

Land degradation study of Ghaziabad district due to urbanization using Geoinformatic techniques for the last 25 years

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Research Article

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Abstract

Land degradation is a major environmental concern that leads to the temporary or permanent deterioration of soil quality and productivity. Rapid population growth, urbanization, declining vegetation cover, water pollution, and soil contamination are key drivers of land degradation. Geospatial technologies, including Geographic Information Systems (GIS), Remote Sensing (RS), and the Global Positioning System (GPS), provide efficient and cost-effective tools for monitoring land use and land cover (LULC) changes over time. This study evaluates the impact of urban expansion on land degradation in Ghaziabad district using Landsat satellite imagery acquired in 1994, 2000, 2010, 2015, and 2018. These years were selected to capture the district's rapid urban growth following its establishment as a Municipal Corporation in 1994. Supervised maximum likelihood classification and Normalized Difference Vegetation Index (NDVI) analysis were employed to assess LULC dynamics. The results indicate that urban areas and water bodies increased by 29.33% and 2.08%, respectively, while forest, barren land, and vegetation declined by 0.66%, 14.32%, and 16.14% during the study period. Land conversion analysis revealed substantial transformation of vegetated areas into urban land, reflecting the influence of rapid urbanization. Additionally, soil quality indicators showed a declining trend between 2011 and 2017, highlighting the adverse effects of urban expansion on land resources and emphasizing the need for sustainable land management strategies.

I. INTRODUCTION

Land is one of the most valuable natural resources, providing food, water, shelter, and ecosystem services essential for sustaining human life. However, increasing anthropogenic activities have accelerated the degradation of land resources, threatening agricultural productivity, biodiversity, environmental quality, and food security (Verma, 2012). Land degradation is generally defined as the temporary or permanent decline in the quality, productivity, and ecological functions of land caused by natural processes and human interventions (Abdelrahman et al., 2016; Sustainable Management, SIA, & INT, 2007; Rabia, 2012). It has become a major global environmental challenge with significant social, economic, and ecological consequences (Fadhil, 2014).

Rapid urbanization, industrialization, population growth, deforestation, intensive agricultural practices, excessive use of fertilizers and pesticides, and poor land management are among the principal drivers of land degradation (Metternicht & Zinck, 2010; Meshesha et al., 2012). The United Nations estimates that more than half of the world's population currently resides in urban areas, a proportion expected to increase to nearly 67% by 2050. This unprecedented urban expansion has resulted in the conversion of natural ecosystems and agricultural lands into built-up areas, thereby altering land use patterns and reducing vegetation cover (Li et al., 2017). In developing countries, where urban growth is particularly rapid, these changes have intensified environmental degradation and increased pressure on natural resources (Sha et al., 2018).

Urbanization is recognized as one of the most significant human-induced drivers of land use and land cover (LULC) change. The expansion of residential, commercial, industrial, and transportation infrastructure frequently occurs at the expense of forests, agricultural land, and open green spaces (Ngie et al., 2013). Consequently, continuous conversion of vegetated land into impervious surfaces reduces ecological resilience, accelerates soil degradation, and contributes to the loss of biodiversity (Abdullah et al., 2019). Understanding these land transformation processes is therefore essential for sustainable urban planning and environmental management.

Advances in Geographic Information Systems (GIS), Remote Sensing (RS), and Global Positioning System (GPS) technologies have greatly enhanced the capability to monitor, quantify, and evaluate land degradation over large spatial and temporal scales. Remote sensing provides timely, accurate, and cost-effective information for detecting changes in land use, vegetation cover, and environmental conditions, while GIS facilitates spatial analysis and visualization of these changes (Metternicht & Zinck, 2010; Gashu & Gebre-Egziabher, 2018). The integration of satellite imagery with GIS has become an indispensable approach for assessing urban expansion and its environmental impacts.

