Land Use Land Cover Change in Jaipur: A Medium Spatial Resolution Satellite Remote Sensing Approach

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Certificate of Originality

This is to certify that the report submitted by us is the outcome of our independent and original research work. We have duly acknowledged all the sources from which ideas and extracts have been taken. The project is free from any plagiarism and has not been submitted elsewhere for publication.

Acknowledgment

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Abstract

This project aims to assess Land Use Land Cover (LULC) changes in Jaipur and its adjoining areas in the year (2014 and 2022). Urbanization plays a vital role in the transformation of the land. With Jaipur being estimated as one of India's most populated cities, Understanding Land Use and Land Cover changes for Jaipur and its surrounding areas become necessary to monitor urban sprawl. Therefore, using Remote Sensing and Geographic Information Systems. LULC change in twenty-first-century Jaipur and adjoining areas was the focus of this study. Forest and vegetated areas will continue to decrease and increase respectively but at slow rates. Scrub vegetation areas face human pressure more than forests as they show faster decline trends. Urban expansion needs to be practiced within a sustainable framework with pragmatic urban and environmental planning.

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Overview

The main objective of this report is to analyze LULC change modeling of Jaipur and its adjoining areas. This project defines the objectives of the research and reviews relevant literature in relation to LULC, urbanization, and remote sensing techniques. It describes the methodology used to answer the research question including imagery pre-processing, classification, accuracy assessment, and change analysis. It also includes the outcomes of the analysis and the following discusses the implications of the results in relation to land sustainability in and around urban areas along with future research prospects and conclusions.

Chapter 1

Introduction

1.1 Theoretical Framework

Human-forced environmental change is one of the crucial global challenges to accommodate within the twenty-first century. Most environments on Earth are modified by anthropogenic exercises. For the foremost part, Land Use and Land Cover Change (LULC) is being finished fulfilling the necessities of always expanding human populace and has prompted a large number of unfavorable natural impacts like biodiversity misfortune, territory size decrease and discontinuity, land degradation, environmental change, ecological contamination so forth (Lambin, Eric F., et al.). The anthropogenic impression is overwhelmingly present within the world's natural biological systems, with an oversized portion of the planet-bound surface of the earth adjusted under its impact(Ellis & Ramankutty, 2008). Land Cover alludes to the biophysical traits of a vicinity like vegetation, soil, geology, water bodies, and so forth. Conversely, Land Use portrays the modification of this land to protect human use. These effects of LULC have sabotaged the final supportability of the planet's environments. For managing this test, the field of Land Change Science has arisen in the twenty-first century(Turner, Lambin, & Reenberg, 2007).

1.2 Urbanization and its Contribution to LULC and Global Change

The impact of LULC is visible in the form of urban areas. Urban and agricultural areas play a crucial role in changing climatic variables like the mean temperature of an area(Kalnay, Eugenia, and Ming Cai, 2003). Loss of biodiversity at a local scale, measures of which include total abundance and within-sample species richness, is essential for maintaining ecosystem services and function of an area and is most adversely affected in urban areas. Natural effects of metropolitan land utilization like metropolitan hotness island impact, biotic homogenization, and biological homogenization are pervasive in many urban communities of the world(Chen, Xiao-Ling, et al). The meaning of 'metropolitan' is different in various regions, and no widespread definition exists to date. In India, in light of population thickness,

any town with a 5000+ population and more noteworthy than 400 individuals for each square km is characterized as Urban(Census of India, 2011). Urbanization can't generally be delimited to the regulatory limits of an area, and metropolitan structure can spread past it. This is apparent in metropolitan agglomerations like Delhi and Lagos and numerous other worldwide urban communities and is a critical managerial as well as a natural test in itself.

Fifty-five percent of the human population lives today in urban areas(United Nations, 2018). The developing parts of the world have a large proportion of the global human population and face socio-economic challenges such as poverty, food insecurity, inadequate healthcare, along with global environmental change. A large proportion of global urban growth is occurring in developing countries(Montgomery, Mark R, 2008). Consequently, there is an urgent need to develop a better understanding of land-use change in growing urban centers of the global south.

1.3 Remote Sensing and GIS for LULC

The understanding of LULC has improved due to developments in the fields of Geographic Information Systems (GIS) and Remote Sensing (RS). RS and GIS have opened new research opportunities in many fields of Environmental Sciences like Climate change, Ecology, Evolutionary Biology, Urban Studie, etc(Leh, M., S. Bajwa, and I. Chaubey, 2013). The collection of remotely sensed data is leading to pushing the researchers to investigate these areas and bring fruitful outcomes. It has been possible via various satellite missions being made open-source by many governments. The most notable are the LANDSAT program of the National Aeronautics and Space Agency(NASA) and the SENTINEL program of the European Space Agency (ESA), both of which provide open-sourced medium-resolution satellite data for analysis(Drusch, Matthias, et al.).

LULC estimation using RS and GIS generally involves the acquisition of satellite imagery, imagery pre-processing (to make essential corrections), classification of imagery into different LULC categories based on a well-defined classification scheme, accuracy assessment using reference data, and detection of LULC by comparing classified imagery of an area at two different points of time(Green, Kass, Russell G. Congalton, and Mark Tukman).

1.4 Relevance of present study

Jaipur is a major tourist destination in India forming a part of the Golden Triangle. In the 2008 Conde Nast Traveller Readers Choice Survey, Jaipur ranked the 7th best place to visit in Asia. According to TripAdvisor's 2015 Traveller's Choice Awards for Destination, Jaipur ranked 1st among the Indian destinations for the year. The Presidential Suite at the Raj Palace Hotel, billed at US$45,000 per night, was listed in second place on CNN's World's 15 most expensive hotel suites in 2012.

Jaipur has also made a strong pitch to be known as an education hub. The Pink City has secured second position in a number of higher educational institutes in the country. The city with 635 institutes is next to Bangalore, which is way ahead with 1,025 institutes. Jaipur has left behind established education cities such as Hyderabad (487), Pune (421), and Mumbai (322). The city may be second in terms of overall institutes but remained at the top when it came to universities. Jaipur has over 25 universities (all types).

