Assessing land use and land cover changes in a linear portion of Patna urban area adjacent to Ganga River, and Correlating with Broad Implications for Biodiversity

A Thesis

Submitted in partial fulfilment of the

Requirements for the award of the Degree of

MASTER OF SCIENCE

IN

ENVIRONMENTAL SCIENCE

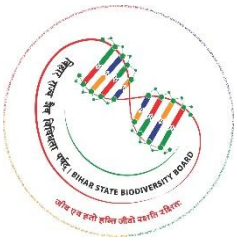
BY

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(जैव विविधता अधिनियम–2002 अंतर्गत वैधानिक निकाय)

Bihar State Biodiversity Board

(A Statutory Body under Biological Diversity Act. 2002)

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DECLARATION BY THE CANDIDATE

We hereby declare that the project entitled "[Assessing land use and land cover changes in a linear portion of Patna urban area adjacent to Ganga River, and Correlating with Broad Implications for Biodiversity]" has been prepared by me under the supervision of my guide, Bhavesh Kumar, Bio-spatial Analyst and GIS expert at the Bihar State Biodiversity Board, Patna.

We would also like to express my sincere gratitude to Dr. Bharat Jyoti, Retd. IFS, chairperson of BSBB for his continuous support and valuable guidance throughout the course of this project.

We further declare that this project is the result of my personal effort and is original in nature. It has not been submitted to any other university or institution for the award of any degree, diploma, or any other academic qualification.

All the details and analytic data provided in the report hold genuine and original to the best of my knowledge.

Submitted by

HARSH RAJ **MD. YUNUS ALAM** **VIKARM ACHARYA**

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ACKNOWLEDGEMENT

We is with great pleasure that I express my heartfelt gratitude to all those who supported and guided me throughout the preparation of this report.

We would like to extend my deepest thanks to my supervisor, Mr. Bhavesh Kumar, Bio-spatial Analyst and GIS expert at BSBB, for his continuous support, insightful guidance, and expert knowledge. His encouragement and valuable inputs played a pivotal role in shaping the content and direction of this report.

We also sincerely grateful to my mentor, Dr. Bharat Jyoti, Retired IFS and Chairperson of BSBB, for his visionary guidance, motivation, and mentorship throughout the course of this study. His vast experience and thoughtful advice have been instrumental in broadening my understanding and approach to the subject.

We would like to thank the others board members and staff members of BSBB for their cooperation and assistance during the course of this work.

We sincerely thanking to my Prof. Inch. Dr. Tripti Gangwar , P.G Dept. Of Environment Science and my faculty members Dr. Mansi Pandey and Dr. Nimisha Vatsyanan to encourage me.

A special thanks to our colleagues for their encouragement, suggestions, and help during various stages of this project.

Lastly, we extend our heartfelt appreciation to our family, whose constant support and encouragement gave us the strength and determination to complete this report successfully.

P.G. DEPARTMENT OF ENVIRONMENTAL SCIENCES

A. N. COLLEGE, PATNA

Patliputra University

Ref no: *Date:*

CERTIFICATE

This is to certify that **HARSH RAJ**, **MD. YUNUS ALAM** and **VIKARM ACHARYA** students of M.Sc. Semester IV (2023-2025), P.G. Department of Environmental Sciences, A.N. College, Patna has successfully completed the project/field work from **BIHAR STATE BIODIVERSITY BOARD** on the topic entitles **"Assessing land use and land cover changes in a linear portion of Patna urban area adjacent to Ganga River, and Correlating with Broad Implications for Biodiversity"**. It is further certified that this report has not been submitted to any other Institution or University for the award of any degree certificate.

Coordinator

(PROF TRIPTI GANGWAR)

ABSTRACT

Land Cover: The physical material observed on the Earth's surface, including both natural elements (vegetation, water, soil, rock formations) and artificial constructions. It represents the biophysical state of the land's surface and immediate subsurface, describing what visibly covers the ground without regard to its function or purpose.

Land Use: The socioeconomic function or purpose for which humans employ a specific land area, reflecting human activities and management practices that alter the land. It describes how people utilize land resources and represents the interaction between human activities and the natural environment.

These complementary concepts form the foundation for understanding landscape dynamics, environmental change, and the human-nature relationship across different spatial and temporal scales.

Land use and land cover (LULC) changes along river corridors critically shape ecosystem integrity, biodiversity, and human well-being. This study examines a 1,120.68 ha stretch of Patna’s southern Ganga bank between 2012 and 2024, employing multi-temporal Sentinel and Landsat imagery, supervised classification in GIS, and rigorous accuracy assessments. Specific LULC classes—agricultural land, natural green cover, water bodies, built-up areas, and roadside open spaces—were mapped at four ime points. Change detection revealed a dramatic 38 % drop in agricultural extent (from 50.31 % to 31.21 %) and a modest decline in green patches (6.07 % to 5.13 %) due to encroachment by infrastructure corridors. Built-up zones surged by over 50 %, reflecting urban sprawl driven by population growth and economic development, while water bodies nearly tripled (2.63 % to 7.77 %) owing to both floodplain alterations and new impoundments.

ABOUT THE ORGANISATION

The Bihar State Biodiversity Board (BSBB) represents a crucial pillar in the conservation landscape of one of India's most ecologically diverse states. Established under the provisions of the Biological Diversity Act of 2002, the Board emerged as Bihar's institutional response to growing concerns about biodiversity loss and the need for sustainable management of natural resources.

The BSBB headquarters in Patna serves as the primary authority for implementing the provisions of the Biodiversity Act within Bihar's boundaries, working at the intersection of conservation science, policy implementation, and community engagement.

The BSBB particularly effective is its three-tiered approach to conservation. At the state level, the Board coordinates major policy initiatives and scientific research. At the district level, it oversees the formation of Biodiversity Management Committees, ensuring regional conservation priorities receive attention. And perhaps most importantly, at the grassroots level, it facilitates the documentation of People's Biodiversity Registers, capturing traditional knowledge and local biodiversity information.

The Heritage Tree initiative represents one of the Bihar State Biodiversity Board's most innovative conservation programs, recognizing that certain trees hold exceptional ecological, cultural, or historical significance to the state's identity and heritage.

These living monuments—some centuries old—stand as silent witnesses to Bihar's history while providing crucial ecological services. The BSBB identifies Heritage Trees based on several criteria: exceptional age (often exceeding 100 years), cultural or religious significance, remarkable size or form, association with historical events, or extraordinary ecological value. Once identified, these trees receive special protection status, safeguarding them from removal and ensuring their preservation for future generations.

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Assessing Land Use and Land Cover Changes in a linear portion of Patna urban area adjacent to Ganga River, and Correlating with Broad Implications for Biodiversity

INTRODUCTION

In recent year, rapid urbanization increased worldwide due to tremendous population growth. The phenomenon of urbanization is experiencing a growth rate of 2.3% annually. Based on the estimation of the United Nations, it is anticipated that by the year 2030, the urban population of India will constitute 40.76% of the overall population. Urbanization can be defined as the process through which individuals migrate from rural areas to urban centres, leading to the establishment of new urban settlements. Alternatively, it can be described as the expansion of urban communities. As of 2011, India's urban population exceeded 30%, with estimations suggesting that it will rise to approximately 41% by the year 2030.

Urbanization along with population rise is directly and indirectly affecting the natural environment of earth surface and influencing the land-use land-cover change (LULC). Land cover refers to how the earth surface is covered with forest, waterbodies, wetlands, vegetation and other type of land. Land use refers to how human use the land cover for the development and conservation purposes, that includes agricultural land, build-up areas, recreation area and wildlife habitats.

Rising human population is the main factor that responsible for the land use land-cover change in many regions. The expanding population and rising socio-economic demands exert pressure on land use/land cover, leading to unplanned and unregulated alterations in LULC. These changes are typically attributed to the mismanagement of agricultural, urban, range, and forest areas, resulting in significant environmental issues like landslides and floods.

With increasing urbanization, changes in LULC affecting the hydrological process of the earth surface such as infiltration, evapotranspiration, interception and erosion, further it also negatively affects the patterns of climate. The climate has the capacity to influence and also be influenced by alterations in land cover, which refers to the natural features covering the land, like vegetation or built structures, and land use, which encompasses human

activities and management practices on the land, such as agriculture or urban development. Urbanization along with climate change leads to urban storm water logging / flash flooding in many countries.

Unplanned urbanization has drastically changed the natural catchment or drainage area and this increases the impervious surface of the ground, further it increases the rate of surface runoff during the monsoon. The current drainage infrastructure within urban areas has proven to be inadequate in managing heavy rainfall, primarily due to poor urban planning and blockage of drains with solid waste, resulting in instances of inundation or water accumulation. Runoff with high intensity can't infiltrate by the impervious surfaces like roads, buildings, etc.., into surface or sub-surface layer of the ground, therefore more runoff generated and resulting flood in urban areas. Natural waterlogging areas and natural drainage channels are reduced by urbanization over time, due to population growth and its housing demand. Flooding and waterlogging become very common in metropolitan cities like Chennai, Mumbai, Bangalore etc.., The major causes of flash flood /waterlogging in urban areas during heavy rainfall is due to inadequate drainage system, blockage of drains by solid waste, encroachment of natural drainage channels and poor urban planning. Urban storm waterlogging or flooding is due to changes in the land use such as occupying water bodies for land and building development, reduction of forest areas and other green space for residential and industrial purposes.

Flooding / waterlogging in urban areas severely impacting the normal life of the inhabitants like damaging the infrastructure, destructing the vegetation, contaminating the water, disrupting the traffic movement and loss of income. And it also causes water borne diseases to the inhabitants when storm water mixes with drainage water and other contaminants. Land-use land-cover changes play an essential role in managing natural resources and monitoring the natural environment, so current LULC changes report is important for the future sustainable planning.

Patna and its surrounding districts form the metropolitan area of Bihar's capital city. Patna is a rapidly growing city with increasing population density and limited land area. Population growth in Patna is increasing day by day due to migration from rural Bihar, Jharkhand, and Uttar Pradesh, and in recent years, commercial development has also increased. The current metro area population of Patna in 2024 is **2,456,000**, a **2.82% increase** from 2023 (Patna,

India Metro Area Population 1950-2024, n.d.). The population rise in Patna increases the demand of land, consequently initiated the land-use land-cover changes over years.

The city of Patna, an urban agglomerate has been growing at rapid pace in the last few decades and the trend is stated continue for coming few decades.

Sl. No.	Year	Population (Lakhs)
1	2011	2,049,156
2	2021	2,663,000
3	2022	2,742,000
4	2023	2,824,000
5	2024	2,908,000
6	2025	2,995,000
7	2026	3,084,000
8	2027	3,176,000
9	2028	3,271,000
10	2029	3,369,000
11	2030	3,470,000

Table 1: Patna urban agglomerate population

All figures from "Patna Metropolitan Region Future Population 2021–2031" table on Census2011.co.in

Currently, numerous techniques are available for assessing and detecting LULC changes. Remote sensing technology and Geographic Information Systems (GIS) stand out as robust instruments capable of delivering precise and timely data concerning the spatial patterns of LULC modifications across vast regions. Previous and ongoing studies conducted by organizations and institutions around the world, have predominantly focused on the application of LULC changes. GIS provides a versatile platform for the collection, storage, visualization, and analysis of digital data essential for the detection of changes. Remote sensing and GIS tools have been used in numerous studies focusing on urban growth analysis, particularly in the context of changes in urban land use. The utilization of remote sensing is predominantly favoured due to its cost-effectiveness and temporal frequency when conducting analyses for land use detection. Satellite based Remote Sensing, by virtue of its

ability to provide synoptic information of land use and land cover at a particular time and location, has revolutionized the study of land use and land cover change.

Understanding the impact of Land Use and Land Cover (LULC) changes on urban flood occurrences and waterlogging is crucial. Remote sensing imagery has already proven to be a reliable data source for identifying floods as well as changes in LULC. The integration of Geographic Information Systems (GIS) and remote sensing technologies plays a pivotal role in evaluating changes in LULC patterns and identifying areas prone to flooding. Several types of research have been conducted to identify various types of LULC changes, such as deforestation and urbanization. These LULC changes play a significant role in increasing hydrological hazards. The identification of areas susceptible to waterlogging and flooding is indirectly related to identifying the relationship between Land Use and Land Cover (LULC) change and flooding occurrences. Proper identification of regions prone to waterlogging and floods can assist policymakers and authorities in mitigating damages caused by waterlogging and floods.