Ghaziabad district, located in the National Capital Region (NCR) of India, has experienced rapid urban growth since its establishment as a Municipal Corporation on 31 August 1994 following the 74th Constitutional Amendment Act, 1992 (Horo & Punia, 2018). The expansion of residential, industrial, and commercial developments has substantially transformed the district's landscape, making it an ideal case study for evaluating the relationship between urbanization and land degradation.

Therefore, the present study investigates the spatio-temporal patterns of land degradation associated with urban expansion in Ghaziabad district over a 25-year period using multi-temporal Landsat satellite imagery acquired in 1994, 2000, 2010, 2015, and 2018. Supervised Maximum Likelihood Classification (MLC) and the Normalized Difference Vegetation Index (NDVI) were employed to analyze changes in land use and land cover. The specific objectives of this study are to: (i) assess temporal changes in LULC; (ii) quantify changes among different land cover classes; (iii) evaluate the influence of urban expansion on vegetation and land degradation; and (iv) provide scientific evidence to support sustainable land management and urban planning in the rapidly developing Ghaziabad region.

The primary objective of this study is to assess the spatial and temporal patterns of land degradation associated with urban expansion in Ghaziabad district over a 25-year period (1994–2018) using Geographic Information Systems (GIS) and Remote Sensing (RS) techniques.

In Introduction you can mention the introduction about your research.

II. IMETHODOLOGY

Ghaziabad turned founded into based in 1740 via the emperor, Ghazi-ud-din, who known as Ghaziuddinnagar after himself and built a spacious form together with 100 twenty rooms of masonry with pointed arches. After the hole, the railway line the name of the area modified into shortened to Ghaziabad. As its boundary is adjacent to Delhi, it acts, as the primary front of Uttar Pradesh and that is why also known as the GATEWAY OF UP. Ghaziabad district split d out of Meerut on November 14, 1976 with a variety more than 872.95 square kilometer. Ghaziabad formerly recognized as Municipal business enterprise on 31 August 1994 following the 74th Constitutional amendment Act 1992. It is one of the rising suburban districts of western Uttar Pradesh lies among the longitudes 77°E to 77°42'E and latitudes 28°36'N and 28°55'N. In addition, its miles located at elevation 214 meters above sea level (Horo and Punia, 2018).

Ghaziabad bounded by in the North direction, from Meerut plus Baghpat, to the East, Jyotiba Phule Nagar, to the South, from Gautama Buddha Nagar, and Bulandshashar, and to the South-west from Delhi. Ghaziabad town is a developing satellite metropolis ruled (Horo and Punia, 2018). Ghaziabad Metropolitan area constitutes a

populace of 2,358,525 out of which 1,256,783 are adult males and 1,101,742 are females (Census of India 2011) and (Horo and Punia, 2018).

Geomorphology & Soils Types

The district of Ghaziabad forms the part of Ganga-Yamuna doab, eastern boundary marked by Ganga River and the river Yamuna defines the western boundaries. The area represents almost a monotonous flat plain dissected by drainage of different order. Ghaziabad situated almost in the old flood plain of river Hindon. Morphologically, the area divided into 3 morpho units viz a viz (i) older Alluvial Plain (ii) Older Flood Plain and (iii) Active Flood Plain. The banks of rivers are steep and ravenous. The older alluvium occupies the entire upland and interfluvial area occurring between major drainage ways i.e. Yamuna and Hindon and Hindon and Ganga. The development of soils in the district ascertained to different erosional and depositional agencies. Different morphological units has bestowed with different types of soils. This Soil is range from pure sand to stiff clays and combinations of those two extreme litho units. The pure sand called Bhur, Clay called Matiyar. When the sand mixed with clay in equal proportion, the soil may be termed as Dumat or loam a good agricultural soil. (R.C. Verma A.A.P.: 2008–2009).

Loam is the fourth type of soil. It is a combination of sand, silt, and clay (less than 52% sand, 28–50% silt, and 7–27percentage clay,) such that the beneficial properties from each are included. For instance, it has the ability to retain moisture and nutrients; hence, it is more suitable for farming. This soil also referred to as an agricultural soil as it includes an equilibrium of all three types of soil materials being sandy, clay, and silt and it happens to have hummus. Apart from these, it also has higher calcium and pH levels because of its inorganic origins (FAO, 1965).

