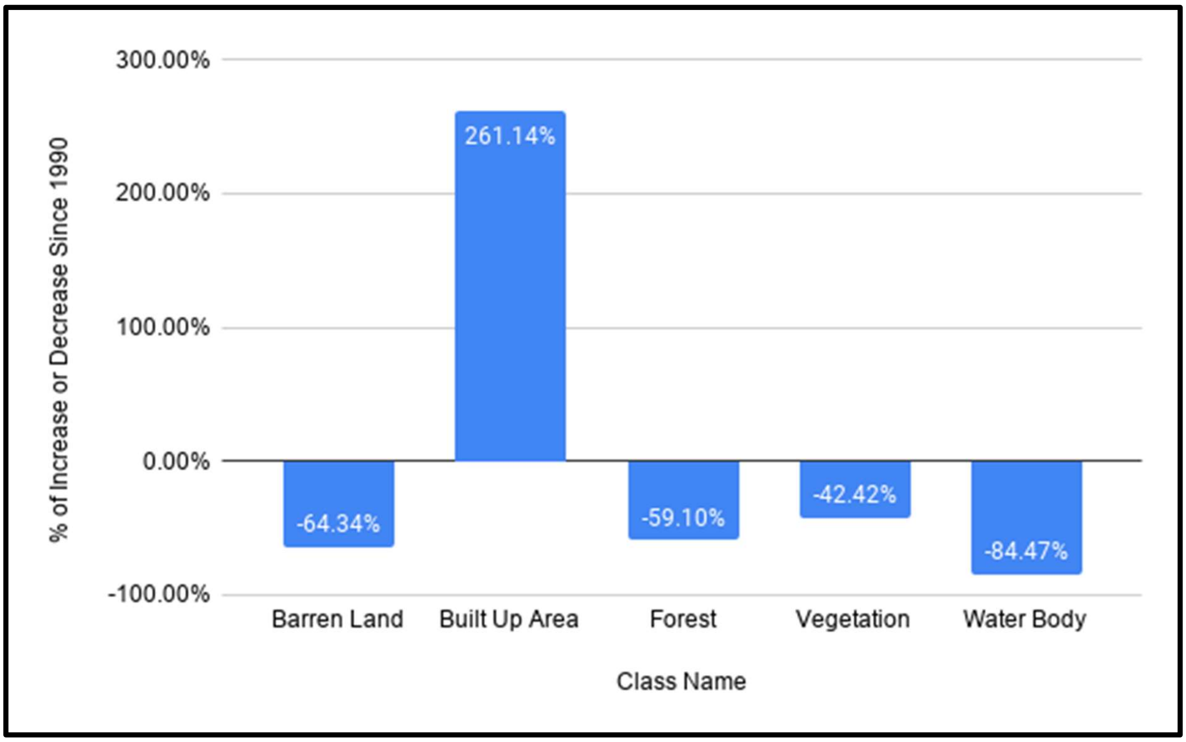


Fig.44. Percentage Increase or Decrease of Area Since 1990

7.5 LAND CHANGE INTENSITY ANALYSIS

Land-change intensity analysis was used to examine the extent and rate of urban land change of the study area (ULC; i.e., a land change from non-built to built) across all the intervals possible.

Attempts were made to firstly calculate the annual change intensity (ACI) for each time Interval. Then, comparison of each ACI to the uniform intensity (UI), which is the rate of change relative to the entire time extent of the land-change analysis is observed.

$$\text{ACI (\%)} = \frac{(LC/LA)}{TE} \times 100$$

where ACI is the annual change intensity for a given time interval (e.g., t1–t2), LC is the area of land change from non-built to built for a given time interval, LA is the area of the entire landscape, and TE is the duration of a given time interval.

$$\text{UI (\%)} = \underline{[(LCTI1 + LCTI2)] /LA} \times 100$$

TETI1 + TET2

where LCTI1 and LCTI2 are, respectively, the land changes from non-built to built during time interval and time interval 2. TETI1 and TETI2 are, respectively, the durations of time intervals 1 and 2.

If the ACI in a particular time interval (e.g., t1–t2) is less than the UI, then the ACI intensity of that particular time interval is considered to be slow; but if it is greater than the UI, it is considered to be fast.