Uncontrolled urban sprawl is a key contributor to the growth and expansion of the city. Controlling this sprawl and supporting the resource demands of such a large population requires better land management practices. Understanding the spatial patterns and projecting future land use can be a useful step in this direction. Many studies focusing on the LULC of Jaipur have been published in academic literature. Some have focused on only specific areas of the city, while others have addressed the entire city. Land use relations with environmental quality have also been explored. However, modeling of future LULC is non-existent for Jaipur and adjoining areas of Jaipur where urban sprawl is occurring. The present study tries to address this knowledge gap and aims to find answers to the following specific questions:

1) To assess the LULC in Jaipur (2014,2022)

2) To address the specific areas subjected to urban sprawl

3) To understand the government policy towards urbanization in Jaipur and its adjoining areas.

Chapter 2

Methodology

2.1 Study Area

Jaipur, formerly Jeypore, is the capital and largest city of the Indian state of Rajasthan. As of 2011, the city had a population of 3.1 million, making it the tenth most populous city in the country. Jaipur is also known as the Pink City, due to the dominant color scheme of its buildings. It is also known as the Paris of India, and C. V. Raman called it the Island of Glory. It is located 268 km (167 miles) from the national capital New Delhi. Jaipur was founded in 1727 by the Kachhwaha Rajput ruler Jai Singh II, the ruler of Amer, after whom the city is named. It was one of the earliest planned cities of modern India, designed by Vidyadhar Bhattacharya. During the British Colonial period, the city served as the capital of Jaipur State. After independence in 1947, Jaipur was made the capital of the newly formed state of Rajasthan.

Jaipur is a popular tourist destination in India and forms a part of the west Golden Triangle tourist circuit along with Delhi and Agra (240 km, 149 mi). It also serves as a gateway to other tourist destinations in Rajasthan such as Jodhpur (348 km, 216 mi), Jaisalmer (571 km, 355 mi), Bharatpur (186 km, 116 mi), Udaipur (421 km, 262 mi), Kota (252 km, 156 mi) and Mount Abu (520 km, 323 mi).

Jaipur has a monsoon-influenced hot semi-arid climate (Köppen climate classification BSh) with long, extremely hot summers and short, mild to warm winters. Annual precipitation is over 63 cm, falling mostly in July and August due to monsoon, causing the average temperatures in these two months to be lower compared to drier May and June. During the monsoon, there are frequent, heavy rains and thunderstorms, but flooding is not common. The highest temperature ever recorded was 49.0 °C (120.2 °F), on 23 May 1994. The city's average temperature remains below 20 °C or 68 °F between December and February. These months are mild, dry, and pleasant, sometimes chilly. The lowest temperature ever recorded was −2.2 °C (28.0 °F) on 31 January 1905 & 1 February 1905. Jaipur, like many other major cities of the world, is a significant urban heat island zone with surrounding rural temperatures occasionally falling below freezing in winter.

According to the provisional report of the 2011 census, Jaipur city had a population of 3,073,350. The overall literacy rate for the city is 84.34%. 90.61% of males and 77.41% of females were literate. The sex ratio was 898 females per 1,000 males & the child sex ratio was recorded at 854. However, the population of the city is expected to grow to around 39.1 lakhs (3.91 million).

As per the official records released by the Directorate of Economics and Statistics (Rajasthan), the GDP(nominal) of Jaipur district is estimated at INR 1,22,140 crores ($15.8 billion) in 2020–21, with a per-capita GDP of INR 1,41,305. In addition to its role as the provincial capital, educational, and administrative center, the economy of Jaipur is fuelled by tourism, gemstone cutting, the manufacture of jewelry and luxury textiles, and information technology.

Three major trade promotion organizations have their offices in Jaipur. These are the Federation of Indian Chambers of Commerce & Industry, (FICCI) the PHD Chamber of Commerce and Industry (PHDCCI), and the Confederation of Indian Industry (CII) which has its regional offices here. In 2008, Jaipur was ranked 31 among the 50 Emerging Global Outsourcing cities. Jaipur Stock Exchange was one of the regional stock exchanges in India and was founded in 1989 but was closed in March 2015.

Jaipur has emerged as a hub of automotive industries. JCB, Hero MotoCorp and Robert Bosch GmbH have their manufacturing plants in Jaipur. Chemical manufacturers in the city are Aro Granite and Emami Agrotech. National Engineering Industries has a plant in Jaipur.

The city is among the top emerging IT hubs of India along with Ahmedabad, Bhubaneswar and Kochi. Mahindra World City is an integrated business zone in Jaipur. It is home to various software and IT companies including Genpact, Appirio, Infosys, Wipro, ICICI Bank, Connexions and Deutsche Bank. The Government of Rajasthan has built Asia's largest incubator in Jaipur – the Bhamashah Techno Hub.

Jaipur is a major hub for arts and crafts. It has many traditional shops selling antiques, jewelry, handicrafts, gems, bangles, pottery, carpets, textiles, leather and metal products. Jaipur is one of India's largest manufacturers of hand-knotted rugs. Jaipur Foot, a rubber-based prosthetic leg for people with below-knee amputations, was designed and produced in Jaipur. World Trade Park Jaipur, is a shopping mall in Jaipur that opened in 2012