Materials/Data usage and sources of data

Multi-temporal satellite images (LANDSAT) of five decayed; Thematic Map per (TM) image of 1994, 2000, Enhanced Thematic Map per (ETM+) image of 2010 and Operational Land Imager (OLI) image of 2018 acquired on June. Which is the maximum vegetation covered month and cloud free (< 10%). All satellite images obtained from eros.usgs.gov Data Centre. In addition, population data of the study area from SENSEUSE of India 2011 and 2001. ERDAS IMAGINE 2014, Arc GIS 10.5 and QGIS are the software packages used in this study work.

	Sensor	Data Accusation Date(June)	Source
Satellite image	LANDSAT5(TM)	1994	Earth Explorer
	LANDSAT7(ETM)	2000,2010	
	LANDSAT8(OLI)	2015,2018	
	Census data		Census of India
	Administrative map of the study area	2011,2001	map of India
	Soil map	1965	FAO
	Soil Parameter		HSDB
Software	ERDAS Imagen2014		HWSD
	Arc GIS10.5		
	HWSD viewer 1.v2		
	QGIS3.4(2018)		

Table:1 Materials/Data usage and sources of data

Pre-processing including radiometric and focal evaluation (gap filling) correction methods. Geo-referencing using WGS 1984, Universal Traverse Mercator (UTM) projection system. Then digitization and rectify to delineate place map that's Ghaziabad district boundary. After Digitization different processing including subset taking location, that is a subset shape file using the observe place and satellite image for every year using ERDAS imagine 2014, Arc GIS1.5 and QGIs in different versions. Then image classification (likelihood supervised classification and NDVI).Accuracy Assessment. Cross-tabulation analysis has accomplished to evaluate the extent of deforestation inside the take a look at place/land degradation because of rapid urbanization activities.

III. RESULTS AND DISCUSSION

A. NDVI Analysis

The NDVI maps (Fig. 3) reveal a progressive decline in vegetation cover between 1994 and 2018. High NDVI values, representing dense vegetation, were predominant in 1994 but gradually decreased with increasing urban expansion. A temporary improvement in vegetation was observed in 2015, whereas the lowest vegetation density was recorded in 2018. These findings indicate continuous loss of vegetative cover due to rapid urbanization.

Table 2
Area and Percentage of NDVI Classification (sq.km & % respectively)

Class	1994		2000		2010		2015		2018	
	Area	%	Area	%	Area	%	Area	%	Area	%
Non-vegetation	452.0	51.75	505.12	57.86	527.61	60.44	454.59	52.08	558.67	63.99
Vegetation	420.9	48.25	367.83	42.14	345.33	39.56	418.36	47.93	314.28	36.00
Total	872.9	100	872.95	100	872.94	100.0	872.95	100	872.95	99.99

Land Use/Land Cover Classification

Maximum Likelihood Classification identified five LULC classes: built-up area, vegetation, barren land, forest, and water bodies. The classified maps demonstrate a continuous expansion of built-up land accompanied by a reduction in vegetation and forest cover throughout the study period. Urban growth was predominantly observed around existing settlements and transportation corridors, indicating outward expansion of the city.

Table 3
Land Use/Land Cover Distribution (1994–2018)

LULC Class	1994 (%)	2000 (%)	2010 (%)	2015 (%)	2018 (%)
Built-up	27.68	42.04	42.58	47.00	57.01
Vegetation	49.37	46.93	44.36	38.00	32.94
Barren Land	20.63	7.78	11.20	12.00	6.31
Water Body	1.16	2.27	0.96	1.00	3.24
Forest	1.16	0.97	0.90	2.00	0.50

