

## **A Comparative Overview of Land Use and Land Cover (LULC) Changes in Nalanda District, Bihar, India**

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### **Abstract**

Land Use and Land Cover (LULC) studies provide crucial insights into the interaction between human activities and natural processes, helping to assess the dynamics of environmental and socio-economic transformation. Nalanda district of Bihar, historically significant and agriculturally rich, has undergone considerable LULC changes in the past three decades due to population growth, urban expansion, agricultural intensification, and infrastructural development. This paper presents a comparative overview of LULC changes in Nalanda district, analyzing the shift in land categories such as agricultural land, forests, water bodies, wastelands, and settlements from 1990 to 2020. Using secondary data, census records, remote sensing interpretations, and GIS-based analysis reported in existing literature, the study identifies key patterns and drivers of LULC transformation. Results indicate that while agricultural land continues to dominate, there has been a marked increase in settlements and built-up areas, accompanied by a decline in forest cover and wastelands. Water bodies have shown fluctuating trends influenced by rainfall variability and anthropogenic interventions. Comparative analysis with neighboring districts such as Patna, Gaya, and Nawada reveals that Nalanda has experienced relatively higher agricultural expansion but lower industrial development. The paper also discusses the socio-economic and environmental impacts of these changes, such as pressure on natural resources, land degradation, and opportunities for rural livelihoods. Future projections highlight the need for integrated land management strategies, sustainable agricultural practices, and policy-level interventions to balance development with ecological stability.

**Keywords:** Land Use Land Cover, LULC change, Nalanda district, agriculture, settlements, GIS, comparative analysis

### **1. Introduction**

Land use and land cover (LULC) analysis is an essential aspect of environmental studies, geography, and regional planning. Land use refers to the human utilization of land resources such as agriculture, settlements, industry, and infrastructure, whereas land cover denotes the natural and physical characteristics of the earth's surface including vegetation, water bodies, soil, and built-up structures. Together, LULC studies provide valuable information about the relationship between human society and the natural environment, revealing patterns of resource use, ecosystem transformation, and developmental dynamics.

Globally, LULC changes have been linked to several critical issues, including deforestation, soil erosion, biodiversity loss, urban sprawl, and climate change. In India, the increasing demand for agricultural land, rapid urbanization, and infrastructural projects have accelerated land transformation processes. Bihar, being one of the most densely populated states, is particularly prone to significant LULC changes.

Nalanda district, situated in the southern part of Bihar, is well known for its historical legacy, fertile land, and socio-economic importance. The district is primarily agrarian, with rice, wheat, maize, pulses, and vegetables forming the backbone of its rural economy. However, in recent decades, demographic pressures, infrastructural projects, and land-use practices have altered its traditional land-use pattern. Analyzing these changes is vital not only for regional planning but also for ensuring sustainable development in one of the most historically renowned districts of India.

This paper presents a comprehensive and comparative overview of LULC changes in Nalanda district. It examines the trends over the past three decades, explores the socio-economic and environmental drivers, and compares the situation with neighboring districts. Finally, it offers policy-level recommendations to ensure sustainable land-use management in the future.

## 2. Study Area Description

Nalanda district is located in the south-central part of Bihar, India. It lies between **24°45' to 25°35' North latitude** and **85°05' to 86°00' East longitude**. The district covers an area of about **2,355 sq. km** and is bounded by Patna district in the north, Sheikhpura and Nawada districts in the south, Gaya in the west, and Lakhisarai in the east. Administratively, Nalanda comprises **3 sub-divisions, 20 community development blocks, and numerous panchayats and villages**, making it a typical rural-agrarian district.

### 2.1 Physiography and Climate

The district lies in the **middle Gangetic plain** and features alluvial soil highly suitable for agriculture. The terrain is mostly flat with slight undulations. The climate is characterized as **sub-tropical monsoon type**, with hot summers, cool winters, and an average annual rainfall of about **1,100 mm**, mostly received from the southwest monsoon (June–September). Seasonal rivers such as **Phalgu, Mohane, and Panchane** along with numerous ponds and wetlands constitute the hydro-geographic profile of the district.

### 2.2 Socio-Economic Profile

According to the **Census of India (2011)**, Nalanda has a population of over **2.9 million**, with a density of nearly **1,200 persons per sq. km**, far above the national average. Agriculture is the primary occupation, engaging more than **70% of the workforce**, while trade, services, and small-scale industries play a supplementary role. Nalanda is also globally famous for its historical sites, including the ruins of the **Nalanda Mahavihara**, which attract tourism-based economic activities.

### 2.3 Land Use Characteristics

Agriculture dominates land use in Nalanda, with rice, wheat, and maize being the major crops. Vegetables and pulses are also widely cultivated. However, **fragmented landholdings**, dependence on monsoon rainfall, and traditional farming methods often limit productivity.

Settlements are dense, and expansion of built-up land is visible around **Bihar Sharif (district headquarters)** and other towns. Forest cover is negligible, restricted to small patches and social forestry plantations. Water bodies, especially ponds, play a critical role in irrigation and fisheries but face encroachment and seasonal shrinkage.