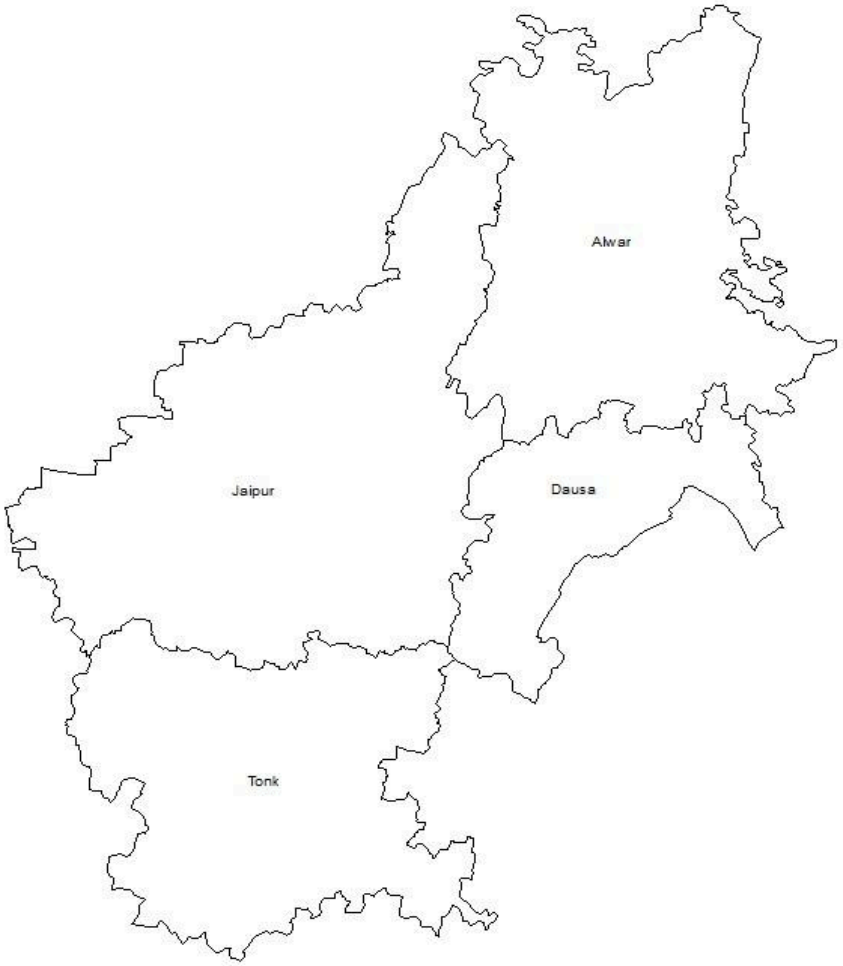


Figure 2.1: Map of Jaipur and its adjoining areas

2.2 Data Collection

The remotely sensed data are selected based on the years to be analyzed i.e. 2014, 2022. The extent of this study was at a regional scale and concerned with macroscopic land-use changes, which requires data of moderate spatial and spectral resolutions. Considering other factors of cost and availability, LANDSAT-8 moderate-resolution satellite data was the most appropriate. It is open-source, and data has been collected since the 1970s. Another essential component is surface reflectance and radiance. True spectral response is recorded in the form of spectral reflectance after atmospherically correcting the radiance values(Green et al., 2017). This is essential if comparisons between satellite images from two or more times are to be compared. Hence, LANDSAT Level 2 (processed to surface reflectance) was used for the analysis.

The satellite imagery data used for land use classification was acquired from the United States Geological Survey (USGS) Earth Explorer portal. LANDSAT data is archived as 'Collections' and provides three different processing levels for their data products. The datasets used for the study belonged to LANDSAT Collection 1 and Level 2. Imagery data that had zero cloud cover over the study area was selected using data filters on the portal. Another feature of the imagery data chosen was an image quality score of 9 which implies the least error in the imagery. Along with these, LANDSAT data is categorized into various 'tiers' according to data quality.

2.3 Image classification

The development of a well-defined classification scheme is a prerequisite of image classification to avoid thematic confusion and depends on the type of data and scientific question at hand(Verburg, Peter H., Kathleen Neumann, and Linda Nol). Generally, two major techniques for image classification exist, Supervised classification and Unsupervised classification. A supervised classifier uses training sample data provided by the user and classifies the entire image based on this sample data. Unsupervised classifiers work on the clustering of spectrally similar pixels and create a number of clusters specified by the user. Techniques for supervised classification of remotely sensed satellite data have been developing continuously for many years, especially in the 21st century. Non-parametric Machine Learning classifiers like Support Vector Machine (SVM), Boosted Decision Trees (BDT), Artificial Neural Networks (ANN), and Random Forests (RF) have been widely used in classification studies(Green, Kass, Russell G. Congalton, and Mark Tukman). Classifiers that incorporate multiple machine learning algorithms are called Ensemble classifiers(e.g., RF, SVM, etc.). These have been found to be better suited for classification than single classifiers like Decision Trees (DT). No 'Universal Classifier' exists, which can be implemented on all datasets with the most accurate results. Instead, different classifiers have been shown to be more accurate than the others in different case requirements(Maxwell, Aaron E., Timothy A. Warner, and Fang Fang). Recently, more advanced algorithms based on Extreme Learning Machines, Convolutional Neural Networks, and Deep Learning have been in development for classifications studies and promise powerful capabilities in large-scale image segmentation tasks though the implementation has focused on high and very high-resolution datasets(Ma, Lei, et al).

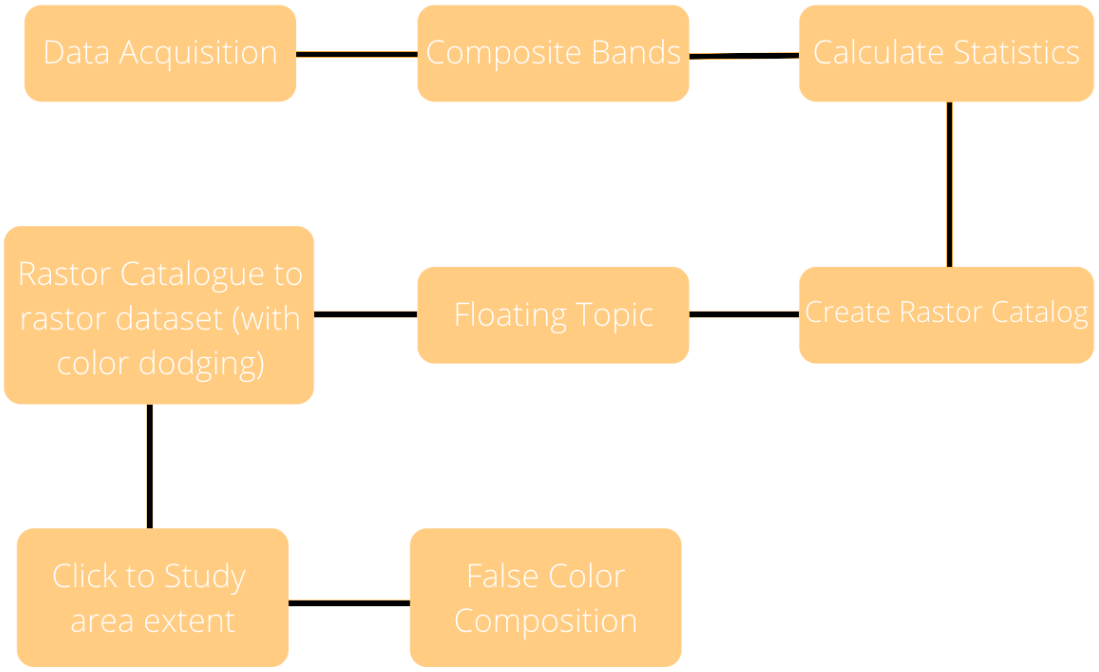
2.4 Image Pre-processing

LANDSAT level 2 data is pre-processed to surface reflectance and geometrically as well as radiometrically corrected. Thus no such corrections were required to be performed on the acquired datasets as they were already processed. ArcGIS Desktop version 10.6 (Developed by ESRI) was used to process, analyze, and classify the raster datasets.