Change Detection

The change detection analysis revealed substantial landscape transformation between 1994 and 2018. Built-up land increased by **29.33%**, whereas vegetation, barren land, and forest cover declined by **16.14%**, **14.32%**, and **0.66%**, respectively. The conversion matrices indicate that most urban expansion occurred at the expense of vegetated land and barren land, confirming the influence of urbanization on land degradation

Table 4
Net Change in LULC (1994–2018)

Land Cover	Net Change (%)
Built-up	+ 29.33
Water Body	+ 2.08
Forest	-0.66
Barren Land	-14.32
Vegetation	-16.14

Soil Characteristics

The analysis of soil properties indicated a decline in soil quality between 2011 and 2017. Electrical conductivity decreased from **0.86 to 0.245 $\mu\text{S/cm}$** , while pH and organic matter also exhibited noticeable variation, reflecting the effects of land-use change and declining vegetation cover. These changes support the satellite-derived evidence of progressive land degradation in the study area.

Parameter	2011	2017
pH	6.5	7.8
Electrical Conductivity ($\mu\text{S/cm}$)	0.86	0.245
Organic Matter (%)	0.41	0.74

Discussion

The observed LULC changes demonstrate that Ghaziabad experienced rapid urban expansion over the 25-year study period, primarily through the conversion of vegetated and open land into built-up areas. Declining vegetation and forest cover, together with deteriorating soil properties, indicate progressive land degradation associated with urbanization. The integration of GIS and Remote Sensing proved effective for quantifying spatio-temporal land cover dynamics and provides a reliable framework for sustainable urban planning and environmental management.

IV. CONCLUSION

Ghaziabad district experienced significant land use and land cover (LULC) changes between 1994 and 2018, primarily driven by rapid urbanization. Remote Sensing and GIS analysis revealed that built-up areas increased substantially from **27.68% to 57.01%**, while vegetation, forest, and barren land decreased, indicating continuous conversion of natural landscapes into urban areas. Overall, built-up land and water bodies increased by **29.33%** and **2.08%**, respectively, whereas vegetation, barren land, and forest declined by **16.14%**, **14.32%**, and **0.66%**, respectively. Soil quality assessment also indicated deterioration during the study period, supporting the evidence of land degradation. These findings demonstrate that uncontrolled urban expansion has significantly contributed to vegetation loss and land degradation in Ghaziabad. The study further confirms that GIS and

Remote Sensing are effective tools for monitoring spatio-temporal LULC changes and can provide valuable information for sustainable urban planning and land management.