The main aim of this study is to analyse the patterns, causes, and consequences of LULC change within a defined geographical region. Land Use Land Cover (LULC) changes from 2012 to 2024 and to evaluate the pressures of to evaluate the pressures of urbanization and environmental changes. By integrating multi-temporal satellite imagery, spatial analysis, and socio-economic data, the research seeks to uncover the complex interplay between human-induced land use changes and environmental processes. Understanding these dynamics is fundamental to achieving balanced development that harmonizes economic growth with ecological conservation.

- This project has been carried out under the **Biodiversity Internship Progrramme of Bihar State Biodiversity Board.**

- "Biodiversity interns **Harsh Raj, Md. Yunus Alam and Vikram Acharya** done this project work under the guidance of GIS And Bio spatial Analyst **Bhavesh Kumar.**

- Rationale for the Study: Patna is witnessing rapid urbanization and infrastructural development, which are significantly altering traditional land uses. There is a critical need to understand how these changes impact the local ecosystem and biodiversity.

- There is still uncertainty regarding how LULC patterns will evolve in the future and their potential effects on biodiversity.

- Human settlements and agriculture are the primary contributors to large-scale LULC transformations.

- Patna, being a fast-growing urban agglomeration, has witnessed rapid land use changes, a trend expected to continue in the coming decades.

STUDY AREA

The City of Patna is the capital of Bihar state and comprises several administrative zones namely Patna City, Pataliputra, Bankipur, and Danapur regions, which are geographically connected. For administrative purposes, the city is divided into two major zones - Patna Municipal Corporation and Patna Metropolitan Region. Patna Municipal Corporation includes Patna City, Bankipur, and Danapur, situated along the southern bank of the Ganges River.

Patna is situated in eastern India along the Ganges River, extending between 25° 30' to 25° 40' North and 85° 0' to 85° 15' East. Covering a total area of 136 Sq Km, it has an average population density of 18,059/km². The region is bordered by the Ganges River to the North and Patna District to the South.

The study focuses on the **southern floodplain of the Ganga River in Patna, Bihar** (Figure 1), covering approximately 1,120.68 hectares. This area lies between the Jay Prakash Setu (Digha Ghat, west) and the Mahatma Gandhi Setu (east), running through the city's central part. Geographic position of this area is 25°38'55.59"N 85° 4'49.92"E east, 25°36'42.85"N 85°12'6.65"E west, 25°38'10.09"N 85° 8'19.00"E and 25°37'21.02"N 85° 8'0.14"E with total area of 1120.68 hectare.

The Ganga in Patna is a wide braided channel with several side streams and oxbow lakes. The riparian zone includes sparse native vegetation, but major portions have been converted to parks (e.g., Sanjay Gandhi Biological Park buffer), institutional areas, or reclaimed for development. Industry and septic waste from the city discharge into the river through drains, while tidal and monsoon backwater influences can inundate adjacent lands.

Key ecological features include:

(i) Riparian vegetation – small wooded strips and grassland patches along the bank
(ii) Agricultural lands – croplands and fallow fields within the floodplain
(iii) Aquatic habitats – the main river channel, side ponds, and seasonal floodwaters
(iv) Urban areas – built-up zones such as parks, roads, institutional areas, and informal settlements.

LOCATION MAP OF STUDY AREA

A. Patna District

B. Patna Urban Area

C. Study Area

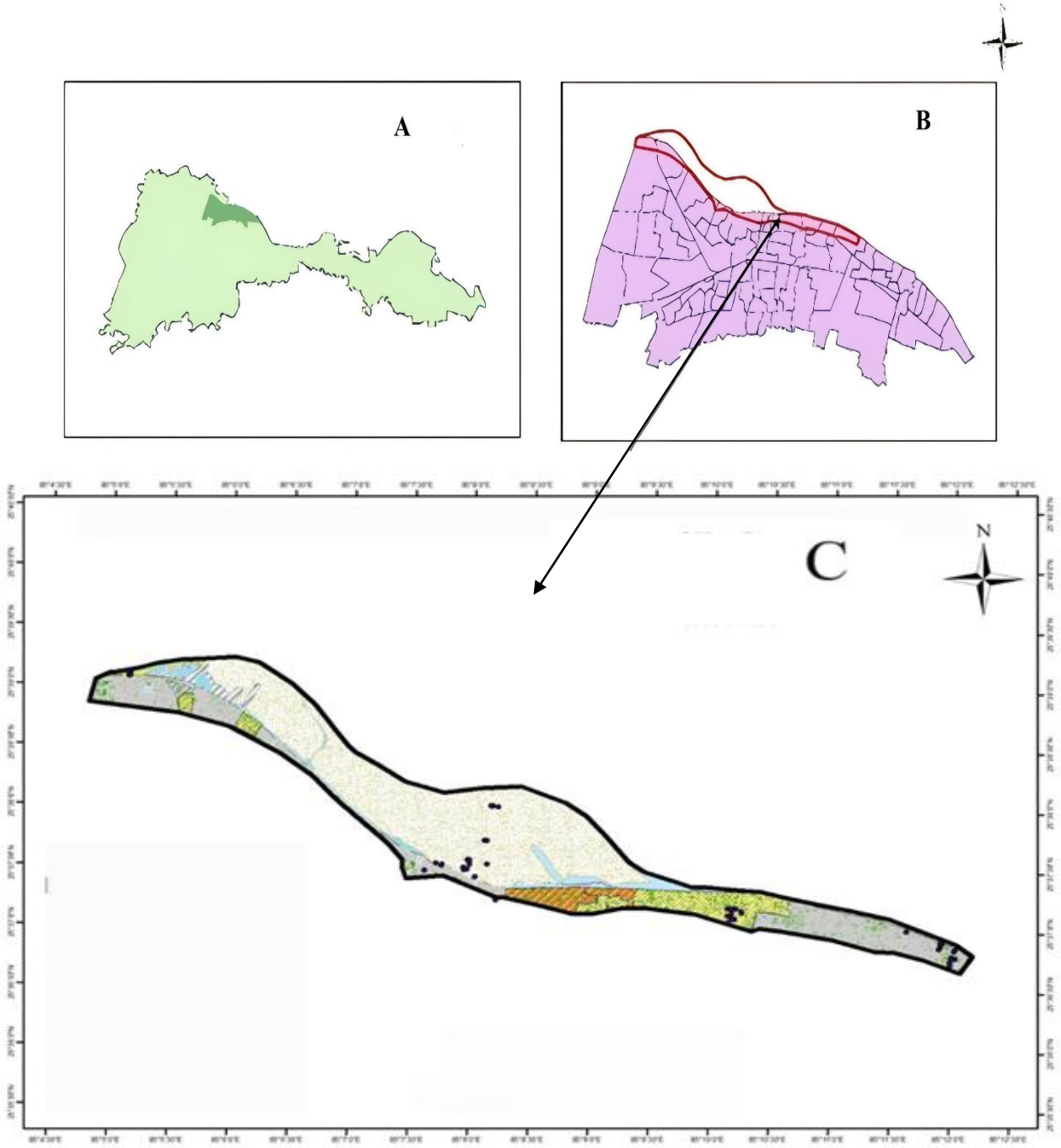


Figure 1: Map of the study area

CLIMATE

Patna experiences a humid subtropical climate, with a mean maximum temperature of about 32º C in all regions and a mean minimum temperature around 18º C. However, during peak summer months of April to June, the maximum temperature can reach 42º - 45º C in Patna. High humidity is observed during monsoon months while winters remain relatively dry.

RAINFALL

Rainfall in the Patna region is influenced primarily by the South-West Monsoon from June to September, with some pre-monsoon showers in May. Rainfall variability is significant, with seasonal and monthly variations. Normal rainfall occurs once in three years, while slight deficit/excess rainfall occurs once in five years, and large excess/large deficit rainfall occurs once in a hundred years.

GEOMORPHOLOGY

Patna is situated on the southern bank of the Ganges River in the Indo-Gangetic plain. The city's geomorphology is characterized by its alluvial plains formed through the deposition of sediments carried by the Ganges and its tributaries over millennia. The terrain is predominantly flat with a gentle slope from south to north toward the Ganges, with elevation ranging from 48 to 51 meters above sea level. Several paleochannels of the Ganges are evident in the region's geomorphic setup, influencing the drainage patterns.

SOIL

The soils of Patna are primarily alluvial in nature, highly fertile and derived from fluvial deposits of the Ganges River system. These soils can be classified into two main categories:

1. Newer Alluvium (Khadar): Found closer to the riverbanks, characterized by coarse texture, high sand content, good drainage, and moderate fertility.
2. Older Alluvium (Bhangar): Found in areas away from the active floodplains, featuring finer texture, higher clay content, and greater fertility.

The soil pH ranges from neutral to slightly alkaline (7.0-8.2), with moderate to high organic carbon content (0.5-0.8%). These soils are rich in potassium but sometimes deficient in nitrogen and phosphorus. The water-holding capacity varies from moderate to high

depending on the clay content, making them suitable for intensive agriculture, particularly rice and wheat cultivation.

STUDY OBJECTIVES

By addressing these objectives, the study aims to link geospatial findings with ecological interpretation, contributing updated knowledge for riverfront management.

i. To assess the extent of land use and land cover changes in area of Ganga River from J.P Setu (Digha) to Mahatma Gandhi Setu bridge in City locality.

ii. To analyze the category wise changes in LULC of the study area over the period 2012 to 2024 year.

iii. To assess the effect of LULC of specified years on biodiversity conservation.

MATERIALS AND METHODS

Data Sources

We used high-resolution satellite imagery for two time points: one around 2012 and one around 2024. 2012 images were obtained from Google Earth historical archives (or Landsat ETM+ circa 2012), and 2024 images from the latest available Google/Earth Engine data. These images were georeferenced and imported into ArcGIS Pro for analysis.

LULC Classification

- The study area was assessed for land use and cover changes using GIS tools; the exercise was done for 3 sections (A, B, C)

- Land use/land cover maps were prepared for 2012 and 2024 using visual interpretation of high-resolution imagery from Google Earth software within ArcGIS, and this was followed up with field surveys for ground truthing.

- 2 major classes of LULC with sub-classes selected:

I. ***Natural and Semi-natural Ecosystems***

- Tree and Vegetation Cover
- Water Bodies
- Flood Plain Areas

II. **Managed Ecosystems**

- Sedentary Agriculture
- Government and Educational Premises
- Road-side Open Strip Lands
- Residential Mixed Area

Commercial Areas

- Comparative analysis was done for LULC changes over the period 2012 and 2024 for category wise and sub-category wise.

- Based on the findings, an attempt has been made to correlate the implications of the LULC changes for biodiversity and ecology of the area of study.

METHODOLOGIES

The present study shows the spatio-temporal dynamics of land use/cover of complex of southern coastal area of GANGA River from JP setu (Digha) to Mahatma Gandhi Setu City area of Patna district, Bihar India. Study area divided into three cross sections A-B-C for comparative change detection in land use and cover pattern.

This study focuses on analyzing changes in land use and land cover (LULC) using satellite imagery as the primary data source. The method employed for this analysis is supervised classification, a well-established approach that involves grouping the LULC categories identified from satellite images.

ArcMap 10.8 software

ArcMap 10.8 is the Esri's ArcGIS Desktop, offering enhanced geoprocessing tools (new and improved functions in 10.8), preserved field ordering when publishing feature services, and updates across mapping and data management.

Land use/land cover map was prepared in ArcGIS, through visual interpretation and Field Survey using High Resolution imagery of open source (Google earth software). As defined research design as the conceptual framework guided for the execution of a study, encompassing the strategies for data collection, measurement, and analysis. Hypotheses to analysing final data. Satellite images were acquired from open source using ArcGIS software. This involved tasks like layer stacking and image extraction for further analysis. Training sample data were selected, and land use land cover (LULC) corresponding to different time points (2012, 2024). Through visual interpretation techniques conducted to generate maps

depicting LULC changes over time. The study also compared LULC change detection per decade and overall changes across 12 years.

Google Earth Pro

Google Earth Pro is the desktop version of Google Earth offering advanced GIS features such as high-resolution printing, movie-making tools, and precise distance/area measurements. It enables users to import and export a wide range of GIS data formats and access historical satellite imagery for time-series analysis.

The satellite imagery of the study area of LULC of May,2012 classified into 9 different categories (agriculture land, commercial area, educational area, flood inundation area, government build up area, road side open land, water bodies and natural green cover area).