Table 2.1: Landsat collection 1 level 2 scene attribute acquired data

Satellite	**Date of Scene Capture**	**Scene Quality**	**Scene Cloud Quality**
LC08-L2SP	07-05-2014	9	0
LC08-L2SP	07-05-2014	9	1
LC08-L2SP	16-05-2014	9	1
LC08-L2SP	16-05-2014	9	0
LC08-L2SP	27-04-2022	9	0
LC08-L2SP	27-04-2022	9	1
LC08-L2SP	28-04-2022	9	0

Each of the images was projected to the WGS 1984 UTM Zone 43N coordinate system. ArcGIS was used for functions of Composite Bands, Calculate Statistics, Color Correction, Mosaicing, and Clipping to study area extent.



Flowchart 2.1: **Image pre-processing workflow**

2.5 Classification

The classification scheme was based on a total of 4 classes: Built Up, Agriculture, Water.

Table 2.2: Classification Scheme

Class	**Description**
Built Up	Areas primarily concretized in nature like residential, commercial, and other public and municipal land use like roads, etc.
Water	Rivers, lakes, wetlands, fields submerged in water, and other water bodies.
Agriculture	Area used for farming and cultivation purposes including seasonal as well as annual crop fields.

2.5.1 Random Forest Classification Algorithm

The Random Forest Classification algorithm was used to classify the raster datasets into the 4 LULC classes through a pixel-based approach. This is an ensemble classification algorithm based on machine learning techniques. It is a non-parametric classifier, i.e., it does not depend on the normal distribution of dataset statistics for classification. In a performance study of RF classifiers, Rodriguez-Galiano et al. reported higher accuracy of RF than DT in LANDSAT ETM+ scene classification. They also showed the minimal impact of dataset size (up to 50 percent) reduction