Interval	ACI(%)	UI(%)
1990-1995	1.43%	1.59%
1995-2000	1.76%	1.85%
2000-2010	1.90%	1.64%
2010-2015	1.12%	1.13%
2015-2018	1.16%	1.06%
2018-2020	0.90%	0.70%
2020-2021	0.28%	0.28%

Table 23: Comparison of ACI and UI for time interval 1990-2021

Average ACI %	Average UI %
1.22	**1.18**

Table 24 : Comparison of Average ACI and Average UI for time interval 1990-2021

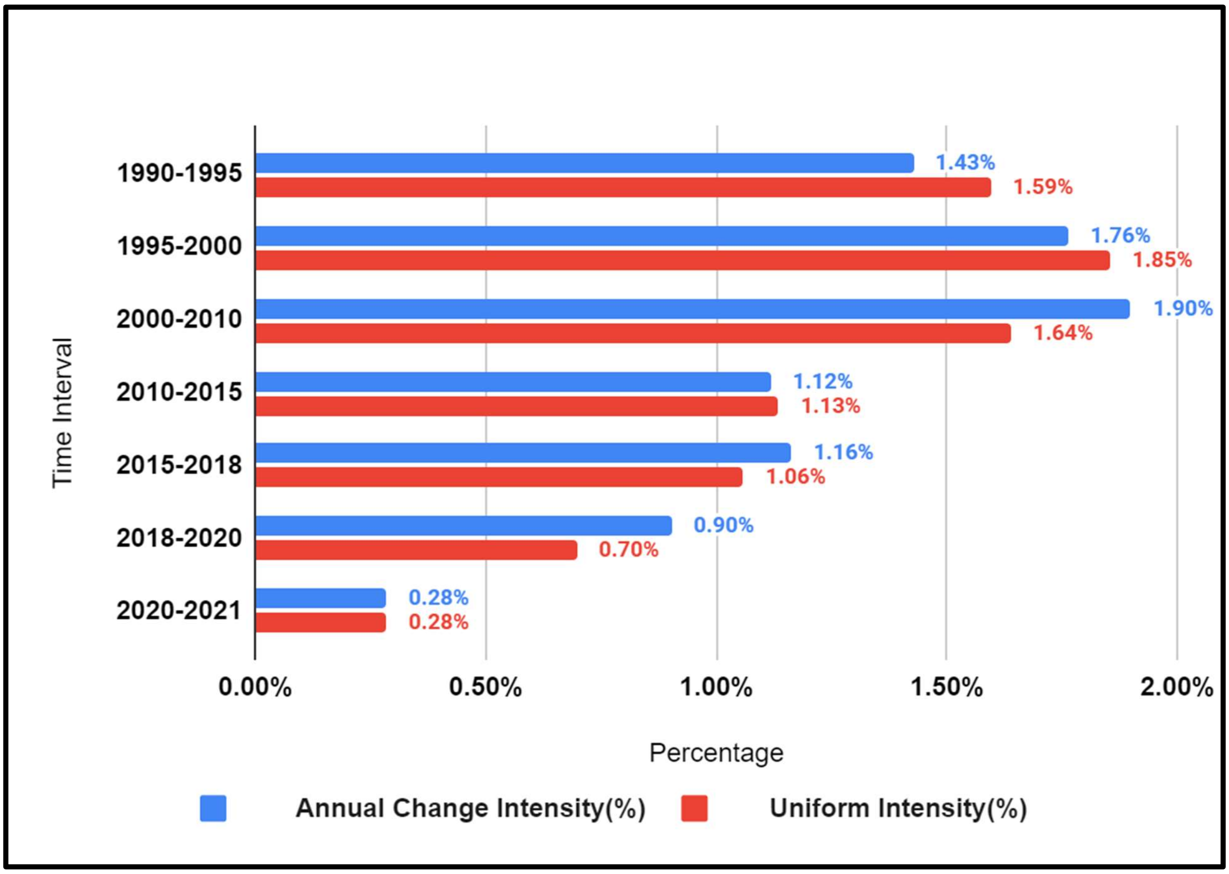


Fig.45.Comparison of ACI and UI for time interval 1990-2021

In this study, the results show that urban growth of the study area occurred mainly in two stages during the study period (1990–2021). In the interval of 1990-2000, as ACI is less than UI, hence the urban growth rate is considered as slow but after that in the interval from 2000 to 2021, as ACI dominated over UI which resulted in fast urban growth rate.