The satellite imagery of the study area of LULC of August,2024 classified into 10 different categories (agriculture land, commercial area, educational area, flood inundation area, government build up area, road side open land, water bodies, J.P. Ganga Path Road and natural green cover area).

Each category was allocated a specific-coloured polygon (red, green, blue and so on) combined into a single KML file.

This software is also used as a secondary data source for the ground survey. The study's workflow is illustrated in a flow diagram (figure 2) to facilitate understanding, with further explanations provided in the subsequent section.

Microsoft Excel was employed for creating tables and conducting calculations related to land cover changes.

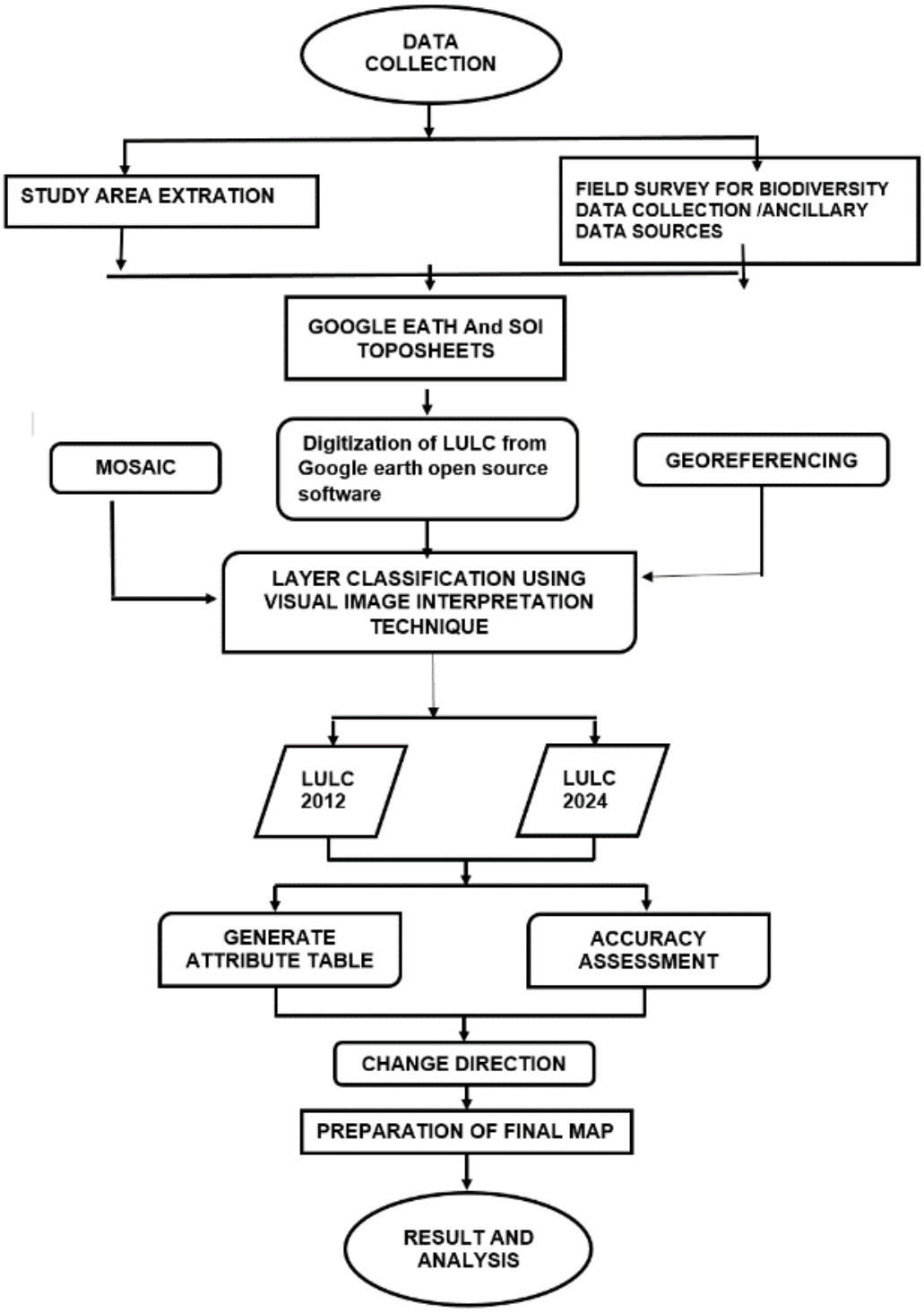


Figure 2. The land use land cover (LULC) mapping process is depicted in a flow chart

LAYER CLASSIFICATION

The KML file of both temporal period 2012 and 2024 were imported into ArcGIS software. All categorized datasets were merged into a single image within ArcMap 10.8n ArcMap 10.8. Each one was allocated to a specific colour channel (Red, Green, and Blue), resulting in various combinations of colour composites for the study area. Subsequently, the composite image was cropped to focus solely on the study area, thereby expediting image processing and analysis. By examining both the colour composites, distinct classes such as “Waterbody,” “Mixed build up area,” “Agriculture,” “Mixed Build up Area,” and “Natural Green Cover Area” could be identified. To extract the study area from the composite band, the study area shapefile created within the ArcGIS was used and with the help of ArcGIS tool the study area was clipped.

IMAGE CLASSIFICATION

Remote sensing encompasses three primary image classification methods: unsupervised classification, supervised classification, and object-based image classification. Widely employed for medium-resolution satellite imagery, the MLC was chosen for classifying the 2012 and 2024 Landsat images to identify land use and land cover (LULC). The classification process involved three main steps: training sample selection, classification, and evaluation or accuracy assessment. The study area was categorized into distinct classes (Settlements, Agriculture, Vegetation, Waterbodies, Wasteland and others) based on texture, tone, and colour, with each class assigned to pixels during image classification. Training sites were established within the imagery by delineating polygons and saved as signature files. Two signature files were generated for training the two datasets (2012 and 2024). Subsequently, these signature files were employed in the supervised image classification process to generate the LULC map for both 2012 and 2024.

CHANGE DETECTION

Remote sensing and GIS-based change detection methods are popular due to their cost-effectiveness and high temporal resolution. Among these methods, the post-classification comparison technique, which relies on maximum likelihood supervised classification, is widely utilized for detecting changes in land use and land cover (LULC). This technique has consistently demonstrated high overall classification accuracy across various datasets. The post-classification comparison technique involves classifying images individually and then comparing the resulting classes to identify areas where changes have occurred. In comparative studies of different change detection techniques, this method consistently achieves the highest classification accuracy. In this study by applying the post-classification comparison technique, the change in area between LULC categories from 1988 to 2023 was calculated.

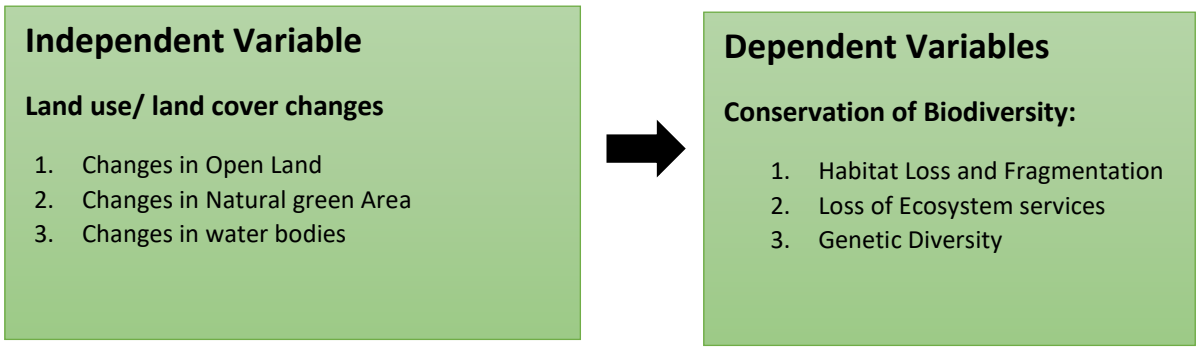
ACCURACY ASSESSMENT

Accuracy assessment is a critical component of any classification project, comparing the classified image against a trusted data source, known as ground truth data. While collecting ground truth data in the field is a traditional method, it is time-consuming and costly. Alternatively, ground truth data can be derived from high-resolution imagery interpretation, existing classified imagery, or GIS layers. After the image classification, their accuracy was evaluated using ArcGIS version 10.8 software.

An accuracy assessment was conducted using randomly sampled reference points (100 per year) validated against Google Earth imagery and field data.

SIGNIFICANCE OF THE STUDY

The research project holds personal significance for the investigator as it represents an opportunity to bridge theoretical knowledge gained through academic studies with practical applications in biodiversity conservation. As a candidate pursuing a Master's degree in environmental studies, particularly focusing on environmental economics and natural resources management, conducting this research aligns with academic and professional goals. Furthermore, the study's findings will providing a valuable resource for future scholars and researchers interested in this field. By contributing to the existing literature, the report aims to facilitate ongoing learning and exploration in the realms of land use, land cover change, and biodiversity conservation. It is anticipated that this study will stimulate interest among fellow researchers, encouraging further inquiry and advancement in this area of study.



DATA ANALYSIS

The processed imageries of 2012 and 2024 was virtually interpreted and classified using field experience. The produced maps were compared with the respective satellite images and was cleaned by re-coding. After classification, the land use and land cover (LULC) datasets were converted to the UTM coordinate system (Zone 45, WGS 84 datum) to facilitate the calculation of change statistics for area measurement Satellite image interpretation was adopted as the appropriate analytical tool for the acquired data. This study also analysed the reports of study area in order to know the trends in loss of major diversity species by using trend analysis.

Land use Land Cover Pattern in 2012			
SL. No	**Name**	**Area (ha)**	**Percentage**
1	Agriculture Land	563.55	50.31
2	Commercial Area	21.07	1.88
3	Education Area	105.81	9.44
4	Flood Inundation Area	8.71	0.77
5	Government Build up Area	42.34	3.78
6	Mixed Build up Area	272.51	24.33
7	Roadside Open Land	9.18	0.81
8	Water bodies	29.51	2.63
9	Natural Green Cover area	68	6.07
	Total	**1120.68**	**100%**