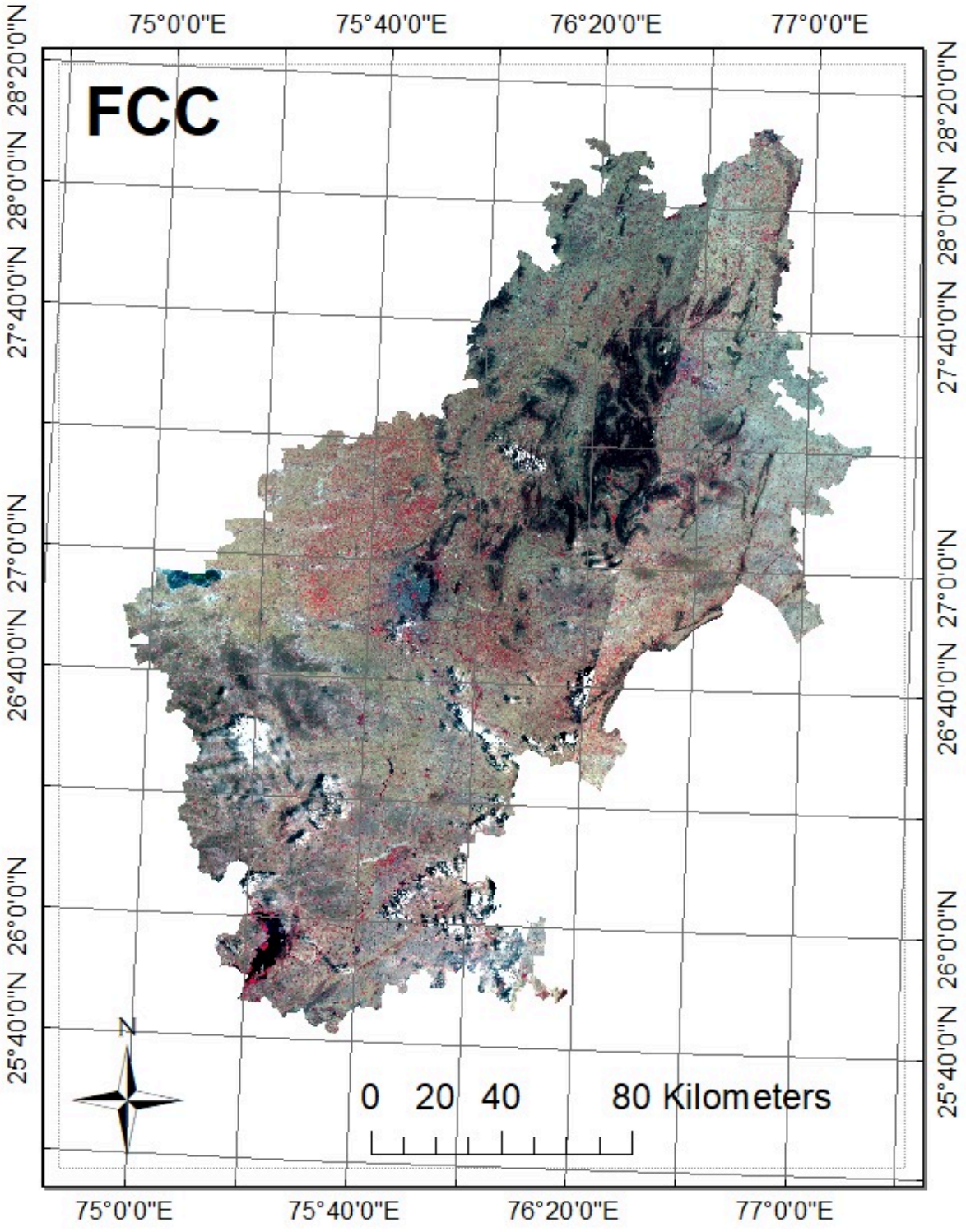


Figure 2.2: False Color Composite(FCC) map of study area 2014

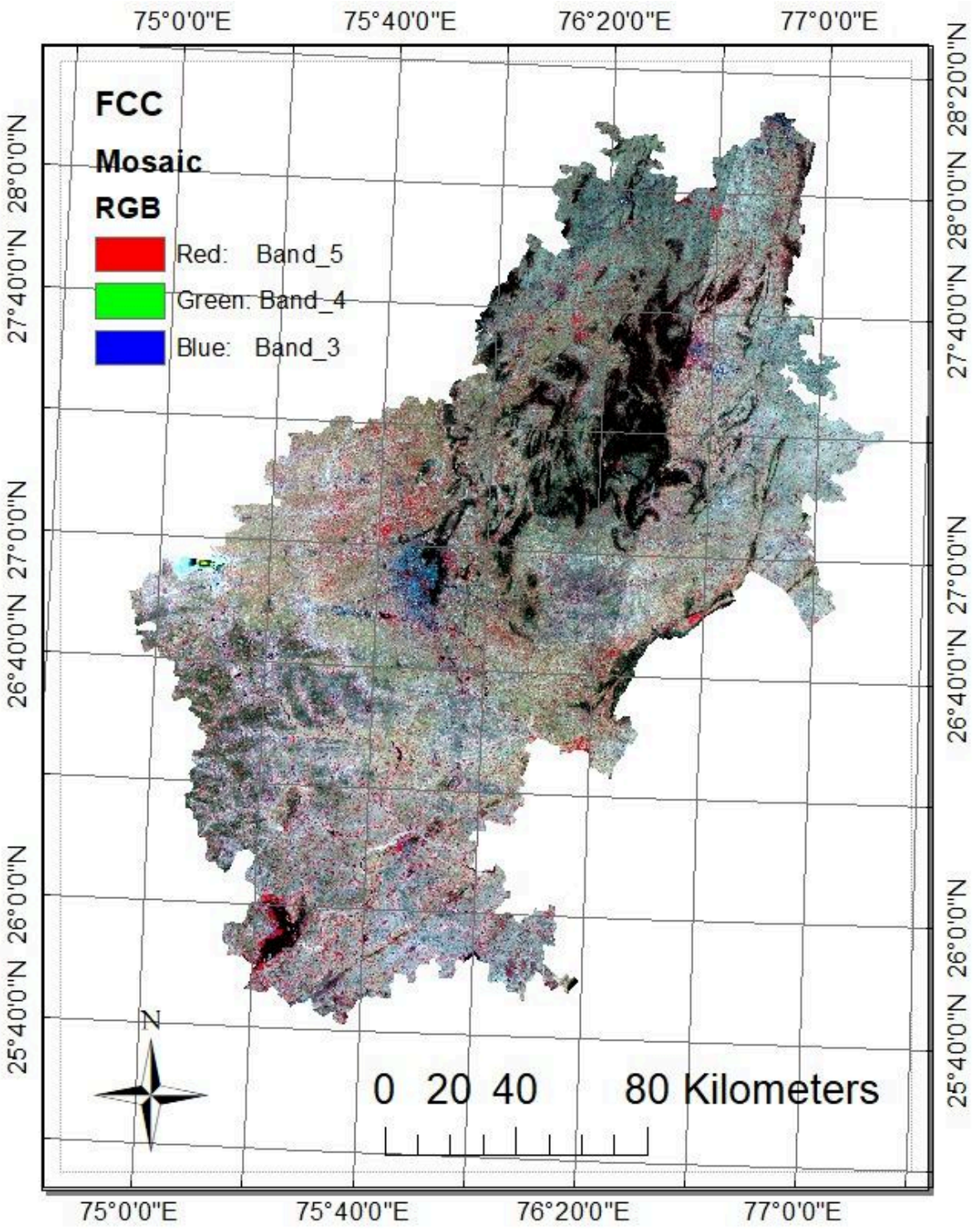


Figure 2.3: False Color Composite(FCC) map of study area 2022

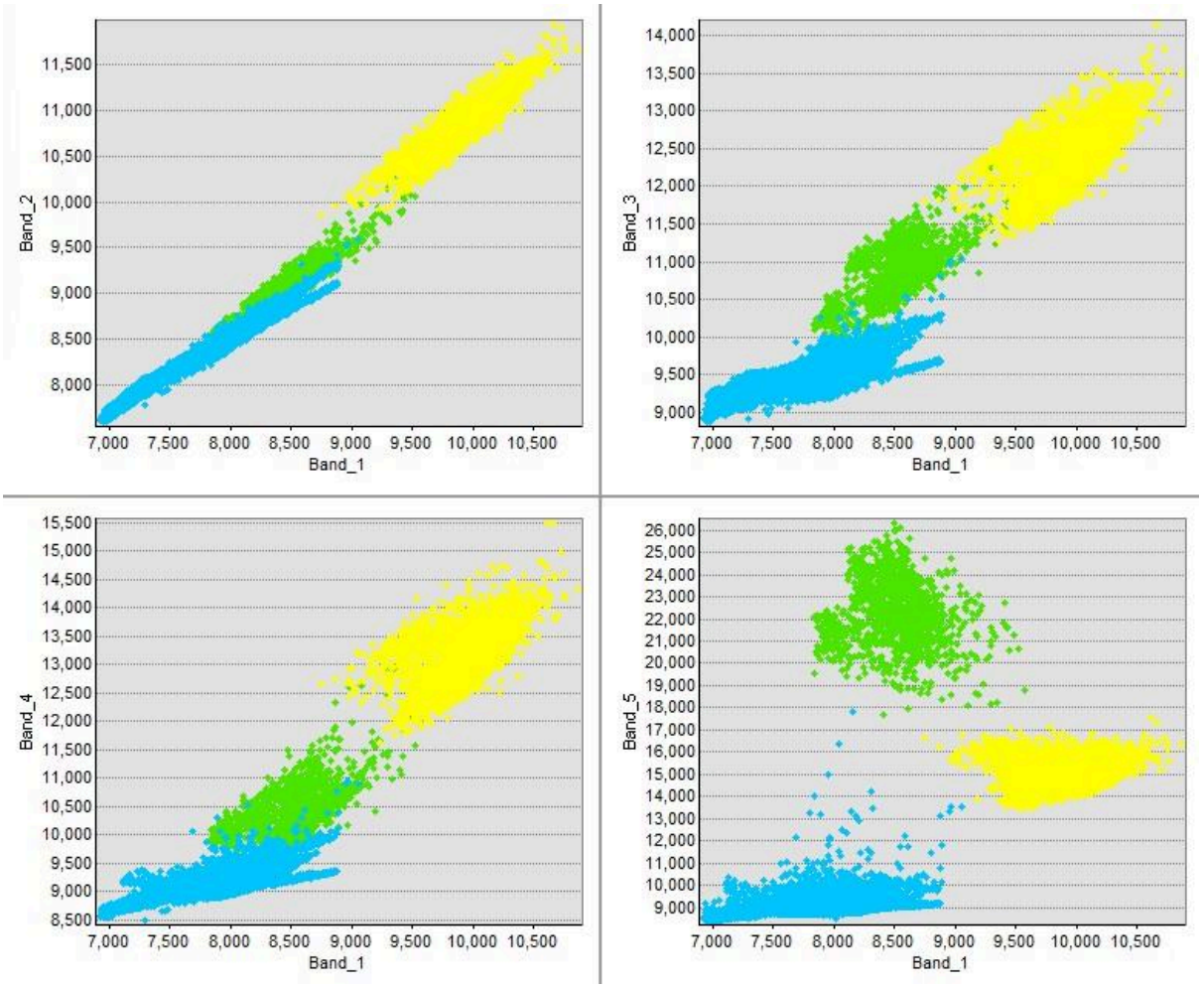


Figure 2.8: Spectral biplots for the image from the year 2014.

