Innovations

Spatio-Temporal Dynamics of Land Use/Land Cover in Ballia City Using Landsat Datasets

Chhaya Mishra[1], Dr. Ashutosh[2], Dr. Ronak Jain[3]
[1]Research scholar, [2]Associate Professor, [3]Assistant Professor
Faculty of Earth Sciences, Banasthali Vidyapith, Tonk, Rajasthan, India

Abstract: *Urbanization has significantly altered land use and land cover (LULC) in Indian cities such as Ballia, resulting in the widespread expansion of built-up areas. This growth often occurs at the expense of agricultural land, vegetation, and open spaces. The present study aims to analyze the spatial and temporal changes in LULC within the urban area of Ballia city over a thirty-year period, from 1991 to 2021. The primary objective is to understand how land use patterns have evolved in response to rapid urban expansion, population growth, and developmental activities. The findings of this research are intended to support the development of sustainable land management strategies.To achieve this objective, satellite remote sensing data from Landsat-5 Thematic Mapper (TM) for the year 1991 and Landsat-8 Enhanced Operational Land Imager (OLI/TIRS) for the year 2021 were utilized. These multi-temporal images were analyzed using supervised classification techniques, specifically the maximum likelihood classification method, to identify and map different land use categories such as built-up area, agricultural land, water bodies, and vegetation cover. The classified maps were then evaluated for their accuracy using overall accuracy percentage and the Kappa coefficient, ensuring the reliability of the classification results.The study reveals a dramatic shift in land use in the Ballia urban area over the three-decade period. This sharp expansion of built-up zones highlights the pace of urbanisation and increasing industrial activities.The expansion of residential, commercial, and infrastructural development has led to a significant transformation of land previously used for agricultural and open green purposes. Specifically, large tracts of fertile agricultural land have been converted into non-agricultural uses, which poses serious concerns for future food security and environmental sustainability in the region.This pattern of urban growth is largely unplanned and has resulted in pressure on the natural environment and available resources. Such unchecked expansion has not only caused a loss of agricultural productivity but also contributed to challenges like increased surface runoff, reduced groundwater recharge, and the urban heat island* *effect. This study underscores the importance of integrated urban planning and robust land management policies to ensure that development progresses in harmony with environmental sustainability. The findings of this research are intended to aid city planners, policymakers and local authorities in understanding the trends and impacts of land use change. By using satellite data and GIS-based analysis, the study provides an evidence-based foundation for formulating sustainable development plans for Ballia city. It emphasizes the importance of protecting agricultural lands and maintaining ecological balance while accommodating urban growth. Ultimately, the research advocates for responsible urban planning that can lead to more sustainable and resilient urban development in the future.*

Keywords: *Land Use Pattern, Remote Sensing, LULC, Urbanization, Ballia City.*

Introduction

The rapid transformation of the Earth's surface due to human activities has drawn increasing attention from researchers, planners, and environmentalists across the globe. Among the most visible and measurable manifestations of this transformation are the changes in LULC. These changes have significant implications for sustainable development, environmental management, and urban planning, particularly in the context of fast-growing urban centers like Ballia city.

Land Use and Land Cover

The land cover refers to the physical and biological surface of the Earth, including vegetation, water bodies, barren land and artificial structures like buildings and roads. It is what we see directly on the surface — forests, grasslands, wetlands, urban areas, etc. At another side, land use relates to how these surfaces are utilized by humans. It includes agriculture, residential settlements, commercial and industrial zones, transportation networks, recreational areas, and more. While land cover provides a snapshot of the Earth's surface at a given time, land use conveys the purpose and manner in which land is managed and utilized by human societies.

Although land use is commonly inferred from land cover data, it is important to understand that the two concepts, while closely related, are not synonymous. For instance, a patch of land covered with buildings (land cover) could be used for a variety of purposes — residential housing, commercial establishments, educational institutions, or industrial facilities — each of which represents different land uses. This distinction is particularly relevant in urban studies, where the complexity and intensity of land use activities are continually evolving.

As noted by Chowdhary (2008), while Both LULC are sometimes used interchangeably in literature and policy discussions, a clear understanding of their interrelationship is essential for accurate analysis, especially in spatial and temporal studies of land transformation.