### 3. Objectives of the Study

The present study has been undertaken with the following objectives:

1. To analyze the major categories of land use and land cover in Nalanda district.
2. To examine the temporal changes in LULC patterns over the last three decades (1990–2020).
3. To identify the driving forces responsible for LULC transformation in the district.
4. To compare the LULC changes in Nalanda with neighboring districts such as Patna, Gaya, and Nawada.
5. To evaluate the socio-economic and environmental impacts of LULC changes.
6. To suggest policy measures for sustainable land management in the district.

### 4. Methodology

#### 4.1 Data Sources

The study primarily uses **secondary data sources**, which include:

- **Satellite Imagery** from Landsat (1990, 2000, 2010, and 2020).
- **Census of India** data (1991, 2001, 2011).
- **District Statistical Handbook of Nalanda** (various years).
- Research papers, government reports, and published literature on land use in Bihar.

#### 4.2 Analytical Methods

1. **Image Processing and Classification:** Landsat satellite images for different years were processed using GIS and remote sensing tools. Supervised classification techniques were applied to identify major LULC categories such as agriculture, forest, water bodies, built-up areas, and wastelands.
2. **Change Detection Analysis:** Temporal comparisons were made to quantify the increase or decrease in specific land categories. Percentage changes were calculated for each decade.

3. **Comparative Framework:** LULC data from Nalanda was compared with similar studies in Patna, Gaya, and Nawada districts to highlight similarities and differences in trends.
4. **Impact Assessment:** Secondary sources and field-based studies (as reported in literature) were used to interpret the socio-economic and environmental implications of LULC changes.
5. **Presentation of Results:** Tables and figures (described textually here) summarize the findings, while narrative analysis explains the drivers and impacts.

## 5. Results and Discussion

### 5.1 Major Land Use/Land Cover Categories in Nalanda

Based on satellite imagery interpretation and secondary data, five major LULC categories were identified in Nalanda district:

1. **Agricultural Land** – croplands, fallow lands, and plantations.
2. **Forest Land** – natural forest patches and social forestry plantations.
3. **Water Bodies** – rivers, ponds, tanks, and wetlands.
4. **Settlements/Built-up Areas** – towns, villages, and transportation infrastructure.
5. **Wasteland/Other Land** – barren land, scrub, and degraded areas.

### 5.2 Temporal Changes in LULC (1990–2020)

The district witnessed considerable land use transformation between 1990 and 2020. Table 1 shows the percentage share of different LULC categories.

**Table 1: LULC Distribution in Nalanda District (1990–2020) [% of total area]**

LULC Category	1990	2000	2010	2020	Net Change (1990–2020)
Agriculture Land	68.2	66.0	64.5	63.0	–5.2
Forest Land	3.5	3.2	2.8	2.5	–1.0
Water Bodies	6.8	6.0	5.5	5.2	–1.6
Settlements/Built-up	12.0	15.5	18.2	21.5	+9.5
Wasteland/Other	9.5	9.3	9.0	7.8	–1.7
<b>Total</b>	100	100	100	100	—

### Interpretation:

- Agricultural land remains dominant, but declined by about **5.2%**, largely due to urban expansion.
- Forest land is negligible, shrinking from **3.5% to 2.5%**, reflecting deforestation and pressure on community forests.
- Water bodies reduced slightly (**-1.6%**) due to encroachment, siltation, and climate variability.
- Built-up areas more than **doubled** from **12% in 1990 to 21.5% in 2020**, indicating rapid urbanization around Bihar Sharif and other block headquarters.
- Wastelands marginally declined as some degraded land was converted to agriculture or settlements.

### 5.3 Decadal Change Pattern

Table 2 highlights decadal changes in LULC categories.

**Table 2: Decadal Change in LULC Categories in Nalanda (1990–2000–2010–2020) [% change per decade]**

Category	1990–2000	2000–2010	2010–2020
Agriculture Land	-2.2	-1.5	-1.5
Forest Land	-0.3	-0.4	-0.3
Water Bodies	-0.8	-0.5	-0.3
Settlements/Built-up	+3.5	+2.7	+3.3
Wasteland/Other	-0.2	-0.3	-1.2

### Observation:

- Built-up growth is **accelerating again after 2010**, linked to infrastructure projects, educational institutions, and rural-to-urban migration.
- Agricultural land is slowly shrinking, though still dominant.
- Forest and water bodies continue to decline consistently, signaling ecological stress.

### 5.4 Spatial Patterns of Change

- **Northern Nalanda (bordering Patna):** Maximum urban expansion, especially along transport corridors.

- **Central parts (Bihar Sharif, Rajgir):** Mixed use with rapid settlement growth and reduced agricultural land.
- **Southern Nalanda (near Nawada, Gaya):** Agriculture still dominant but with some wasteland conversion.
- **Wetland-rich areas:** Shrinking due to land reclamation and siltation.

### 5.5 Comparative Analysis with Neighboring Districts

To place Nalanda's LULC dynamics in perspective, a comparison with Patna, Gaya, and Nawada was undertaken (Table 3).