Table 2: - showing statistics of LULC of year 2012

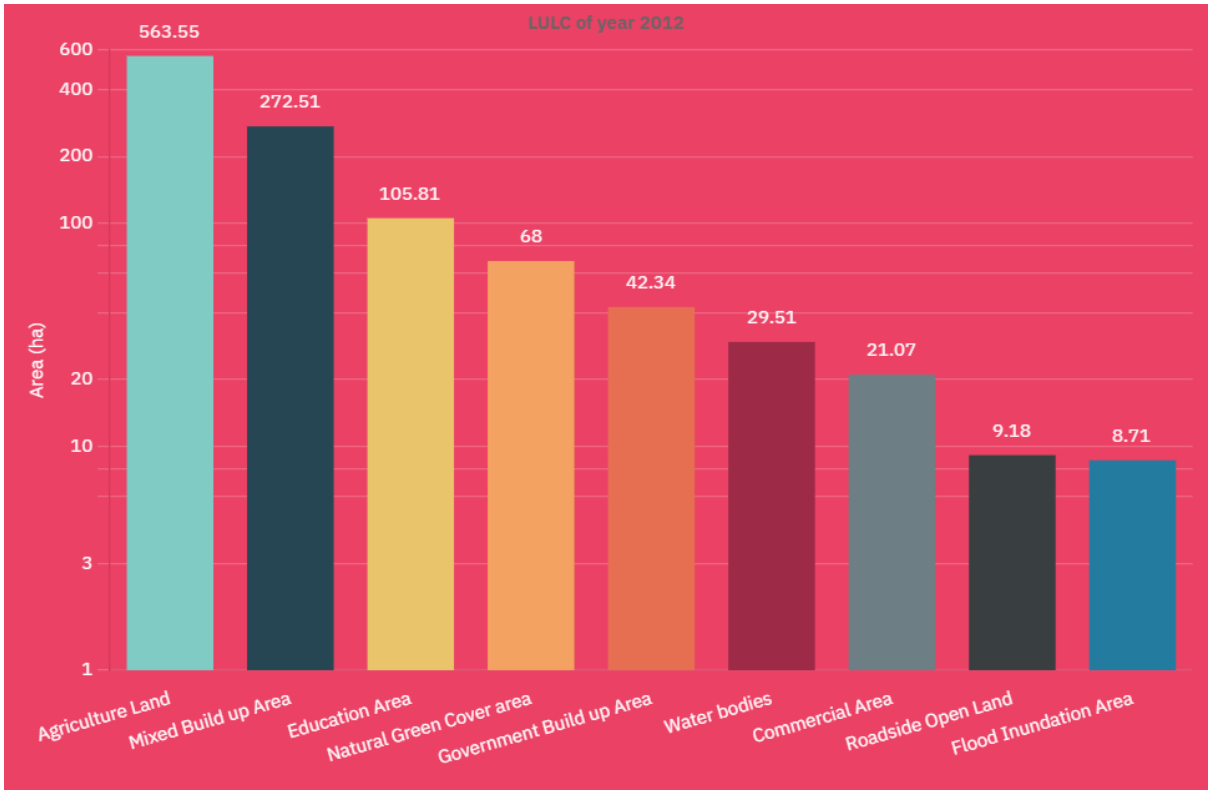


Figure 3: - showing statistics of LULC of year 2012

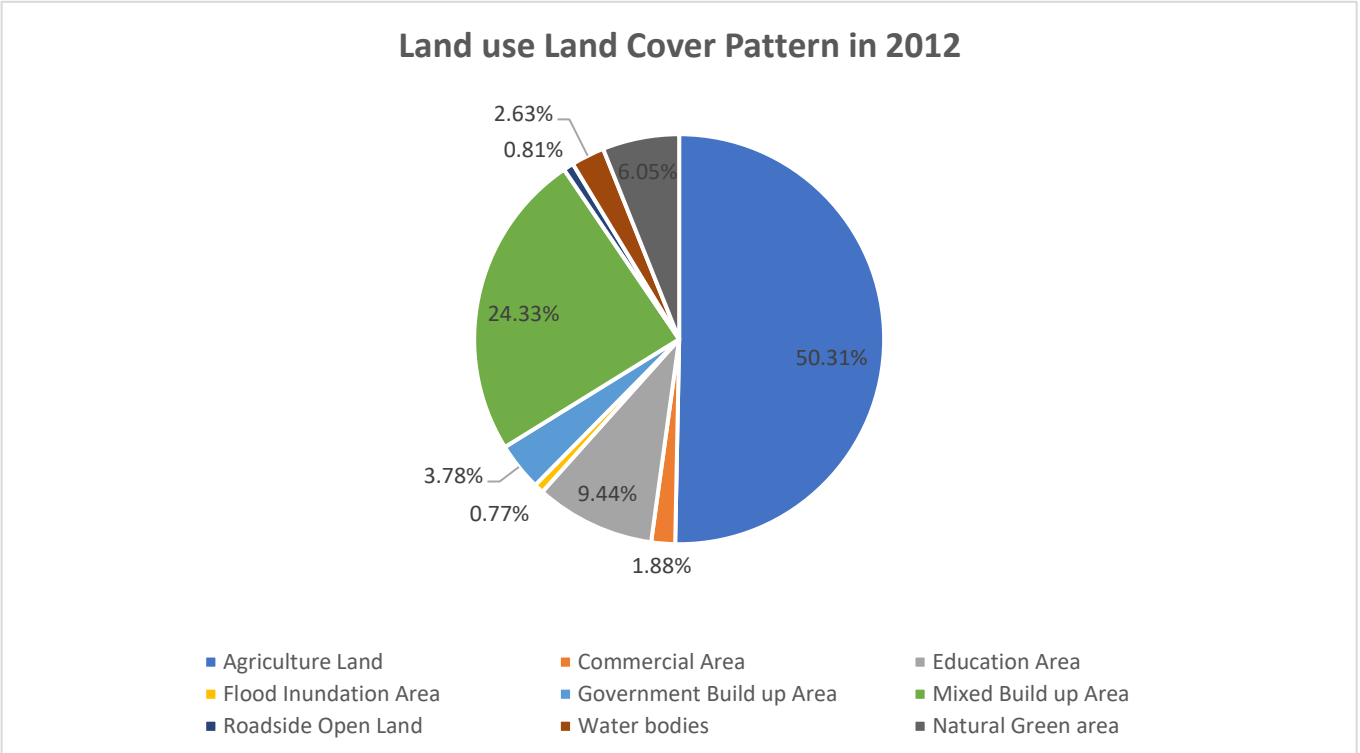


Figure 4: - showing statistics of LULC of year 2012

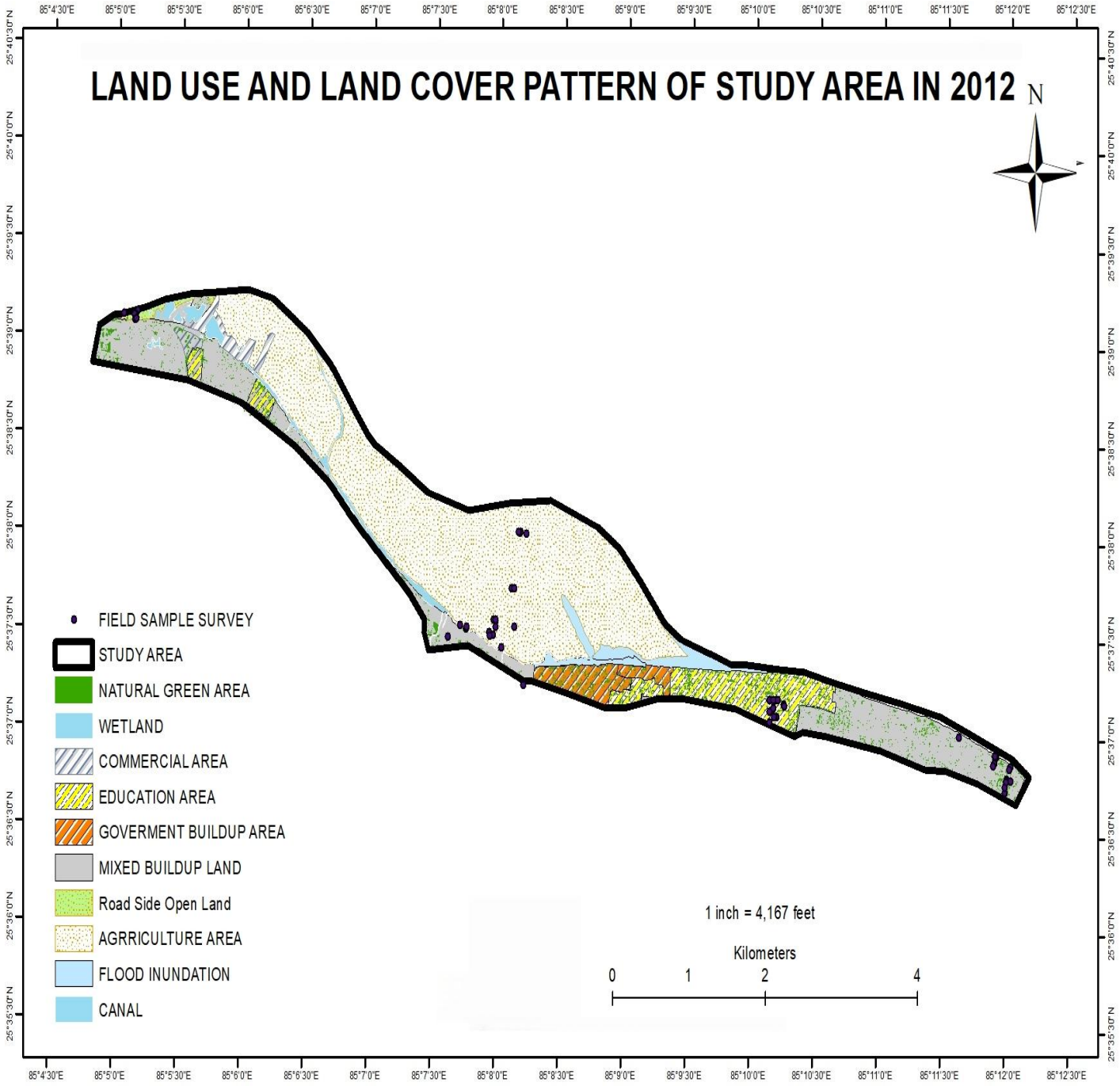


Figure 5: - Showing LULC map of year 2012

Data analysis from google earth image images captured in 2012 month of April revealed significant insights into the land cover distribution within study area. Agriculture land occupied 50.31% of the study area, equivalent to 563.55 hectares. Mixed build up areas comprised 24.33% of the total study area, totalling 272.51 hectares. Natural green area 6.07% of the study area, with a total of 68.0 hectares. Water bodies accounted for 2.63% of total study area, covering 29.51 hectares. Roadside open land accounted for 0.81% of total study area, covering 9.18 hectares. Commercial area for 1.89% of total study area, covering 21.07 hectares these detailed findings highlight the dynamic nature of LULC changes over the specified period and provide valuable intuition into the distribution and composition of various land cover types within the study area.

Land use Land Cover Pattern in 2024			
SL. No	**Name**	**Area (ha)**	**Percent**
1	Agriculture Land	349.87	31.21
2	Commercial Area	42.99	3.83
3	Education Area	73.53	6.56
4	Flood Inundation Area	95.12	8.48
5	Government Build up Area	63.99	5.70
6	Mixed Build up Area	247.40	22.07
7	Roadside Open Land	59.43	5.30
8	Water bodies	87.13	7.77
9	Natural Green area	57.50	5.13
10	J.P. Ganga Path Road	43.72	3.90
	Total	**1120.68**	**100**