Relevance of LULC Studies in the Modern Context

The study of LULC change has emerged as a central focus in monitoring urban expansion, environmental degradation, and sustainable resource management. This is particularly crucial in the context of rapidly urbanizing countries like India, where increasing population and economic growth are exerting unprecedented pressure on land resources. Urban sprawl — the uncontrolled expansion of urban areas — causes to the conversion of agricultural and forest lands into built-up spaces, often without adequate planning or infrastructure.

As cities grow, the demands for housing, transportation, water supply, sanitation, and energy escalate, further accelerating land use change. This, in turn, affects natural ecosystems, reduces biodiversity, and contributes to issues such as increased surface runoff, flooding, heat islands, and pollution. Therefore, monitoring and analyzing these changes is key to formulating sustainable urban development policies.

The Role of Remote Sensing and GIS

Remote sensing and geographic information systems (GIS) have transformed the way LULC changes are studied. Remote sensing involves collecting data from satellite sensors or aerial platforms to observe and measure changes in the Earth's surface over time. This technology provides consistent, repetitive, and accurate data over large geographic areas, making it possible to detect subtle changes in land cover and to classify land use patterns over time.

GIS, on the other hand, enables the integration, analysis, and visualization of spatial and non-spatial data. Together, remote sensing and GIS form a powerful toolkit for assessing urban growth, analyzing spatial patterns, simulating future land use scenarios, and supporting decision-making processes at multiple levels — from local municipalities to national agencies.

Zubair (2006) emphasized that satellite data has become essential in mapping earth's features, managing natural resources, and understanding environmental changes induced by human activities. The importance of such tools is even greater under conditions of rapid and often unregulated urbanization, where traditional land surveys fall short in providing timely and comprehensive data.

Urbanization and Its Challenges

Urbanization, while being a marker of development and economic growth, comes with a host of challenges. In many Indian cities, the pace of urbanization often outstrips the capacity of urban planning and governance mechanisms. Ballia city is no exception, as population density increases and the built-up area expands, the city faces growing pressure on its infrastructure and natural environment.

Some of the major consequences of unregulated urbanization include:

- **Loss of Agricultural Land**: One of the most significant impacts of urban expansion is the conversion of fertile agricultural land into residential and industrial zones. This not only threatens food security but also undermines rural livelihoods and increases dependency on food imports.
- **Environmental Degradation**: The destruction of vegetation, wetlands, and other ecological buffers results in loss of biodiversity, increased greenhouse gas emissions, and degraded air and water quality.
- **Urban Sprawl**: Unplanned horizontal expansion of cities leads to longer commutes, traffic congestion, and inefficient public transport, making urban living more stressful and less sustainable.
- **Rising Land Values**: As demand for land increases, property prices soar, making housing unaffordable for many segments of the population.
- **Infrastructure Stress**: Existing Infrastructure such as water distribution, sewerage, and power and public services often becomes inadequate, leading to service breakdowns and lower quality of life.

These challenges underscore the need for effective monitoring systems and data-driven urban planning approaches that promote sustainable and inclusive development.

The Case of Ballia City

Ballia, a city located in the eastern part of Uttar Pradesh, India, has witnessed rapid changes in its urban landscape over the last three decades. Historically an agrarian region, Ballia is now undergoing a transition, with increasing residential developments reshaping its land use dynamics.

Despite being a relatively small urban center, Ballia faces many of the same issues confronting larger cities — land encroachment, environmental degradation, population pressure, and lack of sustainable urban planning. The unchecked expansion of built-up areas has resulted in the loss of valuable agricultural land and open spaces, disrupting the ecological balance of the region.

The current research aims to systematically analyze these changes using remote sensing and GIS techniques. By comparing satellite imagery from 1991 and 2021, the study seeks to identify the extent and nature of land use transformation in Ballia's urban area. A supervised classification technique — maximum likelihood classification — will be employed to categorize the land into various classes such as built-up land, agriculture, vegetation, and water bodies. The classification accuracy will be validated using metrics like overall accuracy percentage and the Kappa coefficient.

Significance of the Study

This research is expected to contribute valuable insights into the dynamics of urban growth and its environmental implications in Ballia. By providing a clear picture of how land use patterns have changed over time, the study can assist urban planners, local authorities and policy-makers in designing strategies that balance growth with sustainability.