7.6 URBAN GROWTH RATE ANALYSIS(1990-2021)

Urban growth rate analysis is one of the most important parameters that have been used in the project in order to analyze the urbanization trends of the study area.

Table 3 shows the annual urban growth percentage rate (K). K is a key index for evaluating urban growth, and is defined as follows:

$$K = \frac{(Ub - Ua)}{Ua} \times \frac{1}{T} \times 100$$

Where,
K is the annual urban growth percentage rate
Ua represents the urban area at the beginning and period
Ub represents the urban area at the end of the monitoring
T is the period of time from time a to b

Time Interval	Built Up Area (km^2)	Annual Growth (%)
1990-1995	29.472777	8.08%
1995-2000	39.954355	7.11%
2000-2010	62.533988	5.65%
2010-2015	69.177703	2.12%
2015-2018	73.323973	2.00%
2018-2020	75.470244	1.46%
2020-2021	75.808372	0.45%

Table 25 : Annual urban growth percentage rate (1990–2021) of study area

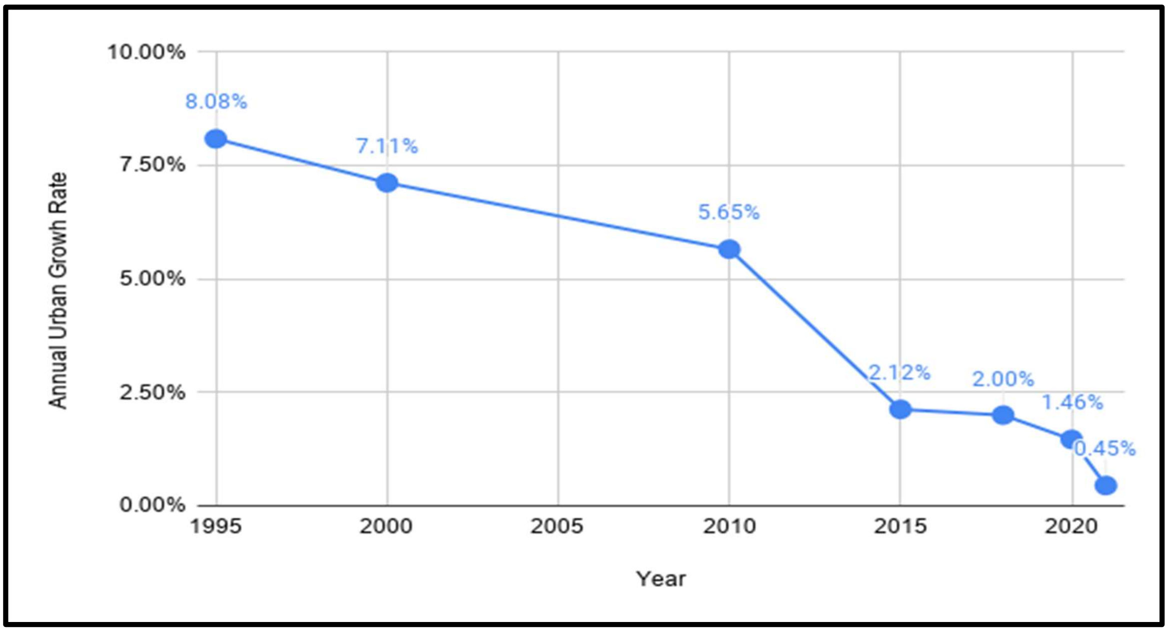


Fig. 46. Annual Urban Growth Rate Analysis

In this study, the results show that urban growth of the study area occurred mainly in two stages during the study period (1990–2021). The first stage was from 1990 to 2000, and the second one was from 2000 to 2021.

During the first stage, urban area increased from 20.99 km2 (or 17.65%) of the total area to 39.95 km^2 (or 33.60%) between 1990 and 2000; the annual urban growth rate was around 7.11%. During this stage, horizontal urban expansion was dominant, and urban growth in Jaipur occurred along transport routes. Concentric urban theory explains the urban growth during the first stage (1990–2000).

In the second stage which extended from 2000-2021, urban growth continued at almost stabilized expansion rates. The urban area expanded by 35.86 km2 during the last two decades. In this stage, concentric and multiple nuclei urban theories explain the urban growth of Jaipur. Infrastructure projects, such as roads, water supply, and electricity, led to the expansion of urban centers resulting from improved accessibility and service delivery. Vertical urban expansion was dominant in Jaipur between 2000 and 2021.