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Figures

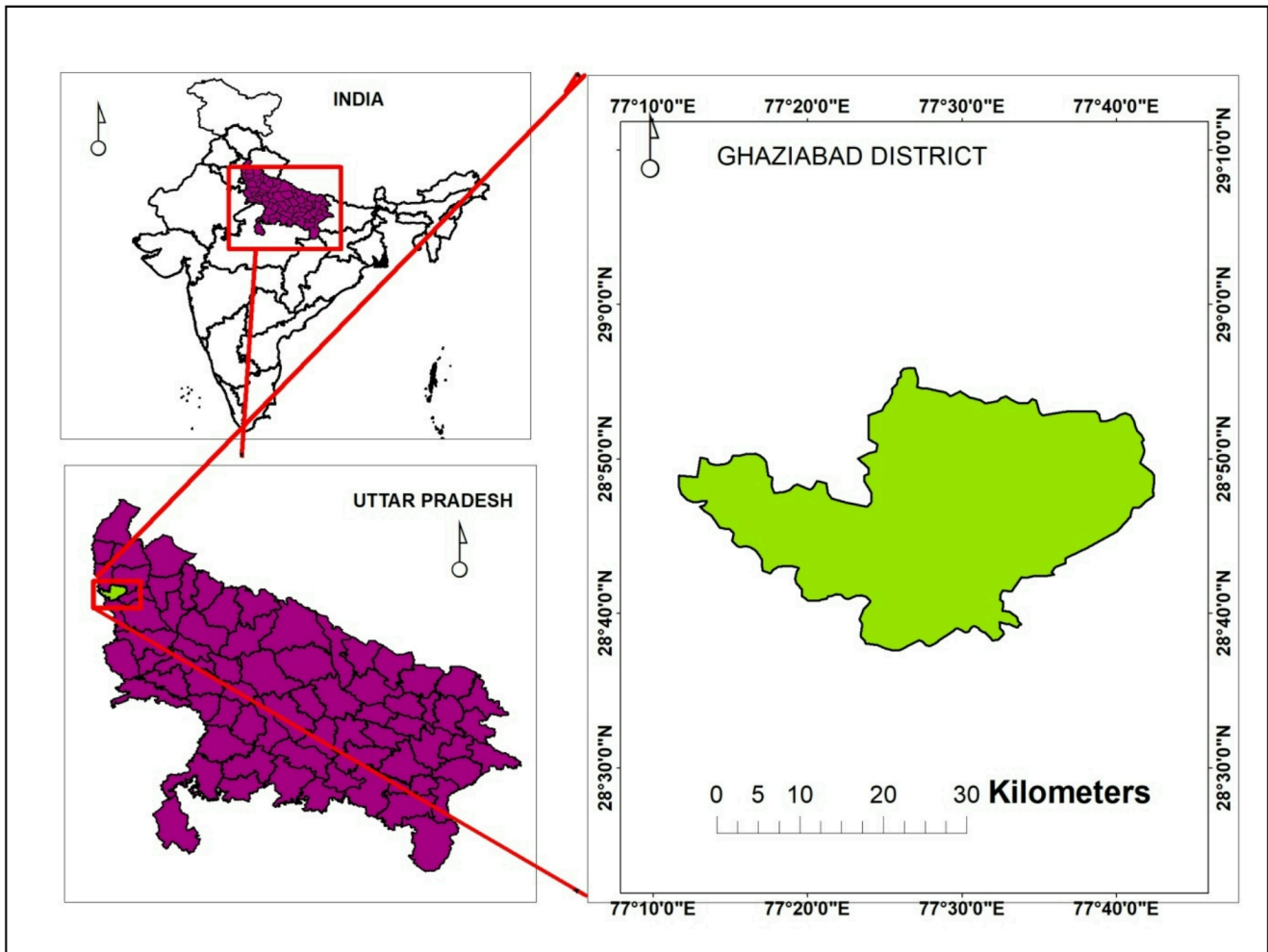


Figure 1

Study area map

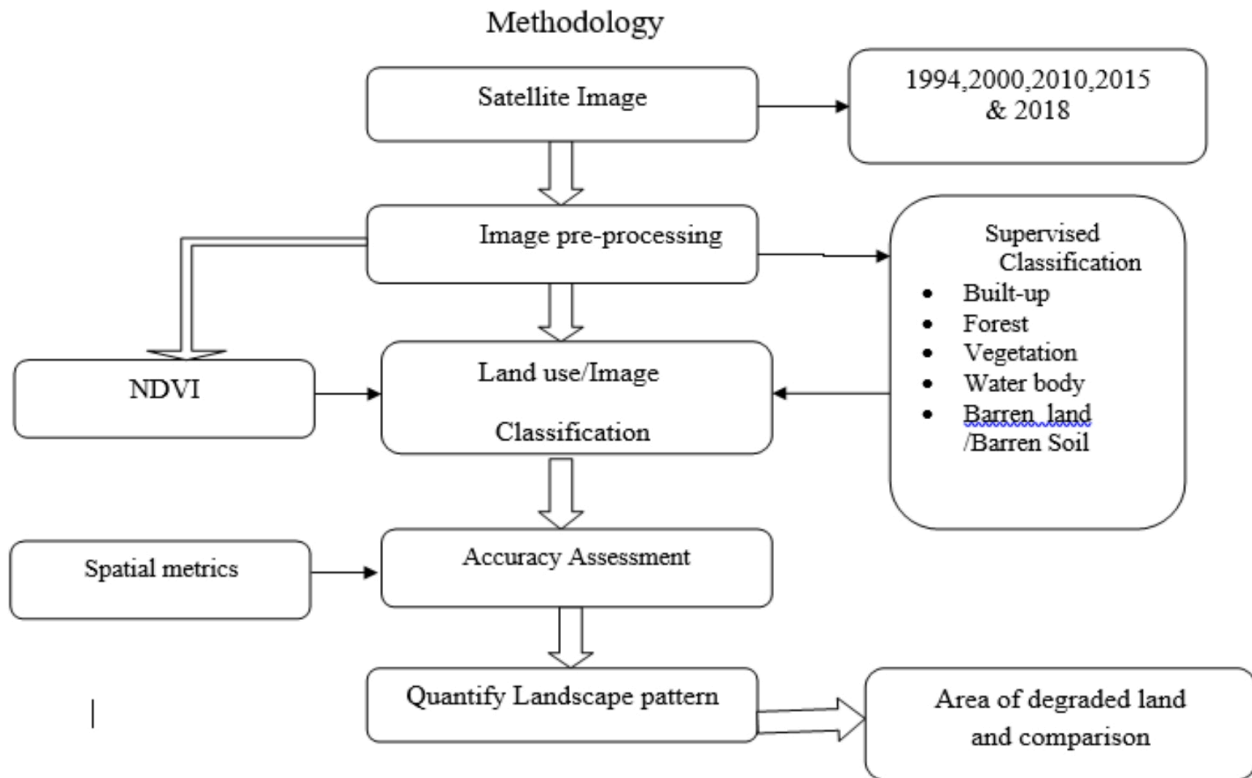


Figure 2
methodology framework