Furthermore, the findings can help promote better land management practices, protect agricultural and ecological resources, and support community engagement in urban development decisions. Ultimately, such studies play a crucial role in ensuring that urbanization does not come at the cost of environmental and social well-being. As of 2011, the area of this urban area has been proposed to be approximately 16.7 square km. In this planning area, the area of the city situated within the old wall, which is settled on the grid iron system, is present. Old bus stand, municipality office and other government offices, hospital, veterinary hospital, warehouse etc. are present here. According to the 2031 Master Plan, residential schemes, commercial centers etc. have been proposed in this planning area for the development of Ballia. Wholesale trade centres, hospitals, public facilities and educational centers etc have been proposed near the City. Apart from this, other community facilities, public facilities have been proposed for the proposed residential areas. In the year 1991, the total population of Ballia city was 84063, which increased to 104442 in the year 2011. Due to rapid urban development, various problems emerged in the city and there was lack of urban development and public services. The expansion lagged behind the increasing population.

Study Area

Ballia has always attracted the attention for its civilization and its rich cultural heritage. There are many different opinions among the scholars regarding the naming of Ballia. Some scholars connect its naming with Maharishi Valmiki, the author of the holy book Ramayana, and some with the demon king Bali.According to Mishra (1986), the name of the Ballia is believed to have originated in the name of

Maharishi Valmiki, the author of Ramayana. There is another belief that the name of Ballia is derived from the sandy nature of the land of this place. It is locally known as 'ballua', because this is situated on the confluence of river Ganga and Ghaghra river. According to Sahay (2002) and Ashoka (2002), the origin of the name Ballia is from sand, due to the Ashwamedha Yagya performed here by King Bali, it got its name Balliag, which later got corrupted to Ballia. Pathak (2002) has also linked the origin of the word Ballia to King Bali. According to him, King Bali was the son of Virochana and he was the son of Bhakta Prahalad. When the Asuras were defeated in the battle of Devasur, then Asura Guru Shukracharya revived the Asura King Bali by using Amrit Sanjivani Vidhya and ordered him to perform a Yagya at the Ganga - Ghaghra Sangam. If the Ganga Ghaghra Sangam would have been built Baliyag (Yagya of Bali) then the origin of the word Ballia from the word Baliyag is appropriate from the point of view of ancient folk stories. The emergence of Ballia city in the ancient pre-British period was inspired by the huge Dadri fair organized every year in the name of Dardar Muni and the origin of Bhrigu Ashram.