The annual growth rates were 1.45% (2018-2020) and 0.45% (2020-2021), indicating that Jaipur's urban growth has almost become steady over the last few years.

CHAPTER 8
CONCLUSIONS

In this study, the trends analysis of urbanization has been performed on the watershed situated in Jaipur which has an outlet point as Amanishah Nala. Trend analysis results revealed an exponential increasing trend of built up area at annual temporal scale over a period of around 30 years based on Land Use Land Cover Change Detection. While significant decreasing trends were found in forestlands, agricultural fields, pasturelands, water bodies and open wasteland.

Also, Maximum Likelihood Classification was used for generation of classified maps. Validation of the stimulated classified maps were performed with the help of error matrix method which gives the satisfactory result.

The annual urban growth rate and percentage change of land cover classes areas were also estimated and successfully plotted.

Comparison of overall accuracy for LANDSAT and Sentinel data reveals that as we shift from LANDSAT to Sentinel data, the improvement in image resolution occurred and significant increase in corresponding overall accuracy was noted.

Attempts were made to fully utilize the free and easily available resources wherever possible to delineate the watershed inorder to estimate our study area and to perform land use land cover change detection analysis on that. Finally, future water planning strategies and recommendations were discussed and suggested as below in detail.

With investment by the government to change the system in place now, Jaipur could have a sustainable water future. Measures such as increasing open areas, creation of artificial recharge zones, educating the public on water issues and conservation, reclamation and reuse of wastewater, rooftop rainwater harvesting, and investment in updating the water distribution and metering system will all help to improve the water supply system and Jaipur as a whole. Policy challenges must be overcome, but it is definitely possible to transform Jaipur from a city with extreme water scarcity issues to a city with a sustainable water supply for the future.

GENERAL RECOMMENDATIONS

- **Increment in open areas:** In the study area, as analysed forestlands, agricultural fields, pasturelands, water bodies and open wastelands have decreased and paved areas have increased. These open areas are important for soaking up rainwater and recharging the aquifers. The increase in impervious areas not only inhibits the percolation of rainwater to recharge the aquifers, it also creates flooding issues, as the water has nowhere to go but follow the surface slope of the land. Recharge shafts/trenches could help alleviate these problems.

- **Conservation of Surface Water:** Those water ponds that have not come under the influence of urbanization and pollution must be kept as pristine as possible for the sake of a clean water source and recharge of the aquifers with clean water.

- **Restoration of water ponds:** Water ponds that have come under the influence of urbanization and pollution should be restored, as this pollution may infiltrate and degrade the quality of groundwater (which is near-impossible to fix once it has been degraded).

- Unaccounted for settlements, agriculture, and industry around surface water sources must be restricted as much as possible.

- Curtailment of construction that would cause diversions of water flow must be implemented so that these surface water sources have the opportunity to fill, as well as recharge groundwater sources.

- **Defluoridation treatment**: Fluoride pollution may result from drawdown of the groundwater table thus magnifying natural fluoride levels from fluoride bearing minerals, but discharge of textile dyeing wastewater also contributes to high fluoride content in waters. Defluoridation treatment must be required for these industries, & low-cost domestic defluoridation technologies are available. It would be even more beneficial if high fluoride rich dyes were banned, & only the use of organic dyes were allowed.

- **Pollution Prevention & Minimizing the Use of Fresh Water in Industrial Areas:** Regulations should be put in place that effectively ban the discharge of industrial wastes into water bodies and require treatment of these effluents before release into water bodies. Arrangements should be made for effective collection of semi-solid and solid wastes from industries, as well as institutions such as area hospitals, so carcinogenic or infectious materials do not pollute water bodies or groundwater. Water-intensive industries and activities must not be further permitted in areas deemed over-exploited for groundwater and incentives for the adoption of recycling and reuse of wastewaters should be put in place to minimize unnecessary use of fresh water sources. The government must formulate a plan for the treatment of sewage and industrial wastewaters, and use this reclaimed water for activities that do not necessarily need potable water.