Table 3: - showing statistics of LULC of year 2024

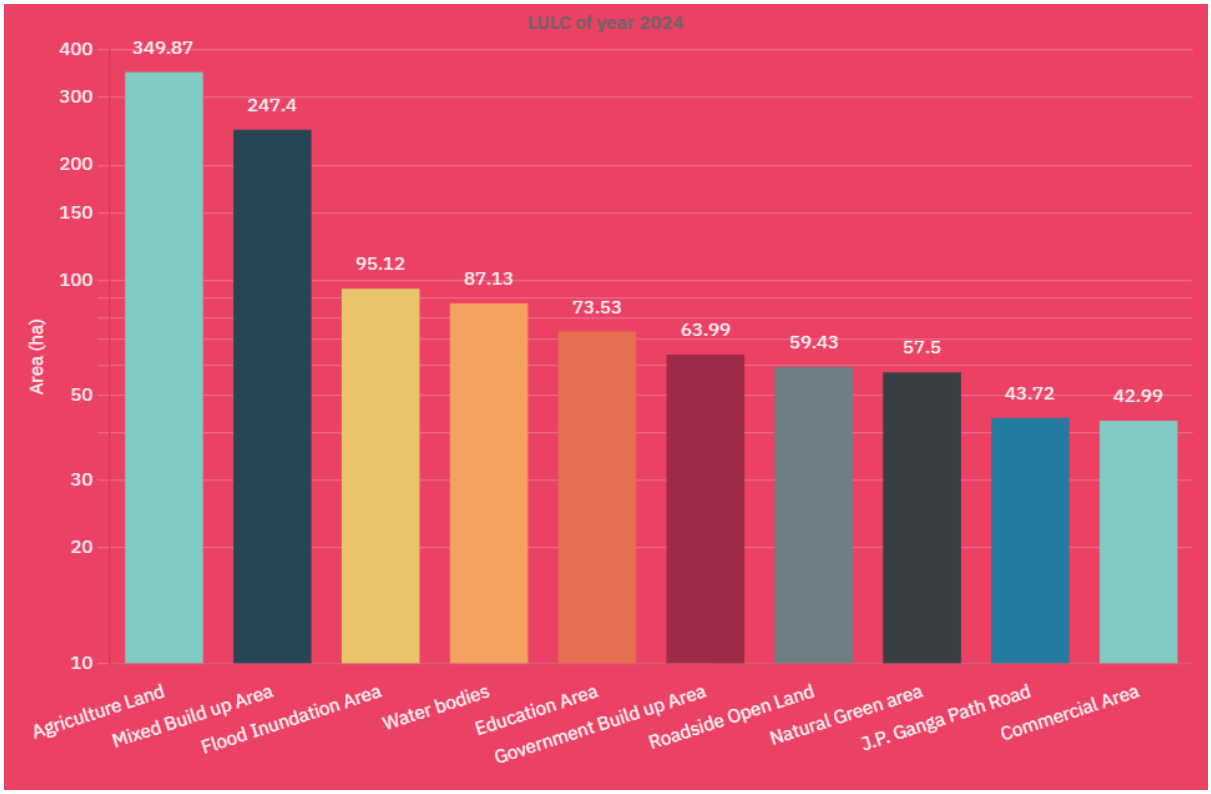


Figure 6: - Showing statistics of LULC of year 2024

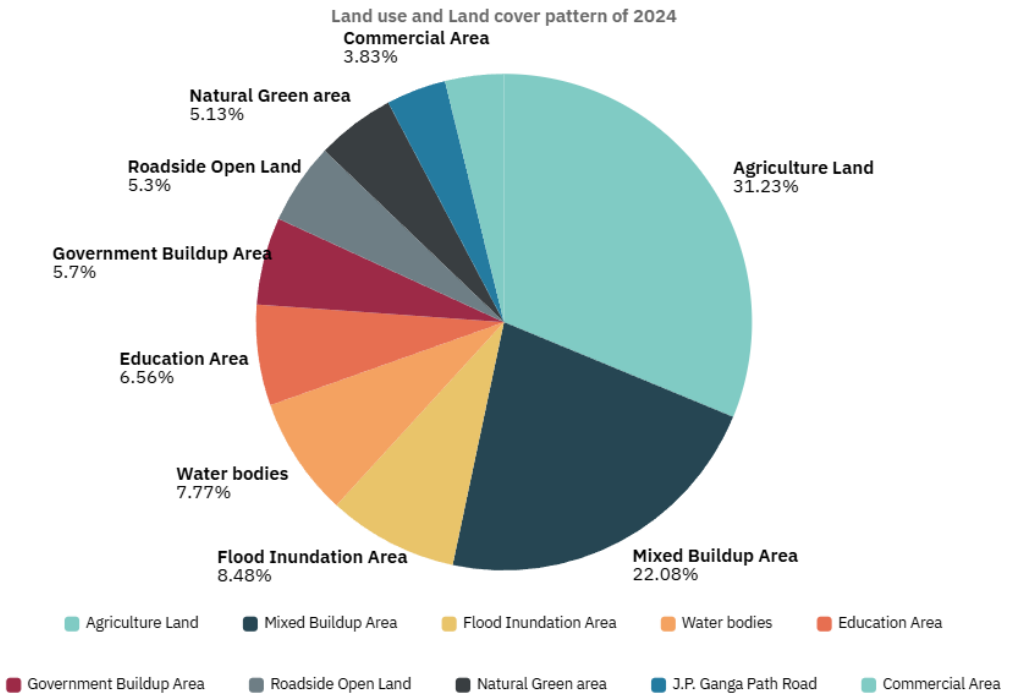


Figure 7: - showing statistics of LULC of year 2024

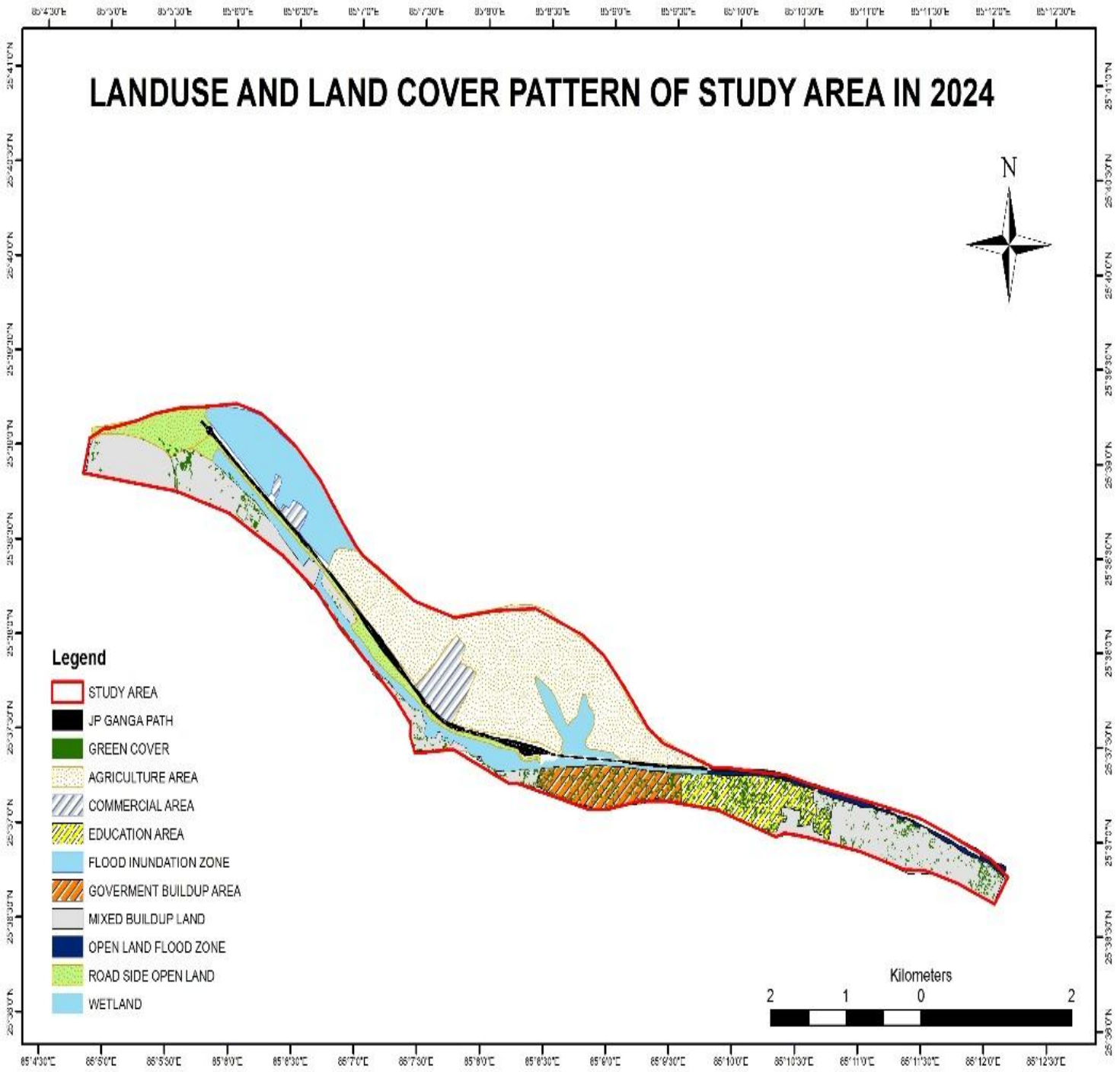


Figure 8: - showing LULC map of year 2024

Data analysis from Google earth image images captured in 2024 month of August revealed significant insights into the land cover distribution within study area. Agriculture land occupied 31.21% of the study area, equivalent to 349.87 hectares. Mixed build up areas comprised 22.07% of the total study area, totalling 247.40 hectares. Natural green area 5.13% of the study area, with a total of 57.50 hectares. Water bodies accounted for 7.77% of total study area, covering 87.13 hectares. Roadside open land accounted for 5.30 % of total study area, covering 59.43 hectares. Commercial area for 3.83% of total study area, covering 42.99 hectares these detailed findings highlight the dynamic nature of LULC changes over the specified period and provide valuable intuition into the distribution and composition of various land cover types within the study area.

COMPARISON OF BOTH YEARS

Comparative Data analysis from captured in 2012 and 2024 revealed significant insights into the land cover distribution within study area. Major changes found in four land use pattern such as Agriculture land, Roadside open land, water bodies, and Natural green cover area. Agriculture area decrease in 2024 relevant to 2012 years Roadside open area increase in 2024 due to new creation of road network, Water body also increase in 2024 relevant to 2012 due to blockage and land use pattern changes in these decades. Natural green area also decreases within decade of 2012 to 2014 in 12 years gaps.

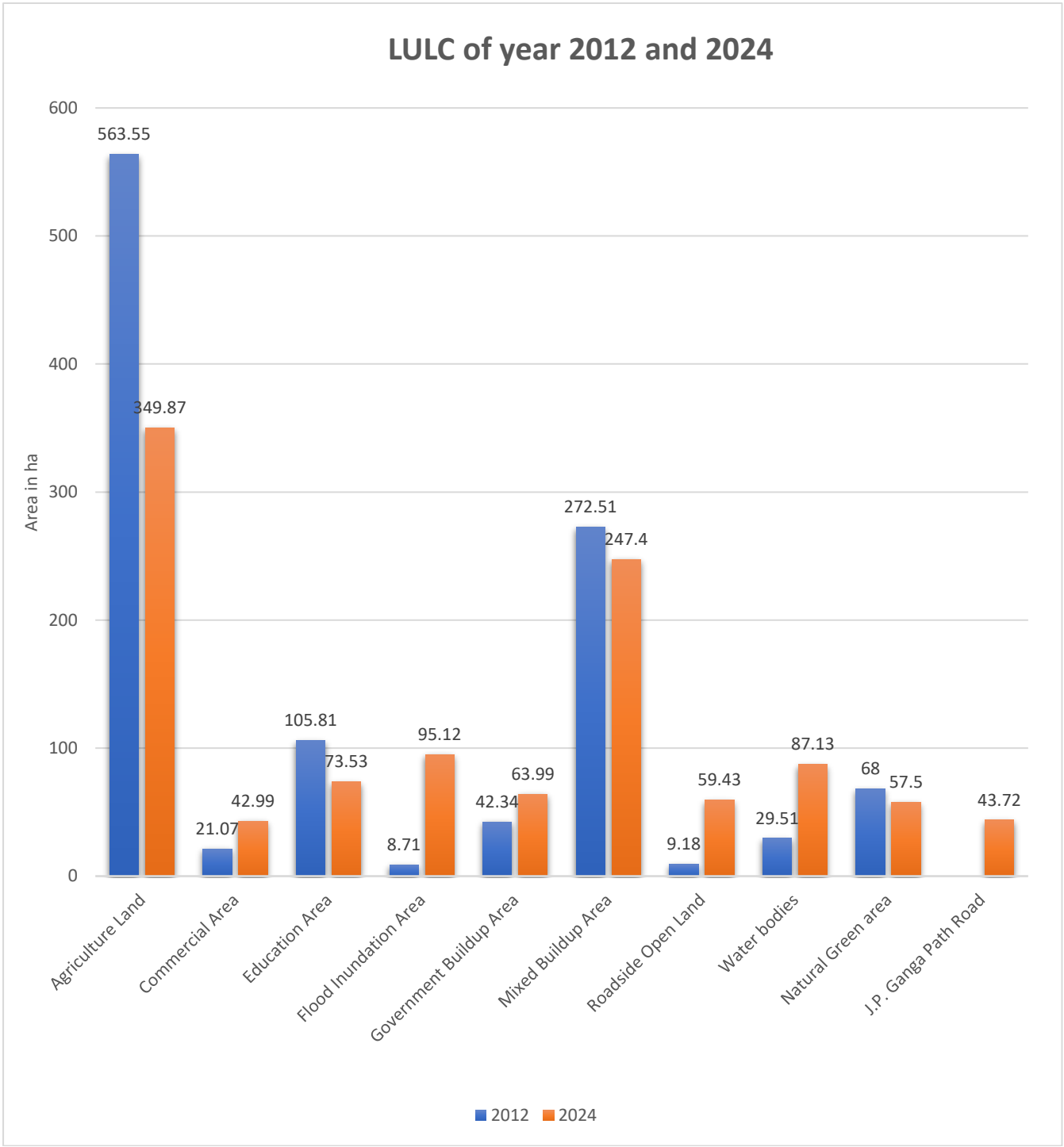


Figure 9: - showing statistics of LULC of year 2012 and 2024

Land use Land Cover Pattern in 2012 and 2024						
Sl.no	**Name**	**Area in (ha) 2012**	**Area in (ha) 2024**	**Change**	**Percent 2012**	**Percent 2024**
1	Agriculture Land	563.55	349.87	-213.68	50.31	31.21
2	Commercial Area	21.07	42.99	+21.92	1.88	3.83
3	Education Area	105.81	73.53	-32.28	9.44	6.56
4	Flood Inundation Area	8.71	95.12	+86.41	0.77	8.48
5	Government Buildup Area	42.34	63.99	+21.65	3.78	5.7
6	Mixed Buildup Area	272.51	247.4	-25.11	24.33	22.07
7	Roadside Open Land	9.18	59.43	-50.25	0.81	5.3
8	Water Bodies	29.51	87.13	+57.62	2.63	7.77
9	Natural Green Cover Area	68	57.5	-10.5	6.07	5.13
10	J.P. Ganga Path Road		43.72			3.9
	Total	**1120.68**	**1120.68**			