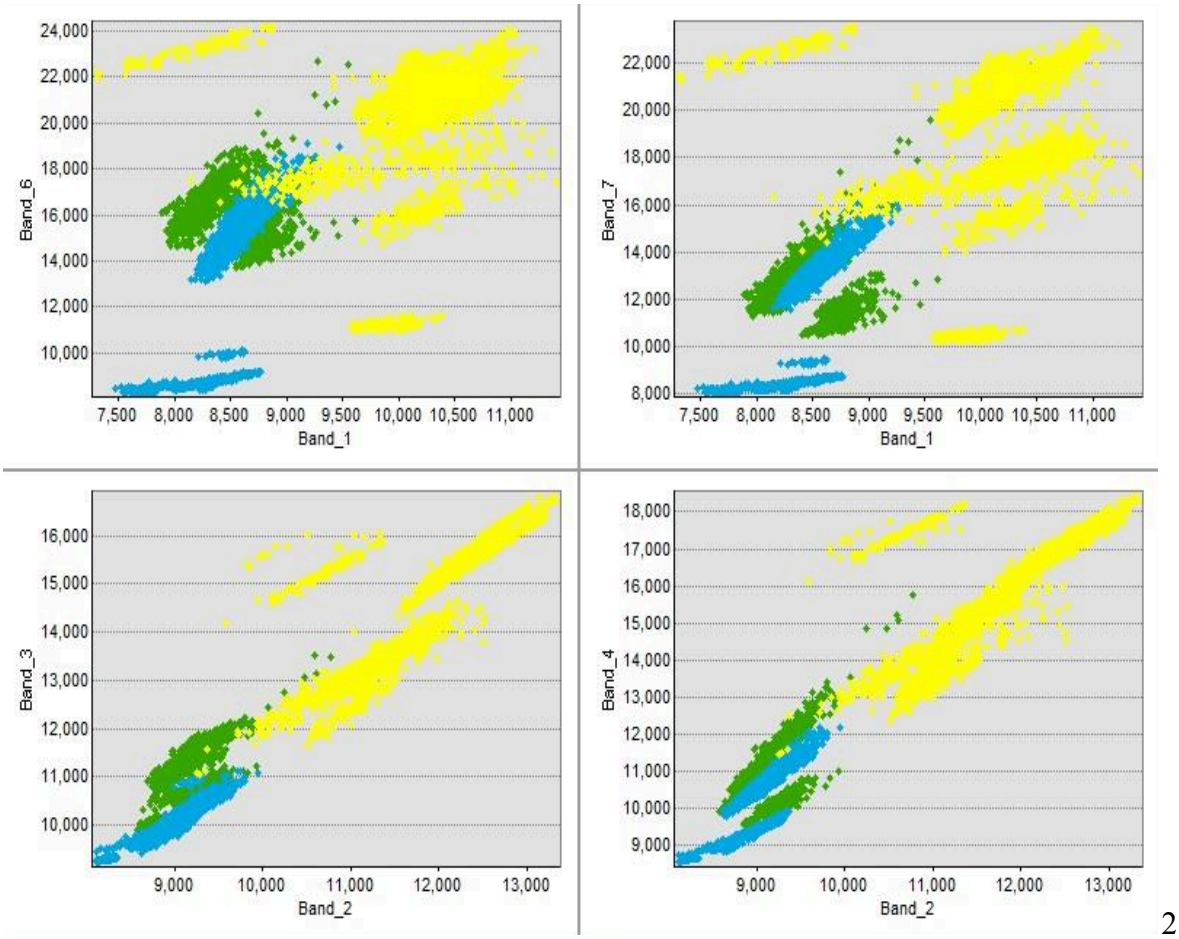


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Figure 2.9: Spectral biplots for the image from the year 2022.