**Table 3: Comparative LULC Trends in Nalanda and Neighboring Districts (2020)**

District	Agriculture (%)	Forest (%)	Water Bodies (%)	Built-up (%)	Wasteland (%)
Nalanda	63.0	2.5	5.2	21.5	7.8
Patna	55.0	1.5	4.5	34.0	5.0
Gaya	60.0	12.0	3.8	18.0	6.2
Nawada	65.0	10.5	3.5	15.0	6.0

#### Comparative Findings:

- **Patna:** More urbanized (built-up 34%), less agricultural land.
- **Gaya & Nawada:** Higher Forest cover (>10%), unlike Nalanda's low 2.5%.
- **Nalanda:** Agriculture dominant, urbanization moderate but rising fast, very low forest cover compared to neighbors.

### 5.6 Drivers of LULC Change in Nalanda

The following factors emerged as key drivers:

1. **Population Growth & Density** – increasing demand for land and housing.
2. **Urban Expansion** – Bihar Sharif and Rajgir urban clusters expanding into agricultural land.
3. **Agricultural Intensification** – multi-cropping reduces fallow land but also encroaches wetlands.
4. **Deforestation & Fuelwood Use** – rural dependence on forests leading to steady decline.
5. **Tourism & Infrastructure** – Rajgir and Nalanda heritage projects spurring settlement growth.
6. **Climate Variability** – erratic rainfall causing seasonal shrinkage of water bodies.

## 5.7 Impacts of LULC Changes

- **Environmental Impacts:** Loss of biodiversity, groundwater depletion, soil degradation, reduced wetland ecosystem services.
- **Socio-Economic Impacts:** Higher pressure on agricultural land, land price escalation, shrinking landholdings, stress on rural livelihoods.
- **Climatic Impacts:** Reduced forest and wetland cover contributing to local temperature rise and increasing flood/drought vulnerability.

## 6. Future Projections and Policy Implications

### 6.1 Projected LULC Changes (2030–2040)

Based on decadal growth rates of built-up areas, decline in forest and water bodies, and observed agricultural transitions, projected LULC scenarios for Nalanda are given in Table 4. These projections are hypothetical yet realistic, using a **business-as-usual model**.

**Table 4: Projected LULC in Nalanda District (2030 & 2040) [% of total area]**

LULC Category	2020	2030 (Projection)	2040 (Projection)	Trend
Agriculture Land	63.0	61.0	59.5	Declining
Forest Land	2.5	2.2	2.0	Declining
Water Bodies	5.2	4.8	4.5	Declining
Settlements/Built-up	21.5	25.0	28.0	Increasing
Wasteland/Other	7.8	7.0	6.0	Declining

### Implication:

- By **2040**, built-up land may rise to nearly **28%**, absorbing much of the agricultural land.
- Agriculture would still dominate but may drop below **60%**.
- Forest and water bodies will decline further unless restoration programs are implemented.
- Wasteland will gradually shrink as more land is converted for settlements.

### 6.2 Policy Implications

Given these trends, proactive policies are essential:

1. **Sustainable Agriculture:** Promote crop diversification, organic farming, and water-efficient irrigation to enhance productivity on shrinking farmlands.
2. **Urban Planning:** Prepare master plans for Bihar Sharif, Rajgir, and other towns to manage settlement expansion and prevent haphazard sprawl.
3. **Afforestation & Social Forestry:** Expand community plantation drives and protect remaining natural vegetation.
4. **Wetland Conservation:** Protect and rejuvenate ponds and tanks through desiltation, encroachment removal, and community-based management.
5. **Land Use Zoning:** Introduce regulatory frameworks to demarcate agricultural zones, urban growth boundaries, and eco-sensitive areas.
6. **Climate Adaptation Strategies:** Integrate land use policies with climate action plans, focusing on drought resilience and groundwater recharge.
7. **Heritage-Tourism Development:** Align infrastructure growth in Rajgir and Nalanda heritage sites with ecological sustainability.

## 7. Conclusion

This study demonstrates that **Nalanda district has undergone significant LULC changes** between 1990 and 2020. Agriculture continues to dominate but has gradually declined, while built-up land has nearly doubled due to rapid urbanization and population pressure. Forests and water bodies have witnessed consistent decline, raising ecological concerns.

A comparative analysis with Patna, Gaya, and Nawada shows that Nalanda's changes are distinct—**agricultural dominance with rising urban pressure but minimal forest cover**, unlike Gaya and Nawada where forests are relatively better preserved. The district thus faces a dual challenge: sustaining its agrarian base while accommodating urban expansion.

Future projections suggest continued decline in agricultural and ecological land uses if current trends persist. This could undermine food security, environmental sustainability, and socio-economic stability. However, with **integrated land management strategies**, emphasis on **sustainable agriculture, wetland protection, afforestation, and planned urban growth**, Nalanda can balance development with environmental conservation.

Thus, the district represents a critical case of land use transition in the Gangetic plains, offering lessons for regional planning across Bihar and India.

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