Table 3: - Showing statistics of LULC of year 2012 and 2024

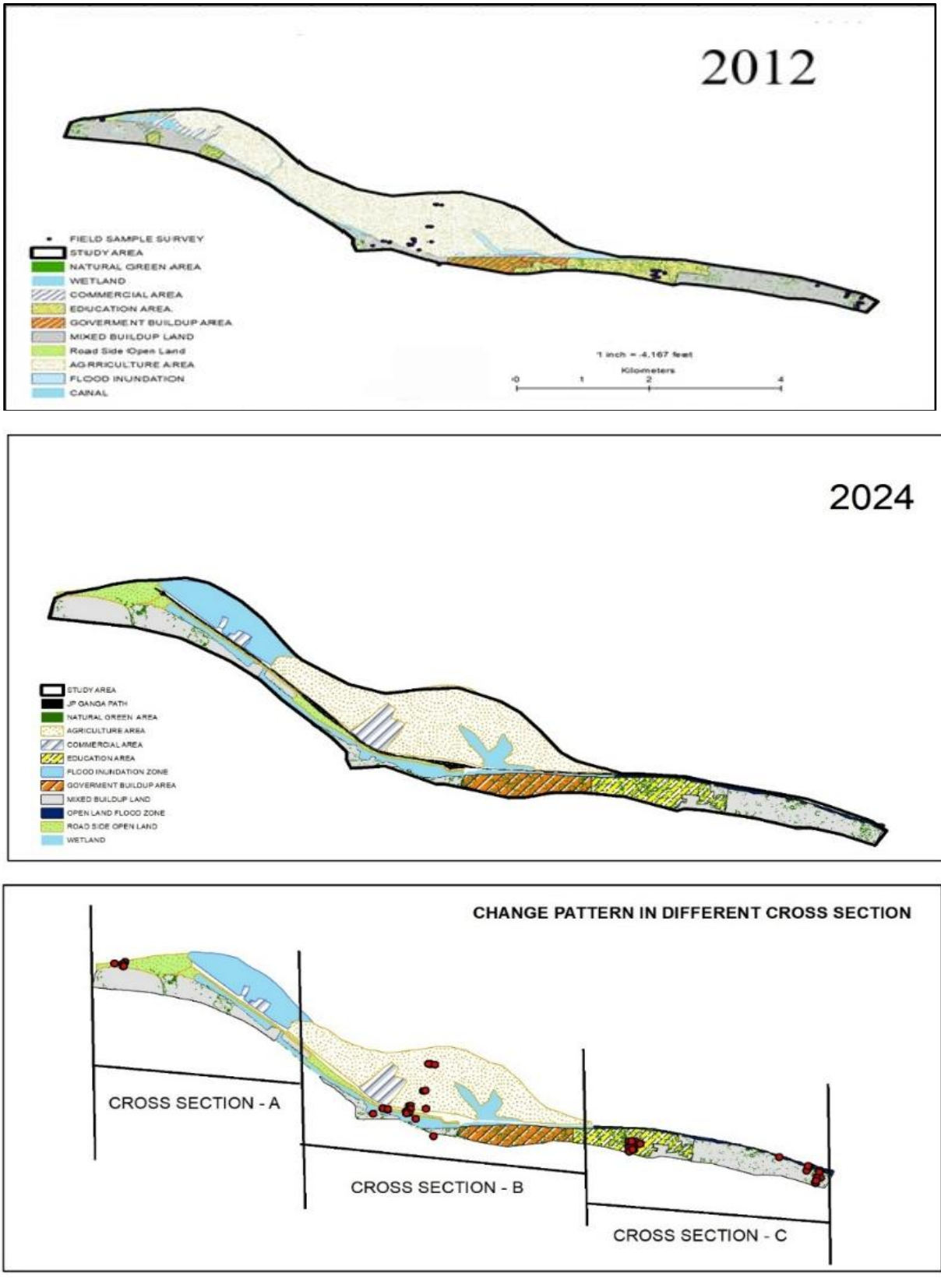


Figure 10: - Showing comparison and change in different cross section of year 2012 and 2024

BIODIVERSITY ECOSYSTEM SERVICES AND FUNCTIONING INDEX

The Biodiversity Ecosystem Services and Functioning Index (BESFI) or related composite indices are tools designed to measure and integrate the relationships between biodiversity, ecosystem functioning, and the ecosystem services they provide.

What it Represents

This kind of index attempts to quantify:

1. Biodiversity – Species richness, genetic diversity, habitat diversity.
2. Ecosystem Functioning – Ecological processes like productivity, nutrient cycling, and resilience.
3. Ecosystem Services – The benefits humans receive, such as clean water, food, climate regulation, and pollination.

Purpose Of the Index

- Evaluate the health of ecosystem.
- Track changes over time due to human impact or climate change

Study area – 1120.68 hectare

Total cross section – 3 (A, B, C)

- Biodiversity and ecosystem services on the basis of that indicators we establish the city biodiversity index with appropriate scoring system.
- To calculate the BESF (Biodiversity and ecosystem services and function)

formula and process has been taken.

$$BESF = \frac{\text{Total area of indicators X score given to indicator}}{\text{Total study area}}$$

On the basis of above formula first we have calculated index for different indicators of year 2012 then 2024.

Biodiversity ecosystem services and functioning index 2012

Study area of 1120.68-hectare area. Has been divided in three major parts and cross section A, B, C and taken total nine Biodiversity and ecosystem services on the basis of that indicators we establish.

Land use land cover pattern in 2012			BSEF (Biodiversity and ecosystem services and functions) scores			BSEF Index
SL No.	Name	Area in ha.	Ideal score	Reduction due to quality and extra	Final score	
1.	Natural Green area	68	10	2.5	7.5	0.4015419
2.	Water bodies	29.51	10	2.5	7.5	0.1974917
3.	Flood Inundation Area	8.71	10	3	7	0.0544045
4.	Agriculture Land	563.55	7.5	2.5	5	2.5143217
5.	Roadside Open Land	9.18	5	-	5	0.0409573
6.	Educational Institutional area	105.81	5	1	4	0.3776636
7.	Government Build up Area	42.34	6	1	5	0.1889032
8.	Mixed Build up Area	272.51	4	1	3	0.7294946
9.	Commercial Area	21.07	1	-	1	0.0188011
	Total	1120.68	**Index**			4.5235794339

Biodiversity ecosystem services and functioning index 2024

Study area of 1113 hectare area. Has been divided in three major parts and cross section A, B, C and taken total nine Biodiversity and ecosystem services on the basis of that indicators we establish.

Land use land cover pattern in 2024			BSEF (Biodiversity and ecosystem services and functions) scores			BSEF Index
SL No.	Name	Area in ha.	Ideal score	Reduction due to quality and extra	Final score	
1.	Natural Green area	57.5	10	2.5	7.5	0.384811008
2.	Water bodies	87.13	10	2	8	0.621979512
3.	Flood Inundation Area	95.12	10	3	7	0.594139273
4.	Agriculture Land	349.87	7.5	2.5	5	1.56097191
5.	Roadside Open Land	59.43	5	-	5	0.265151515
6.	Educational area	73.53	5	1	4	0.2624478
7.	Government Build up Area	63.99	6	1	5	0.285496306
8.	Mixed Build up Area	247.4	4	1	3	0.662276475
9.	Commercial Area	42.99	1	1	1	0.038360638
10.	J.P. Ganga Path Road	43.72	1	1	1	0.038119713
	Total	1120.68	**Index**			4.7137541493

Biodiversity Ecosystem Services and Functioning (BESF) Index

A key aspect of the project involves correlating LULC changes with implications for biodiversity:

• **BESF Index Trends**

- In 2012, the BESF index was calculated at 4.523.
- In 2024, the index improved to 4.713.

• **Interpretation**

Although many of the land cover changes (e.g., loss of agricultural land and reduction in vegetation) might suggest a potential negative impact on biodiversity, the increase in the BESF index indicates that the composite measure—based on multiple biodiversity and ecosystem services indicators across different cross-sections of the study area—improved over the study period. This could reflect positive aspects such as increased water bodies or the creation of new green spaces in urban planning, which might enhance local biodiversity and ecosystem services if managed appropriately.

Results or findings

On the basis of comparative Analysis of Different indicators of year 2012 – 2024

- On the basis of above analysis of interval of decadal of year 2012 – 2024 found that the BSEF index increase in 2024.
- In the year 2012 the index score was 4.56 and in year 2024 index score is 4.90.

Species list founded during field survey in study area

SL. No.	Site Name	Lat	Long	Species Common Name	Species Scientific Name	Category Flora / Fauna	Class	Order	Family	Native/ Invasive	Vegetation type (Tree / Climbers Shrubs/Herb/ woody shrubs/ Vine)	Faunal Type (Aves/ butterflies/ Reptiles/ Amphibians/ Mammals etc.
1	Patna Science College	25.619028	85.16953	Ashok	Saraca Asoca	Flora	Equisetopsida	Fabades	Fabaceae	Native	Tree	
2	Patna Science College	25..618682	85.169154	Teak	Tectona Grandis	Flora	Mangoliopsida	Lamiales	Lamiaceae	Native	Tree	
3	Patna Science College	25.618713	85.169191	Semal	Bombatceiba	Flora	Dicotyledons	Malvales	Malvaceae	Native	Tree	
4	Patna Science College	25.618734	85.169067	Mango	Mangifera Indica	Flora	Mangoliopsida	Sapindales	Anacardiaceae	Native	Tree	
5	Patna Science College	25.619732	85.169067	Bottle Plam	Hyophorbe Lagenicaulis	Flora	Liliopsida	Arecales	Areacaceae	Invasive	Tree	
6	Patna Science College	25.619742	85.169978	Mango	Mangifera Indica	Flora	Mangoliopsida	Sapindales	Anacardiaceae	Native	Tree	
7	Patna Science College	25.619717	85.170093	Eucalyptus	Eucalyptus Species	Flora	Mangoliopsida	Myrtales	Myrtaceae	Invasive	Tree	
8	Patna Science College	25.619306	85.170925	Ashok	Saraca Asoca	Flora	Equisetopsida	Fabades	Fabaceae	Native	Tree	
9	Patna Science College	25.61921	85.170937	Bottle Plam	Hyophorbe Lagenicaulis	Flora	Liliopsida	Arecales	Areacaceae	Invasive	Tree	
10	Patna Science College	25.618272	85.169923	Rugmini (Ixora)	Ixora Coccinea	Flora	Mangoliopsida	Gentianales	Rubiaceae	Native	Shurbs	
11	Patna Science College	25.61827	85.16995	Bottle Plam	Hyophorbe Lagenicaulis	Flora	Liliopsida	Arecales	Areacaceae	Invasive	Tree	
12	Patna Science College	25.619742	85.169519	Ashok	Saraca Asoca	Flora	Equisetopsida	Fabades	Fabaceae	Native	Tree	
13	Patna Science College	25.619043	85169512	Neem	Azadirachta Indica	Flora	Mangnoliopsida	Sapindales	Meliaceae	Native	Tree	
14	Patna Science College	25.619732	85.169513	Peepal	Ficus Religiosa	Flora	Mangnoliopsida	Rosales	Moraceae	Native	Tree	
15	Patna Science College	25.617786	85.169101	Japanese Maple	Acer Palmatus	Flora	Mangnoliopsida	Sapindales	Sapindaceae	Invasive	Tree	
16	Patna Science College	25.618257	85.169717	Crotons	Codiaeum Variegatum	Flora	Mangnoliopsida	Malpighiales	Euphorbiaceae	Invasive	Shurbs	
17	Patna Science College	25.618257	85.169717	Rugmini (Ixora)	Ixora Coccinea	Flora	Mangoliopsida	Gentianales	Rubiaceae	Native	Shurbs	