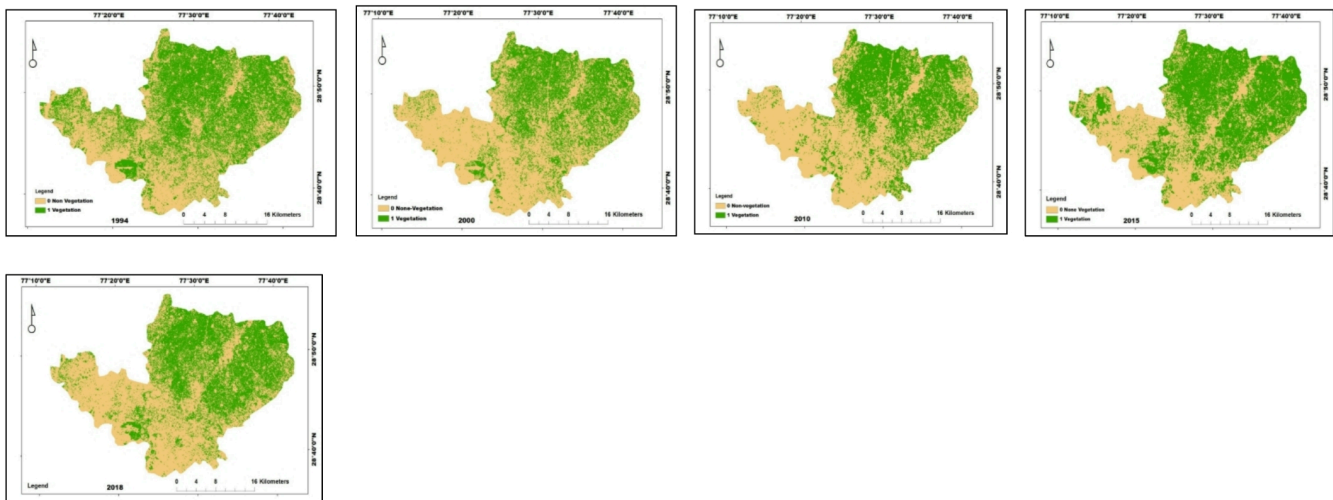


Figure 3

High-resolution NDVI maps of Ghaziabad district for **1994, 2000, 2010, 2015, and 2018** arranged as five panels (a–e) with a common legend and north arrow.