Chapter 3

Results

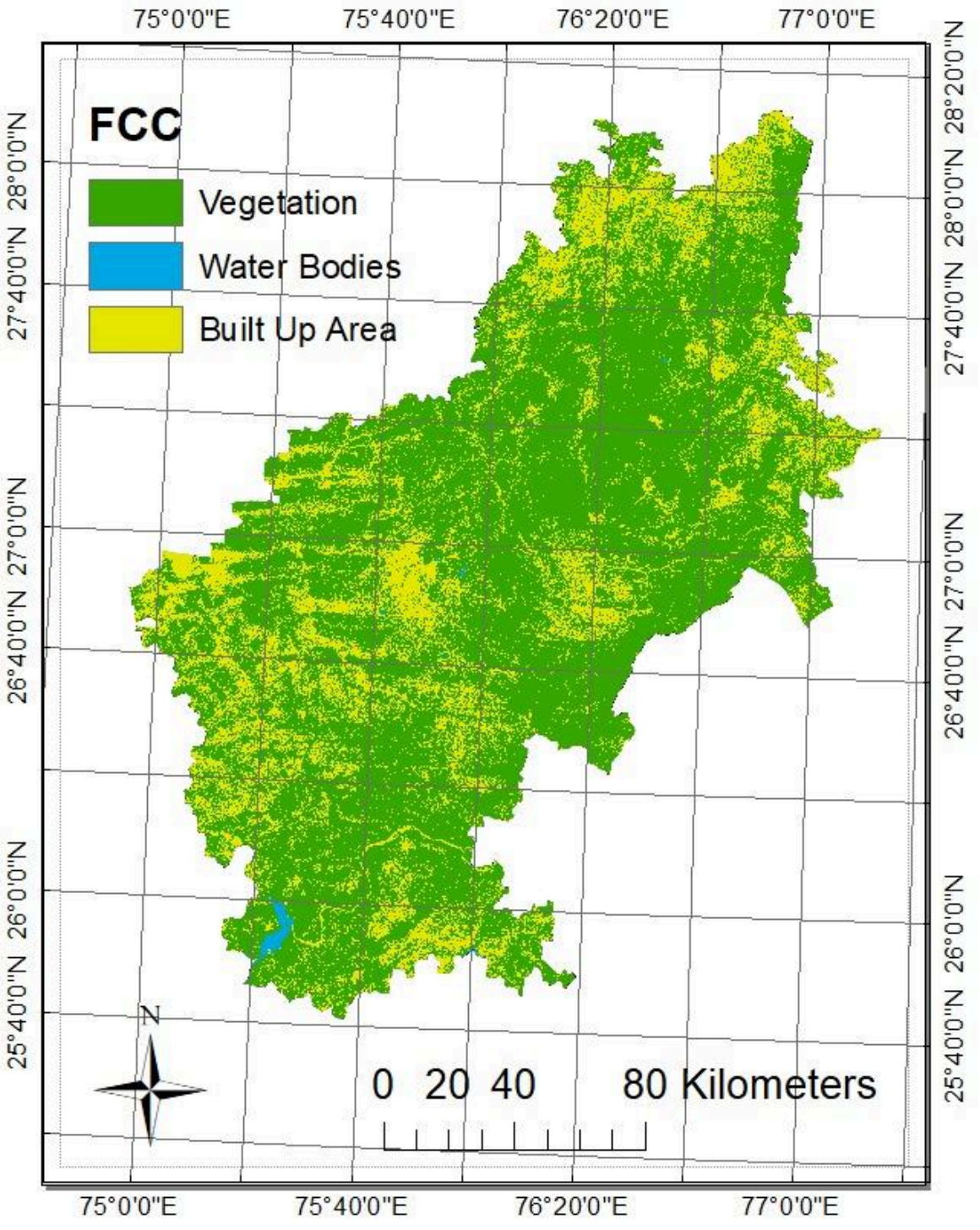

Figure 3.1: Classified LULC map for 2014

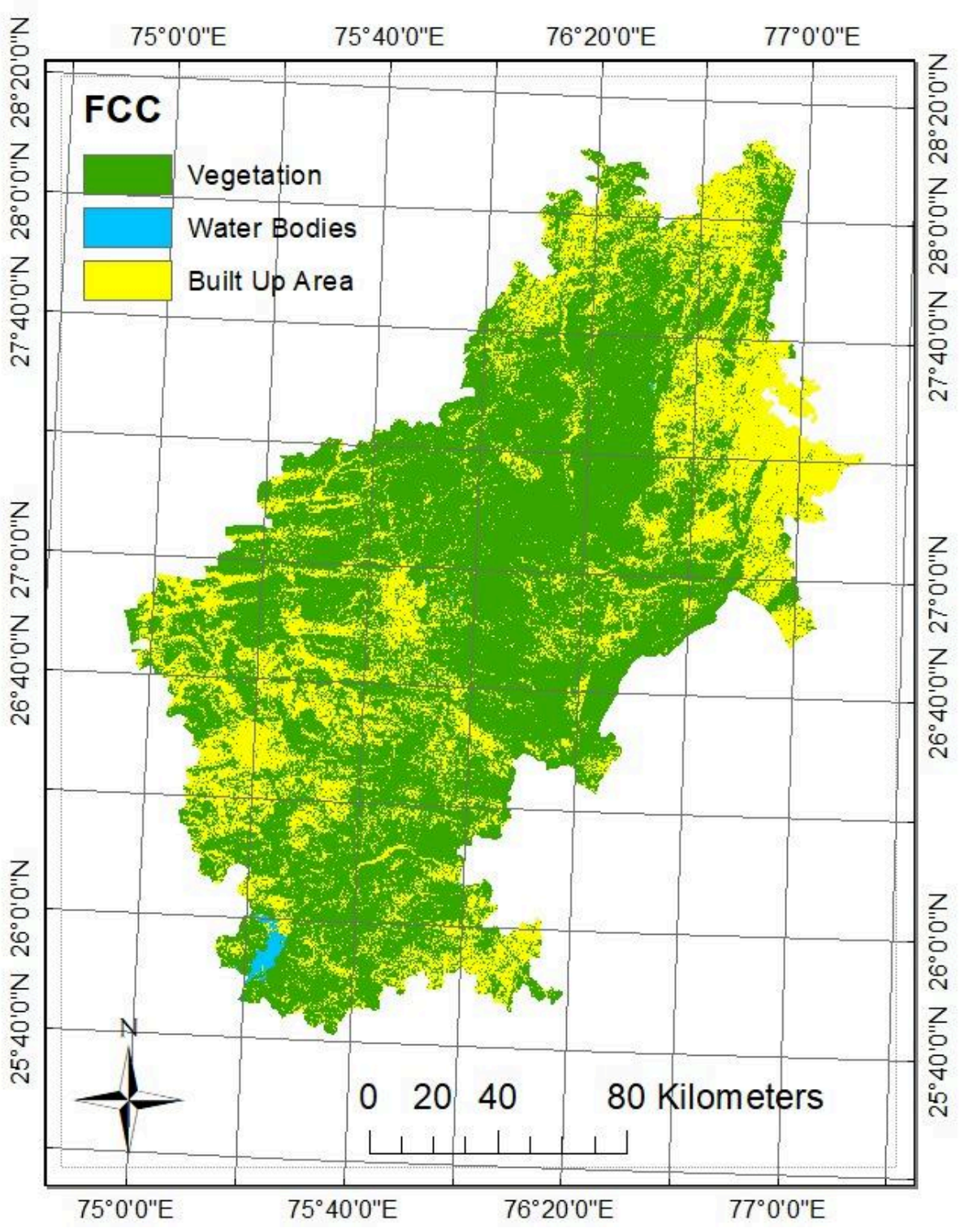

Figure 3.2: Classified LULC map for 2022

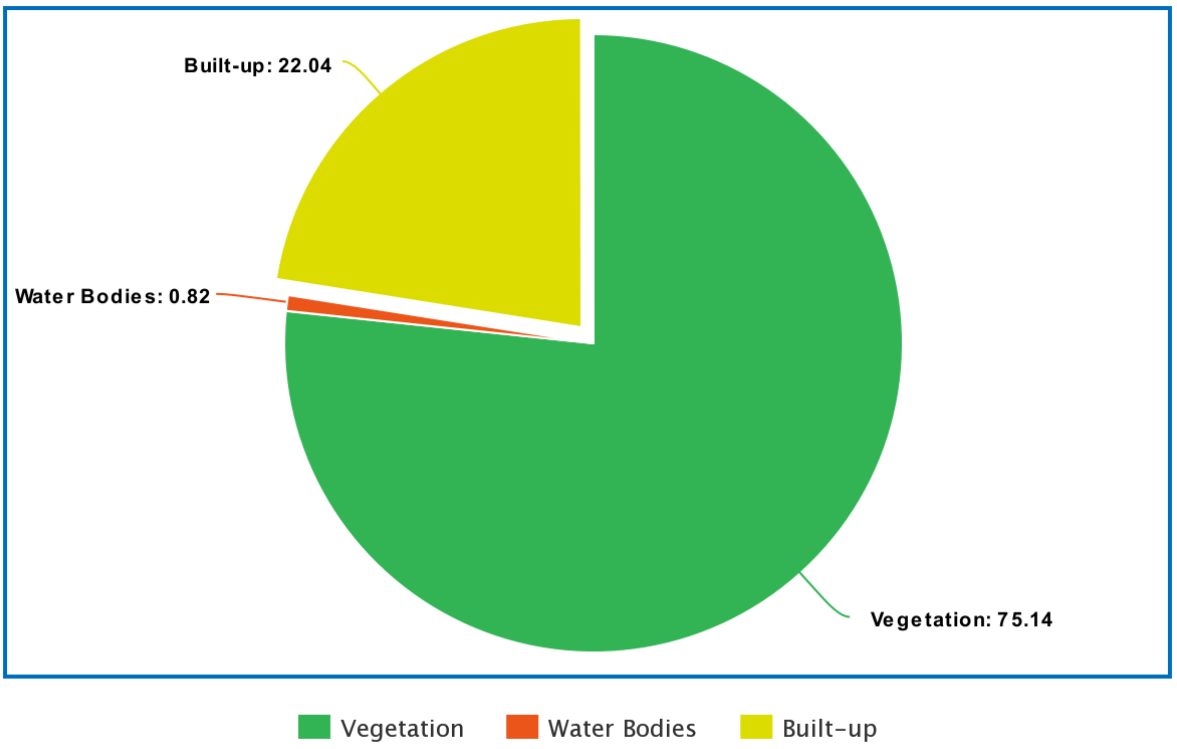

Figure 3.5: Pie charts of overall land use in 2014

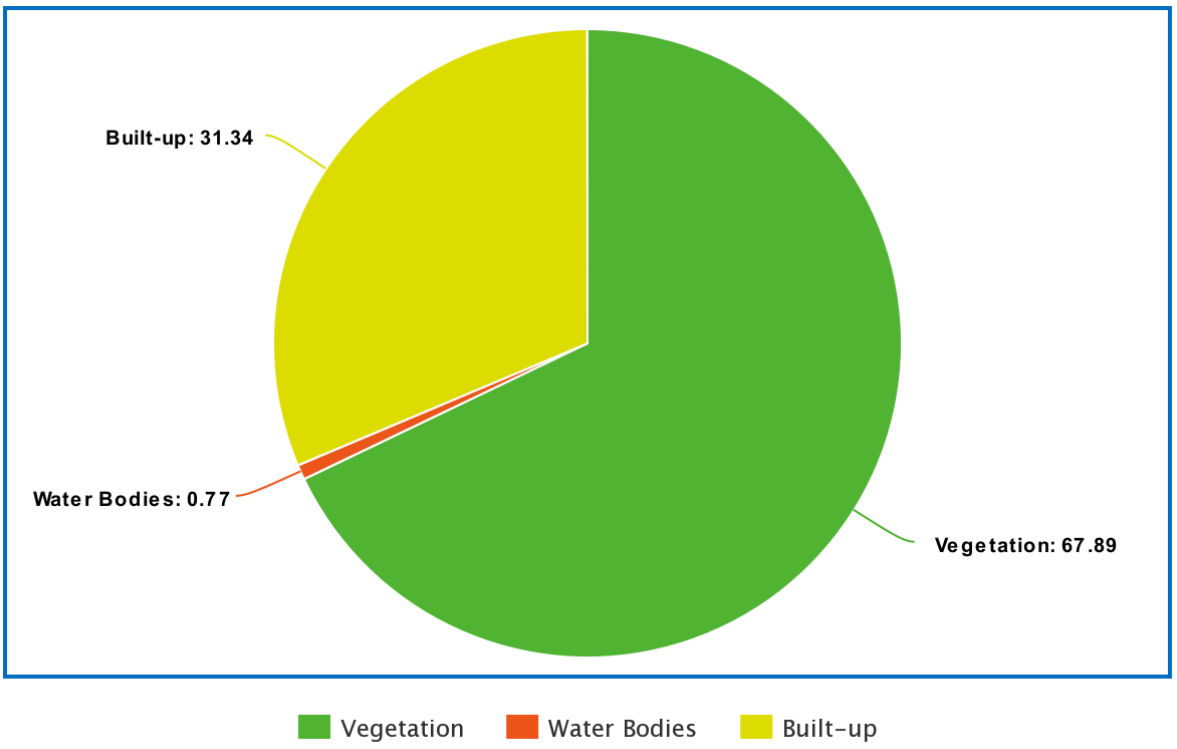

Figure 3.6: Pie charts of overall land use in 2022

Chapter 4

Discussion

4.1 Implication of results

The change analysis reflects a continued increase in built-up areas. Natural land cover like forest cover and scrub vegetation areas experienced a decline in area directly related to urban and agricultural pressure. Agricultural land area has been decreasing owing to more land being needed for secondary and tertiary sector activities. Since much of the study area landscape had already been under agricultural and built-up land uses before 2014, new land for the growing population is obtainable by either converting agricultural land to built-up or by encroaching the remaining natural land cover. This land use change, though not very rapid, indicates how urbanization is impacting the land on its periphery. Water bodies tend to decrease between 2014 and 2022. All areas of Jaipur and adjoining districts experienced an increase in built-up areas and a decline in agricultural areas.

Conclusion

The urban landscape is changing and growing continuously. Managing and restructuring land use in existing cities should be an important goal of city managers. This needs to be synergized by innovative and sustainable planning of new urban settlements that are resilient and efficient. This is a clear-cut example of Urban Sprawl.

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