- **Curbing Nitrate Pollution:** Investment in sanitation and sewage disposal systems, especially in densely populated areas such as the walled-city, is the most appropriate and effective way to curb further nitrate pollution in these areas. A proper sewage disposal system must be employed and maintenance should be given a priority.

- **Educating the Public:** Education and public awareness campaigns must be put in place to curb the pollution of water sources from domestic solid and sewage wastes and to promote the conservation of freshwater. The public must be made aware of the severity of water scarcity in Jaipur, and techniques to conserve water must be communicated to the public. Possible strategies include incentives for installation of rainwater collection and storage technologies and the use of dual water supply systems (using water of inferior quality for purposes other than drinking). Ways to save domestic water include using a container of water for shaving and teeth brushing instead of using flowing tap water, bathing using buckets instead of bathtubs or showers, and the use of a bucket for clothes washing instead of more water intensive techniques.

- **Groundwater Regulation & Conservation:** Permitting for further construction of groundwater extraction structures and registration of drilling agencies should be made mandatory and enforced to the greatest extent possible. Metering of new wells should occur, and groundwater should only be mined in proportion to open land area. It should be required that large-scale agricultural programs employ drip agricultural methods if they are to use groundwater sources. The government should invest in recharge shafts/trenches in order to allow for protection against flooding and recharge to aquifers.

- **Development of Natural Resource & Land Use Monitoring System:** Unplanned expansion of the city and encroachments must be kept in check to alleviate problems to both the environment and people living in the area. Urban growth boundaries must be put in place so that further obstruction of natural water flow does not occur.

- **Rooftop Rainwater Harvesting** Recently rooftop rainwater harvesting has been made mandatory in state owned buildings of plot sizes more than 300 m2 by the Central Ground Water Board of India. All newly constructed government buildings are to have rooftop rainwater harvesting structures. This must be strictly enforced and incentives created to encourage the construction of domestic rooftop rainwater harvesting structures.

- **Investment in Update of Distribution Systems & Metering:** Current distribution losses in Jaipur's water system are estimated at about 40-50%; of this total water loss 80% is likely due to leaky service mains. - These losses result in both loss of revenue to the water department and low pressure for customers. Many meters are not functioning or not checked on a regular basis and the tariff system is undefined. A system must be put in place for regular meter checks so that billing can be done fairly and uniformly (i.e. customer does not get over- or under-billed), and to keep track of the status of these meters so they may be repaired if need be. Investment should be made in installing and updating water metering systems.

- **Conservation of Water in the Irrigation Sector:** The government should initiate metering systems for agricultural wells so water charges for the intensive use of water can be levied. Incentives for growing low water requirement and salt tolerant crops in saline water areas and the installation of sprinkler and drip irrigation systems should both occur.

- **Artificial Recharge from Paved Areas:** Paved areas inhibit recharge to groundwater; however, constructing recharge shafts/trenches, using previous pavement, and improving existing storm water drain designs along roads, footpaths, etc. can initiate artificial recharge.

POLICY RECOMMENDATIONS

- A shift in how the water supply sector is viewed must occur— the water supply and sanitation sector must be recognized as a utility service so that full cost recovery can be achieved.

- Adequate subsidies should be provided in a transparent manner to the poor in order to meet minimum water and sanitation requirements for all in Jaipur.

- Efforts must be made to achieve cost reduction in areas such as manpower, energy consumption, reduction in the waste of water, and improvements in billing and collecting.

- The government and water supply agencies must be invested in maintenance of the system on a continuous basis, with comprehensive metering as a necessary policy.

- Greater inclusion of private companies in installation, operation, and management in the water supply and sanitation sector could also save the government money. The government and regional institutes could collaborate in order to provide training courses for those in or interested in the water supply and sanitation sector at different levels of education to both entice new workers in the field and ensure adequate educational preparedness.

- The government must pass and enforce legislation to curb overexploitation of groundwater, avoid deterioration of groundwater quality, and reduce the cost of pumping (incurred when pressures are low in the pumping system due to a lower water table).

- The government must also put in place legislation or incentives to promote the reclamation and reuse of treated wastewater for uses such as horticulture, flushing sewers and toilets, air conditioning, cooling, and many other industrial uses in order to conserve fresh and potable water and reduce pollution load in the receiving water body.

- The government should have an open dialogue with leaders of various communities or interested community groups to determine necessary allocation of water sources for various activities.

CHAPTER 9

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