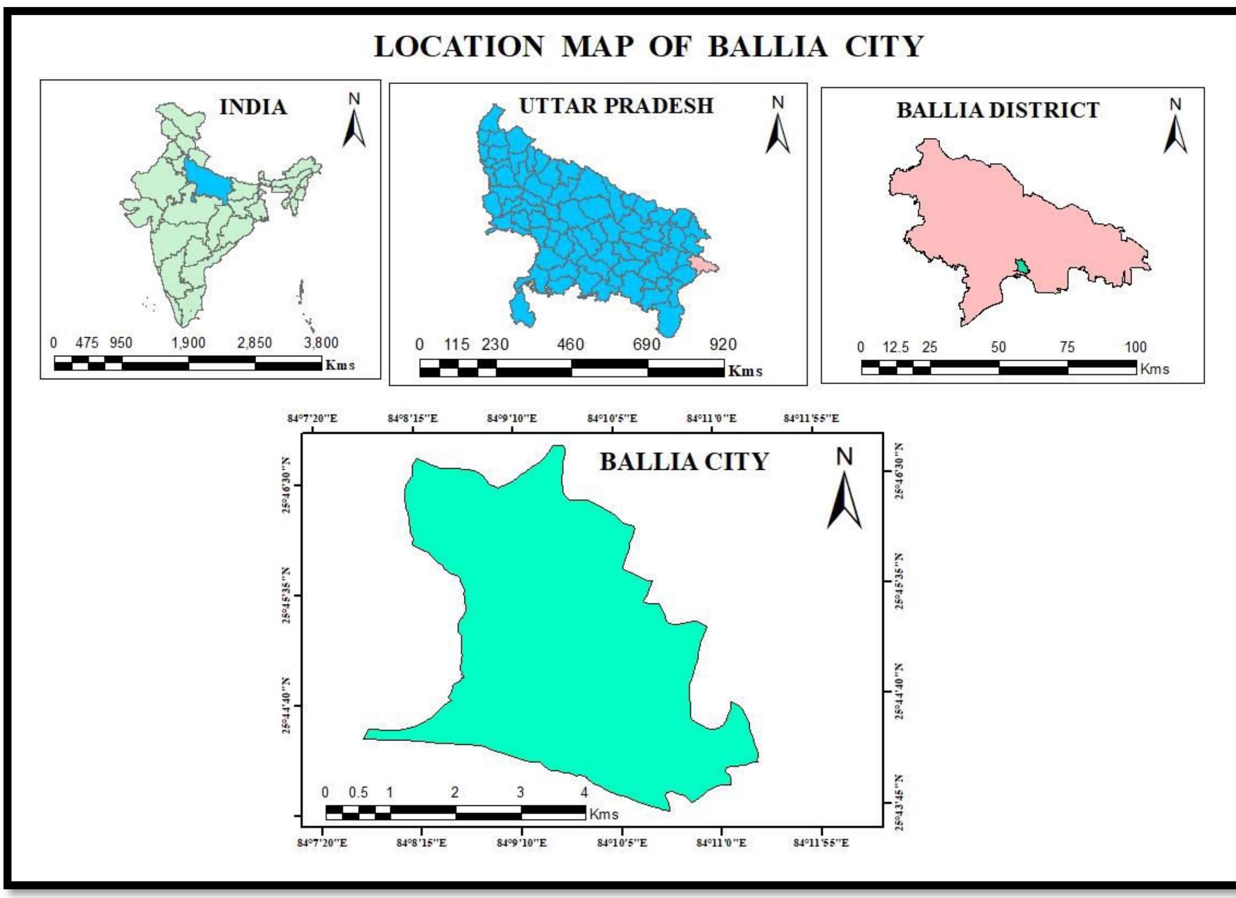

Fig. 1. Location of the study area

The easternmost region of Uttar Pradesh, Ballia city is situated between 25⁰ 44'40" N to 25⁰ 46'30" N latitude and 84⁰ 08'41" E to 84⁰ 10'34"E longitude. The total geographical area is 16.5 km^2 . The district headquarters is also situated in Ballia City. (District census handbook, 2011) Ballia City is located in the middle of the Ganga Plain. The terrain is generally flat to gently undulating. The climate in Ballia City is described as sub-humid, with grassland vegetation. The temperature varies throughout the year, with the maximum recorded in May (42.25˚ C) and the minimum in December (12.15˚C). The humidity is highest in August (82.5%) and slightly lower in September (80%). The normal annual rainfall is 983 mm, with monsoon rainfall contributing 864.8 mm. According to the 2011 census, Ballia City has a population of 1, 11,487, comprising 59,109 males and 52,378 females. The literacy rate in the city is 74.05%, with 78.07% of males and 69.5% of females being literate. The total number of households in Ballia City is reported to be 16,129 (District census handbook, 2011).

Objective

This study focuses on assessing three decades of LULC transformation in Ballia city with the help of modern technologies like remote sensing and geographic information systems.

Research Method

The temporal satellite data of the study is related to Landsat-5 TM (Thematic Mapper) and Landsat-8 OLI (Operational Land Imager). The resolution of each image is 30 m. First image from Landsat-5. It was taken in april 1991 with zero percent cloud coverage. The second image was taken by Landsat-8 on april 2021 with zero percent cloud cover. Both the pictures are from before monsoon. Both images have been compiled from Earth Explorer, the website of the United States Geological Survey.

Table 1 Overview of Satellite Data

S. No.	Satellite	Sensor	Spectral Bands	Resolution	Month/Year of Acquisition	Path/Row	Cloud Cover
1	Landsat 5	TM	7	30 meters	14/04/1991	141/042	0
2	Landsat 8	OLI/TIRS	7	30 meters	14/04/2021	141/42	0

Image Processing and Analysis

To analyze changes in land use in Ballia city, a land use map was created using ArcGIS software. For this purpose, bands 1 to 7 from Landsat satellite images were used for classification. A supervised classification method was applied using the Semi-Automatic Classification Plugin (SCP) available in ArcGIS. This technique involves selecting known land cover types (training samples), which helps the software classify the entire image accurately.

Before the classification, it was important to preprocess the satellite images to improve the quality and accuracy of the results. Preprocessing helps correct issues caused by sunlight, atmospheric conditions, and uneven terrain. This includes radiometric correction (which adjusts the brightness values), geometric correction (which aligns the image to real-world coordinates), and atmospheric correction (which removes haze and distortion from the image).