18	Patna Science College	25.618238	85.169657	Crotons	Codiaeum Variegatum	Flora	Mangnoliopsida	Malpighiales	Euphorbiaceae	Invasive	Shrubs	
19	Inland Water Bodies Authority of India	25.613125	85.200085	Kalp Brikh	Alstonia Scholaris	Flora	Dicotyledonede	Gentianales	Apocynaceae	Native	Tree	
20	Inland Water Bodies Authority of India	25.613125	85.200085	Beer	ZiZiphusmauritiana	Flora	Magnoliopsida	Rosales	Rhamnaceaae	Native	Tree	
21	Inland Water Bodies Authority of India	25.613294	85.200124	Mango	Mangifera Indica	Flora	Magnoliopsida	Sapindales	Anacardiaceae	Native	Tree	
22	Rajaghat	25.614375	85.200593	Banayan	Ficus Religiosa	Flora	Magnoliopsida	Rosales	Moraceae	Native	Tree	
23	Narakat Ghat	25.616837	85.19384	Arjun	Terminaliaarjuna	Flora	Magnoliopsida	Myrtales	Combretaceae	Native	Tree	
24	Alamganj	25.613252	85.20013	Kasoda	Senna Siamea	Flora	Magnoliopsida	Fabades	Fabaceae	Invasive	Tree	
25	Rajaghat (Road Side)	25.614097	85.200428	Baugainuillea	Baugainuilleaglabra	Flora	Magnoliopsida	Caryaphyllales	Nyctaginaceae	Not native	Climber	
26	Rajaghat (Road Side)	25.613178	85.20068	Gulmohar	Delonixregia	Flora	Magnoliopsida	Fabades	Fabaceae	Not native	Tree	
27	Rajaghat	25.613049	85.200053	Neem	Azadirachta Indica	Flora	Dicotyledons	Sapindales	Meliaceae	Native	Tree	
28	Rajaghat	25.613049	85.200054	China Rose	Hibicusrosa Sinensis	Flora	Dicotyledons	Malvales	Malvaceae	Invasive	Shrubs	
29	Holy Trinity School	25.612165	85.199859	Mango	Mangifera Indica	Flora	Magnoliopsida	Sapindales	Anacardiaceae	Native	Tree	
30	Holy Trinity School	25.612165	85.19986	Neem	Azadirachta Indica	Flora	Dicotyledons	Sapindales	Meliaceae	Native	Tree	
31	Mandir	25.614632	85.198499	Neem	Azadirachta Indica	Flora	Dicotyledons	Sapindales	Meliaceae	Native	Tree	
32	Mandir	25.614632	85.1985	Peepal	Ficus Religiosa	Flora	Dicotyledons	Rosales	Moraceae	Native	Tree	
33	Mandir	25.614632	85.198501	Amla	Phyllanthusemblica	Flora	Dicotyledons	Malpighiales	Phyllanthaceae	Native	Tree	
34	Devi Asthan	25.614388	85.198365	Neem	Azadirachta Indica	Flora	Dicotyledons	Sapindales	Meliaceae	Native	Tree	
35	Devi Asthan	25.614388	85.198366	Peepal	Ficus Religiosa	Flora	Dicotyledons	Rosales	Moraceae	Native	Tree	
36	Alamganj	25.615218	85.198632	Peepal	Ficus Religiosa	Flora	Dicotyledons	Rosales	Moraceae	Native	Tree	
37	KL7 Hotel	25.6125974	85.1998802	Ashok	Saraca Asoca	Flora	Equisetopsida	Fabades	Fabaceae	Native	Tree	
38	KL7 Hotel	25.6125974	85.1998803	Peepal	Ficus Religiosa	Flora	Dicotyledons	Rosales	Moraceae	Native	Tree	
39	KL7 Hotel	25.6125762	85.199889	Bottle Plam	Hyophorbelagenicaulis	Flora	Monocots	Arecales	Arecaceae	Not native	Tree	

40	Hanuman Ghat	25.61516	85.198764	Neem	Azadirachta Indica	Flora	Dicotyledons	Sapindales	Meliaceae	Native	Tree	
41	Hanuman Ghat	25.615258	85.198552	Barari (Boal Fish)	Wallago Attu	Fauna	Actinopterygii	Siluriformes	Silurid	Native		Pisces (Fish)
42	Hanuman Ghat	25.615258	85.198552	Moi (Chital))	Chitala Chitala	Fauna	Actinopterygii	Osteoglossiformes	Notepteridae	Native		Pisces (Fish)
43	Hanuman Ghat	25.615258	85.198552	Tangra	Mystustengra	Fauna	Actinopterygii	Siluriformes	Bagridae	Native		Pisces (Fish)
44	Hanuman Ghat	25.615258	85.198552	Bashpata	Ailiacoila	Fauna	Actinopterygii	Siluriformes	Ailiidae	Native		Pisces (Fish)
45	Hanuman Ghat	25.615258	85.198552	Baghair	Bagarius Bagarius	Fauna	Actinopterygii	Siluriformes	Sisoridae	Native		Pisces (Fish)
46	Hanuman Ghat	25.615258	85.198552	Bachuwa	Eutropiichthys Vacha	Fauna	Actinopterygii	Siluriformes	Schilbeidae	Native		Pisces (Fish)
47	SEC-C J.P GANGA PATH	25.626127	85.132905	Shisham	Dalbergia sissoo	Flora	MAGNOLIOPSIDA (DICOTYLEDOT)	Fabales	Fabaceae	Native	Tree	
48	ROAD ADJACENT TO J.P GANGA PATH	25.625996	85133099	Jamun	Syzygium cumini	Flora	MAGNOLIOPSIDA (DICOTYLEDOT)	Myrtales	Myrtaceae	Native	Tree	
49	ROAD ADJACENT TO J.P GANGA PATH	25.626123	85133099	Kadam	Neolamarckia Cadamba	Flora	MAGNOLIOPSIDA (DICOTYLEDOT)	Gentianales	Rubiaceae	Native	Tree	
50	Road Adjacent to j.p Ganga Path	25.625548	85133099	Mango	Magnifera Indica	Flora	Magnolipsida	Sapindales	Anacardiaceae	Native	Tree	
51	Road Adjacent to j.p Ganga Path	25.624817	85.132785	Neem	Azadirachta	Flora	Dicotyledons	Sapindales	Meliaceae	Native	Tree	
52	Road Adjacent to j.p Ganga Path	25.62374	85.133903	Mexican poppy (Satyanozshi)	Argemone Mexicana	Flora	Eudicots	Asterales	Asteraceae	Invansive	Herbs	
53	Road Adjacent to j.p Ganga Path	25.625068	85.132319	Carrot Grass	Parthrnium hysterphorus	Flora	Eudicots	Asterales	Asteraceae	Invansive	Shrubs	
54	Road Adjacent to j.p Ganga Path	25.624717	85.132366	Dhatura Thorn apple	Dhatura inoxia	Flora	Eudicots	Solanales	Solanaceae	Invansive	Shrubs	
55	Sec-c Bans Ghat near j.p Ganga Path	25.625548	85.135614	Brinjal	Solanum Melongena	Flora	Eudicots	Solanales	Solanaceae	Native	Shrubs	
56	Sec-c Bans Ghat near j.p Ganga Path	25.633603	85.136242	Potato	Solanum Tubersum	Flora	Magnoliopsida	Solanales	Solanaceae	Native	Herbaceous	
57	Sec-c Bans Ghat near j.p Ganga Path	25.633647	85.136268	Cauli Flower	Brassica Oleracea var Botrytis	Flora	Magnoliapsida	Brassicales	Brassicaceae	Invansive	Herbaceous	
58	Sec-c Bans Ghat near j.p Ganga Path	25.633654	85.136	Broad bean (BAKLA)	Viciafaba	Flora	Eudicots	Fabales	Fabaceae	Invansive	Legume	
59	Sec-c Bans Ghat near j.p Ganga Path	25.633523	85.137045	Tomato	Solanum Lycopersicum	Flora	Magnolopsida	Solanales	Solanaceae	Invansive	Herbs	
60	Sec-c Bans Ghat near j.p Ganga Path	25.628787	85.13518	French Bean	Phaseolus Vulgaris	Flora	Magnoliospida	Fabales	Fabaceae	Invansive	Climber	

61	Sec-c Bans Ghat near j.p Ganga Path	25.628815	85.135516	Pumpkin	Hagenaria Siceraria	Flora	Dicotyledons	Cucurbitales	Cucurbitaceae	Native	Climber	
62	Sec-c Bans Ghat near j.p Ganga Path	25.625548	85.135614	Mustard	Sinapis alba	Flora	Mangnoliopisda	Brassicales	Brassicaceae	Native	Shrubs	
63	Sec-c Pahalwan Ghat Buddha Colony	25.62533	85.129289	Water Hyacent	Pontederid Crassiper	Flora	Liliopsida	Alismatales	Pontederiaceace	Invansive	Shrubs	
64	Sec-c Pahalwan Ghat Buddha Colony	25.62462	85.126906	Ricinus (Caster)	Ricinus Communis	Flora	Eudicots	Malpighiales	Euphorbiaceae	Invansive	Shrubs	
65	Sec-c Pahalwan Ghat Buddha Colony	25.625626	85.12852	Bagula	Egrettag arzetta	Fauna		Pelecaniformes	Heron Family (Ardeidac)	Native		Aves
66	Sec-c Pahalwan Ghat Buddha Colony	25.625461	85.129308	The Black Drongo	Dicrurus Macrocercus	Fauna		Passeriformes	Dicruridae	Native		Aves
67	Sec-c Pahalwan Ghat Buddha Colony	25.620594	85.136818	Black Kite	Milvus Migrans	Fauna		Accipitriformes	Accipitridae	Native		Aves
68	Section D	25.651655	85.085687	Banyan	ficus Benghalensis	Flora	Eudicots	Rosales	Moraceae	Native	Tree	
69	Section D	25.651941	85.085962	Peepal	Ficus religiosa	Flora	Dicotyledeons	Rosales	Moraceae	Native	Tree	
70	Section D	l25.6516	85.085696	Neem	Azadiracht a	Flora	Dicotyledeons	Sapindales	Meliaceae	Native	Tree	
71	Section D	25651539	85.0857	Moringa	Moringa oleifera	Flora	Eudicots	Brassicales	Moring-aceae	Native	Tree	
72	Section D	25.651617	85.085604	Dhatura	Dhatura Inoxia	Flora	Eudicots	Solanales	Solanaceae	Invasive	Shrubs	
73	Section D	25.651613◦	85.08558	Madar	Calotropis gigantea	Flora	Magnoliopsida	Gentianales	Apocynaceae	Native	Shrubs	
74	Section D	25.6516122	85.085536	Mango	Magnifera Indica	Flora	Magnoliopsida	Sapindales	Anacardiaceae	Native	Tree	
75	Section D	25.651936	85.085686	Gulmohar	Delonix-regia	Flora	Magnoliopsida	Fabales	Fabales	Invasive	Tree	
76	Section D	25.651186	85.085639	Kalp Virikh	Alstonia Scholaris	Flora	Dicotyledoneae	Gentianales	Apocynaceae	Native	Tree	
77	Section D	25.651697	85.084214	Mexican Poppy	Argemone Mexicana	Flora	Eudicots	Asterales	Asteraceae	Invasive	Shrubs	
78	Section D	25.651211	85.085612	Moringa	Moringa oleifera	Flora	Eudicots	Brassicales	Moring-aceae	Native	Tree	
79	Section D Danapur Main Road	25.65122	85.085747	Kaner	Nerium Oleander	Flora	Magnoliopsida	Gentianales	Apocynaceae	Invasive	Shrubs	

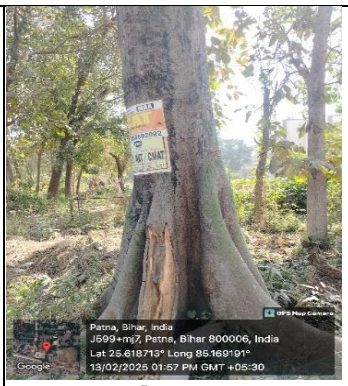
Images of species founded during field survey in study area



Ashok (Saraca Asoca)



Teak (Tectona Grandis)



Semal (Bombatceiba)



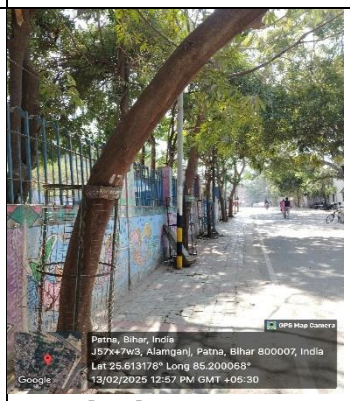
Mango (Magnifera Indica)



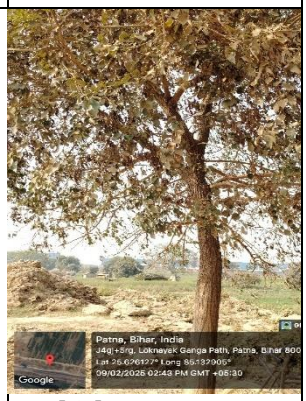
Bottle Plam (Hyophorbe Lagenicaulis)