Additional steps like gap filling (to fix missing data), subsetting (to focus on the area of interest), and choosing the best band combinations were also done. All these preprocessing and classification steps were carried out using the Semi-Automatic Classification Plugin in ArcGIS to ensure accurate analysis of land use changes.

Image Classification

Image classification is the process of identifying different types of land cover by assigning labels to the pixels in a satellite image. This helps group together pixels that have similar values and represent similar land features. In this study, fourLULC classes were selected: built-up area, open land, agricultural land, and water bodies.

A **supervised classification** method was used with the help of ArcGIS software. In this method, the user selects specific areas in the image (called training samples) that clearly represent each LULC class. The software then uses these samples as a reference to classify the rest of the image. This helps ensure that the classification is accurate and meaningful.

To choose these training samples, visually interpreted regions of interest were marked throughout the study area based on the satellite images. Composite images (combinations of different image bands) were used to enhance the visibility of features, making it easier to distinguish between the LULC types. Additionally, satellite images from Google were used both to guide the selection of training areas and to verify the final classification results.

Accuracy assessment

Checking the accuracy of maps made using remote sensing is very important. It helps ensure the reliability of the results, allows researchers to evaluate their methods, and helps compare different techniques. In this study, we followed the USGS standard, which suggests that land use and land cover classification should have at least 85% accuracy.

To measure how accurate the classification was, we used two main methods: **Overall Accuracy** and the **Kappa Coefficient**.

Overall Accuracy shows the percentage of correctly classified pixels out of all the pixels in the map. If more than 70% of the pixels are classified correctly, it is considered acceptable.

The **Kappa Coefficient** goes a step further by checking not just the correct classifications, but also adjusting for the possibility of random matches. A Kappa value of 1 means perfect agreement (complete accuracy), while a value of 0 means the classification was no better than random guessing. A Kappa value above 0.75 is usually considered excellent.

In this study, both Overall Accuracy and Kappa Coefficient were calculated to confirm that the land use maps are reliable and accurate.

To detect changes in land use/land cover (LULC)

Change detection is a method used to find out how land use and land cover have changed over time by comparing satellite images from different years of the same area. In this study, changes in Ballia's land use and land cover were examined over a period of 30 years, from 1991 to 2021.

To do this, the **post-classification comparison method** was used. This means that land use maps were first created separately for 1991 and 2021 through classification, and then compared to find out what has changed between the two time periods.

A special **thematic change detection tool** in ARCGIS software was used to compare these two classified maps. It analyzed the pixels from both years to find differences and measure how much each land cover type has changed over time. This method is effective because it clearly shows what areas have changed from one type of land use to another, like from agricultural land to built-up areas.

Results and Analysis

Accuracy assessment result

To ensure that the land use maps created for 1991 and 2021 were accurate, an accuracy assessment was carried out. This involved comparing the classified maps with real-world data to see how well they matched. Two main error metrics were used: **Overall Accuracy** and the **Kappa Coefficient**, both calculated using an error matrix.

The results showed that the **overall accuracy** of the 1991 map was **85.86%**, and for the 2021 map, it was **89.28%**. These values meet the **USGS standard**, which requires at least 85% accuracy for reliable land use and land cover classification.

In addition, the **kappa coefficient**—which measures the agreement between the classified map and actual ground conditions—was **0.82** for 1991 and **0.76** for 2021. Since a kappa value above **0.75** is considered very good, it means both maps were classified with a high level of accuracy and reliability.

LULC Classification Analysis

Table 2Change dynamics of area under each LULC classes during 1991–2021

LULC Categories	**1991**		**2021**	
	Area in sq. km	**Areain Percent**	**Area in sq. km**	**Area in Percent**
Urban	3.42	20.39	4.30	25.64
Agriculture	4.10	24.45	1.59	9.49
Water	0.045	0.27	0.0009	0.005
Open Area	9.30	54.89	10.88	64.87
Total	**16.77**	**100.00**	**16.77**	**100.00**