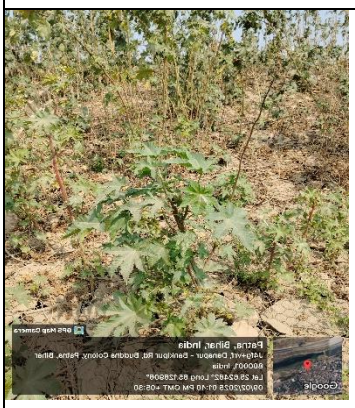
Baugainuillea (Baugainuilleaglabra)



Gulmohar (Delonixregia)



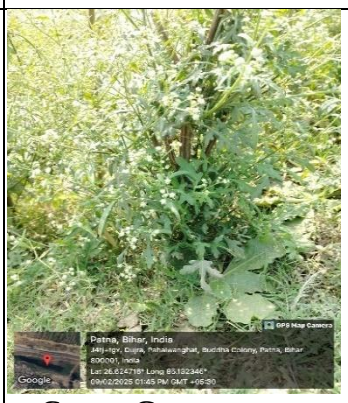
Shisham (Dalbergia-Sissoo)



Castor (Ricinus communis)



Kalp Virikh (Alstonia Scholaris)



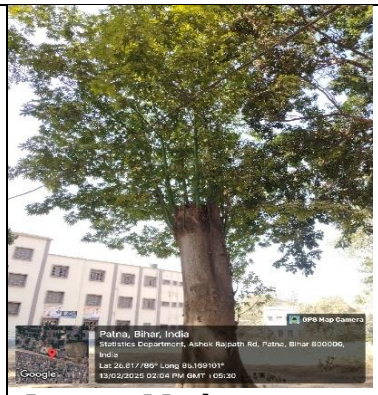
Carrot Grass (Parthrnium hysterphorus)



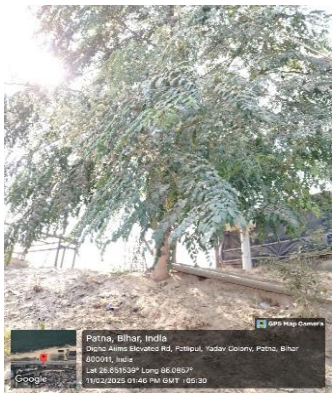
Neem (Azadirachta)



Rugmini (Ixora) (Ixora Coccinea)



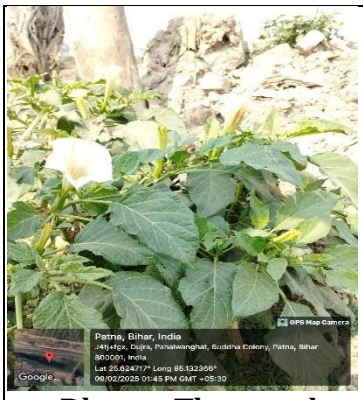
Japanese Maple (Acer Palmatus)



Moringa (Moringa oleifera)



Kaner (Nerium Oleander)



Dhatura Thorn apple (Dhatura Inoxia)



Brinjal (Solanum Melongena)



Potato (Solanum Tubersum)



Cauli Flower (Brassica Oleraceavar Botrytis)



Broad bean (B) (Viciafaba)



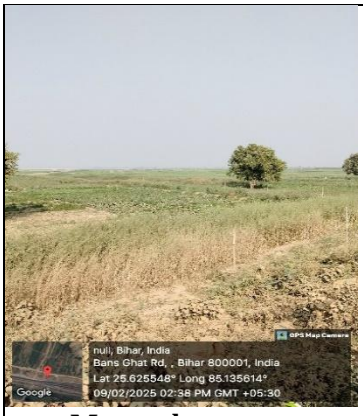
Tomato (Solanum Lycopersicum)



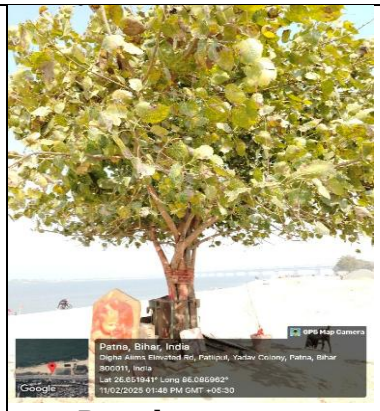
French Bean (Phaseolus-vulgaris)



Pumpkin (Phaseolus Vulgaris)



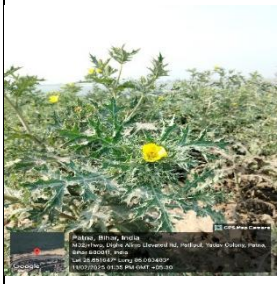
Mustard (Sinapis alba)



Peepal (Ficus religiosa)



Banyan (ficus Benghalensis)



Mexican Poppy
(Argemone Mexicana)



Madar (Calotropis gigantea)



Gulmohar (Delonix- regia)



Migrants Birds (Unidentified)



Bashpata (Ailiacoila)



Baghair (Bagarius Bagarius)



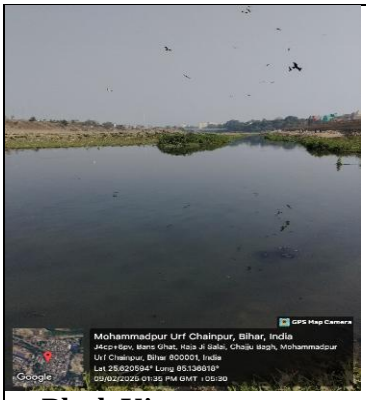
Moi (Chital) (Chitala Chitala)



The Black Drongo (Bird) (Dicrurus Macrocercus)



Tangra (Mystustengra)

 **Black Kite** (Milvus Migrans)	 **Bagula** (Egrettagarzetta**)**	 **Bachuwa** (Eutropiichthys Vacha)	 **Barari (Boal Fish)** (Wallago Attu)

DISCUSSION AND RESULT

The study area is experiencing a rapid loss of biodiversity as a result of unprecedented LULC changes. Overall LULC Change Detection 2012-2024 in this segment, the investigation delves into LULC of study area, with a particular emphasis on the shifts witnessed in land use and land cover from 2012 to 2024. Showing the change in land use and land cover within the study area is crucial for evaluating their influence on biodiversity conservation. Depicts the comprehensive distribution of Land Use and Land Cover (LULC) over a span of 12 years, showcasing a notable in Agriculture land, roadside open land, water bodies and Natural green Area. This accounts for 49.42% of the total landscape, corresponding to a substantial 59.43 hectares for open land and 5.3%, 87.13 hectares for water bodies. These findings underscore the dynamic changes in the LULC pattern, emphasizing the significant expansion of open land and water bodies within the studied timeframe. From the past 12 years there was reduction of natural green area by 68 hectares from 57.5 hectares respectively. According to above research found that Open land, natural green area and water body spatial changes in decades. And changes in this area play an important role in biodiversity and landscape ecosystem.

AGRICULTURE

The area dedicated to agricultural land diminished from 563.55 hectares in 2012 to 349.87 hectares in 2024, indicating a net reduction of 213.68 hectares. This decline in agricultural land can be attributed to increasing demand for urbanization and ongoing socio-economic development activities within the study area. Additionally, another contributing factor to the decrease is the Ganga River run off and new construction of J.P Ganga Path, J.P setu and commercial casting yard along the bank of Ganga River have replaced patches of shrubs and grasslands.

NATURAL GREEN COVER

The area covered by vegetation experienced a notable increase, expanding from 68 hectares in 2012 to 57.5 hectares in 2024, marking a net reduction of 10.5 hectares. This represents a decrease of between 2012 and 2024 showing demand of urban housing within the study area. However, construction of roads, bridges and commercial complexes have affected the natural vegetation and green spaces. Patna major source of pollution in form of dust particle mobilized and came in the city through wind from north to eastern area, Miniature forests play an important role to prevent and depressed the impact of PM10 and PM2.5 in the city. These miniature forests in our cities create ecosystems, bringing a diversity of insect and bird species which, will turn, surrounding ecosystem healthy. There in the study area 57.5 hect. of road side and complex of small patches open area available in the study area which can be utilized as miniature forest that enhance the high diversity plant communities are critical for stable ecosystem function over time and ecological, environmental, social, and human health benefits.

WATERBODIES

The area occupied by water bodies witnessed a significant increase, expanding from 29.51 hectares in 2012 to 87.13 hectares in 2024, indicating a net increase of 57.62 hectares. This could be due to infrastructure developments, mainly J.P Ganga Path created water logging condition to mainly southern part of study area. However, it's important to acknowledge that some smaller water bodies may have vanished due to urbanization, commercial and

agricultural expansion, alongside a reduction in overall rainfall received by the study area over the past 12 years.

Recommendation for Restoration of land use pattern in study area relevant to Biodiversity conservation and Management

1. By increasing the diversity of trees on our streets we can create miniature forests.

2. Replanting native vegetation counteract the loss of Green Area, grassland, in road side open area along with approx. 59.43hect.

3. Should prioritize habitat restoration projects to wetland areas.

4. Replanting native vegetation and implementing erosion control measures can help restore degraded habitats.

5. Should actively engage with local communities to foster a sense of stewardship and promote sustainable land use practices.

6. Collaborative conservation initiatives involving local stakeholders can help mitigate human-wildlife conflicts and support biodiversity conservation efforts.

7. Should advocate for policies and practices that prioritize sustainable development and environmental conservation. This includes promoting eco-friendly agricultural practices, supporting alternative livelihoods for communities near the study area, and investing in renewable energy projects.
8. Integrate green roofs, bioswales, permeable pavements, and urban wetlands into Patna's development plans to reduce stormwater runoff and create micro-habitats in built-up areas.

For Future Researchers

1. Should conduct longitudinal studies to monitor changes in LULC patterns and biodiversity over time. Long-term data collection efforts are essential for understanding ecosystem dynamics and informing conservation strategies.

2. Should explore the socio-economic influence of LULC changes on local individuals surrounding study area. This includes assessing the effects of habitat loss on livelihoods, food security, and human wildlife conflicts.

3. Should evaluate the effectiveness of conservation interventions implemented, such as habitat restoration projects, this can help identify best practices and inform evidence-based conservation strategies moving forward.

4. Investigate how altered monsoon patterns, extreme flood events, and land-surface temperature changes interact with LULC dynamics to affect ecosystem resilience and human adaptation. Coupled hydrological and land-surface models can elucidate feedback loops between climate and land-cover change

CONCLUSION

Over the period 2012–2024, the southern bank of the Ganga at Patna underwent profound LULC transformations that mirror broader patterns of urbanization across Indian river basins. Agricultural lands, which constituted over half (50.31 %) of the study area in 2012, contracted to just 31.21 % by 2024, a loss of roughly 21 percentage points. This contraction reflects conversion of fertile floodplain tracts into residential, commercial, and transportation infrastructure—a hallmark of rapid urban sprawl in emerging metropolitan centers. Similarly, natural green cover, including riparian forests and scattered tree lines, declined from 6.07 % to 5.13 %, signalling not only outright loss but also degradation of patch quality as corridors fragmented under infrastructural footprints.

Built-up areas expanded by over 50 %, fuelled by a quadrupling of roadside open zones and unplanned peri-urban settlements. This trend aligns with national urban growth rates of 2.3 % years and underscores the pressures on municipal authorities to balance housing demands with ecological safeguards. The near-tripling of surface water bodies—from 2.63 % to 7.77% was driven partly by embankment construction and drainage pits that fill seasonally, and partly by intentional impoundments for flood control. While increased water cover may appear beneficial.

The project highlights that while urbanization and the conversion of agricultural land are markedly changing the landscape of the Patna urban area adjacent to the Ganga River, there are nuanced effects on the ecosystem. The slight improvement in the BESF index from 4.56 to 4.90 between 2012 and 2024 suggests that, despite reductions in some critical land cover types, there may be compensatory ecological benefits or successful conservation interventions at play. Understanding these dynamics in greater detail through longitudinal, socio-economic, and intervention-based studies will be key to informing future urban planning and biodiversity conservation strategies.

This comprehensive assessment not only provides a snapshot of historical changes but also lays the groundwork for future research aimed at ensuring sustainable development and biodiversity conservation in rapidly urbanizing landscapes.

In sum, the LULC shifts documented here threaten both biodiversity and human well-being. They compromise riparian connectivity, exacerbate flood risk through loss of natural floodplains, undermine water purification functions, and erode cultural ecosystem services valued by local communities. The data underscore the imperative for integrated governance frameworks that couple spatial planning with ecological restoration, supported by robust monitoring, stakeholder engagement, and adaptive management policies.

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