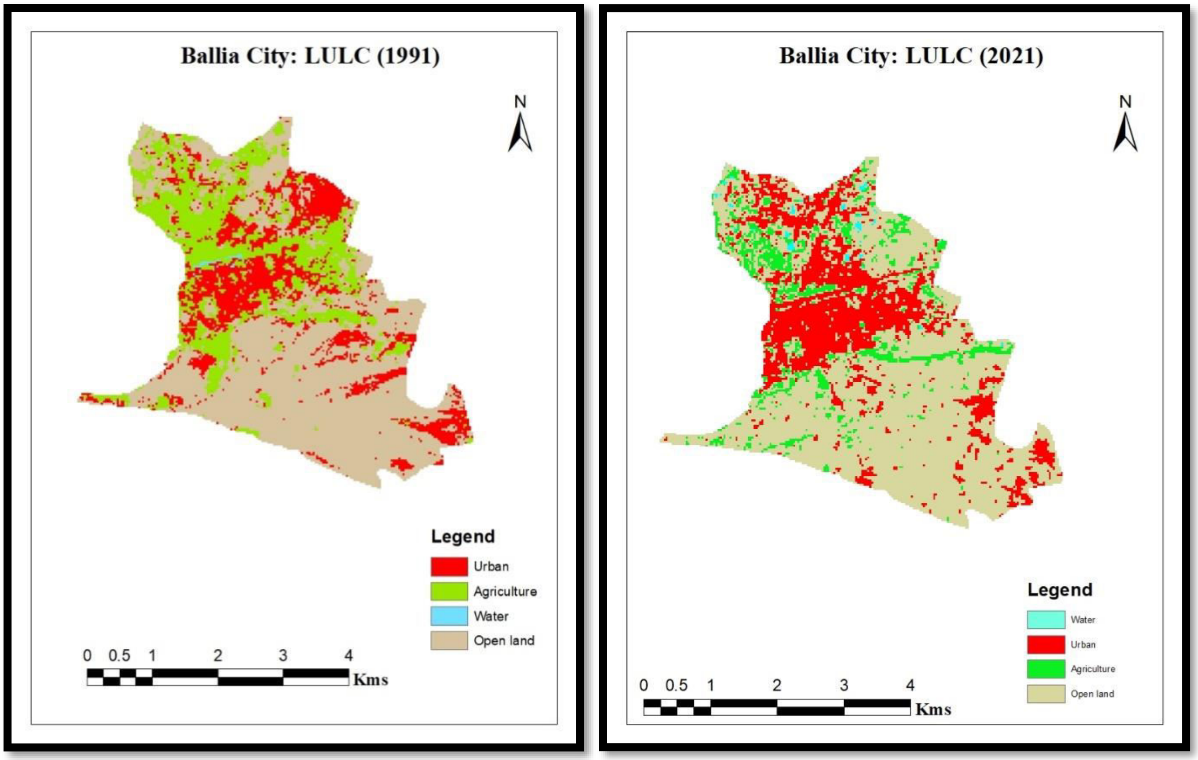

Fig. 2. Dynamics of LULC change in Ballia city between 1991 and 2021

The classification of both Landsat images produced LULC maps for each respective year, as illustrated in Map-2, highlighting the spatial distribution of four land cover classes. Table 2 presents the statistical area distribution and proportional representation of each class. The results reveal that residential or man-made areas dominate the land use in the study region.

It is clear from Map 2 and Table 2 that there has been a change in the size and land use of Ballia city. In the last 30 years, the man-made area of the city i.e. buildings has increased almost many times. In 1991, it was only 3.42 square km, which has increased to 4.30 square km in 2021. Over three decades, the spread of urban land has increased, reflecting rapid urbanization. Looking at Table 2, it can be seen that there has been rapid conversion of agricultural and agricultural land into urban areas in this area. Open land was 54.89 percent in 1991, which has to 64.87 percent in 2021. Similarly, the agricultural land which was 24.45 percent in 1991 has decreased to 9.49 percent in 2021. WaterBodies has also reduced from 0.27 percent to 0.0009 percent. Vegetated land has been converted for residential and other human purposes. Land management is one of the most important elements in city development.

According to the present scenario, under the pretext of urban expansion of Ballia, valuable agricultural land is being converted into non-agricultural use land. In the year 1991, the total population of city was84063, which has increased to 104442 in the year 2011. Rapidly increasing population is one of the reasons for unregulated urban development. Secondly, Ballia is the oldest business center of Balliadistrict, where both retail and wholesale business activities are carried out. The market of Ballia does not function more as a commercial center of regional importance compared to Ballia. Urban land is a scarce and expensive resource and needs to be divided among different uses very judiciously. Ballia urban area itself has other natural resources, which form an important ecology of the area, but various human activities and interventions are changing the topography and ecology of the area. There is no policy or plan to envisage their condition in future. These areas are very important and need to be kept green for the ecological stability, sustenance and sanctity of Ballia.

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