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RESEARCH ARTICLE

DETECTION OF LAND USE/ LANDCOVER IN PRAYAGRAJ CITY

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ABSTRACT

Land use and land use and land cover (LULC) analysis plays a crucial role in comprehending the dynamic urban changes, particularly in rapidly growing cities such as Prayagraj. This research focuses on identifying and evaluating the LULC trends of Prayagraj city based on remote sensing and Geographic Information Systems (GIS) tools. Owing to the ongoing urbanization, comprehending these changes holds paramount importance for making informed urban planning, environmental management, and sustainable development. Prayagraj, which lies in the north of India, has experienced considerable urbanization within the last two decades, hence contributing to impressive land use patterns. The city is a religio-historic, administratively important one that is represented by varied forms of land usage such as residential, agricultural, industrial, and recreational land types. The growth of urban areas and the decrease in greenbelts and agricultural areas are distinguishable trends that have arisen as a result of increasing population, development of infrastructure, and industrialization. Foranalyzing the LULC changes, satellite data of Landsat and Sentinel satellites was utilized to produce multi-temporal land use maps. The data were processed based on different image classification methods, such as supervised and unsupervised classification, to classify the land into specific classes like residential, commercial, agricultural, water bodies, forests, and bare land. The classifications were then verified using secondary data sources and field surveys for the validation of the results. The findings of the study indicated a pronounced change in the land use scenario of Prayagraj. Urban settlements have increased, especially in the northern and southern directions of the city, leading to a substantial decline in agricultural land and green cover. The study also indicated a decline in the cover of water bodies and forests, posing questions to the ecological sustainability of the city. This urban spread, in terms of residential and commercial development, is expanding at the expense of previously open and agricultural land, emphasizing the importance of strategic land management policies.

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INTRODUCTION

Land is one of the most significant natural resources, providing a base for human habitation, agriculture, industries, transportation, and ecological processes. The utilization and cover of land by natural or artificial features is known as Land Use and Land Cover (LULC). Land Use pertains to human activities carried out on land (e.g., residential, commercial, or agricultural use), whereas Land Cover is the physical material covering the earth's surface, such as forests, water bodies, bare ground, and built-up areas. With the fast pace of urbanization, industrialization, and population growth, Indian cities have undergone large-scale and at times unplanned land use change patterns. Such changes have direct consequences for environmental sustainability, resource management, and urban planning. Land Use and Land Cover change detection and analysis enable us to comprehend the nature and direction of urban expansion and its impacts on natural resources and ecosystems.

Background of the Study: Allahabad, now called Prayagraj, is one of the most prominent cities in Uttar Pradesh, India. Situated at the meeting point of the Ganga, Yamuna, and the legendary Sarasvati rivers, the city is not just a religious and historical center but also a serious administrative hub. The city has also experienced widespread growth, particularly in recent decades, that has resulted in widespread land use and land cover change. Traditionally, Prayagraj has been an agricultural and cultural hub with expansive agricultural fields encircling the city. The city's landscape is now changed with the widespread growth of residential, commercial, and industrial areas. With the city's population steadily increasing as a result of migration and urbanization, the need for urban infrastructure and housing has resulted in a strain on the available land

resources. Consequently, agricultural land, green areas, and water bodies are being encroached upon for development purposes. This has caused worries regarding the environmental sustainability of the region, especially concerning the availability of resources like water, soil, and vegetation, which are essential for ecological balance. Research on LULC in Prayagraj is important since it offers a clear picture of the transformation happening to the land resources of the city and the consequences of these changes. Remote sensing and GIS technologies enable the examination of large-scale land use changes through time, with critical data provided to urban planners, policymakers, and environmentalists. Through satellite imagery, this research seeks to determine the different land cover categories in Prayagraj and examine the patterns and trends of land use change over the last decades.

Objectives of the Study

- The main goal of this research is to evaluate the land use and land cover changes in Prayagraj city, especially during the last two decades. The specific aims are:
- To map and classify the land use and land cover categories in Prayagraj based on remote sensing information from satellite imagery with emphasis on various classes like built-up land, agricultural land, water bodies, green areas, and barren land.
- To identify temporal variations of LULC across various years (2000, 2010, and 2020) to study the trends of urban sprawl, conversion of agricultural land, and loss of water bodies and forests in the city.
- To evaluate the influence of urbanization on the environment, such as the loss of agricultural land, loss of green cover, and the diminishment of water resources.
- To confirm the LULC classification results based on ground-truth data and accuracy assessment methods, to ensure that the results are reliable for potential applications in urban planning and policy-making.
- To make recommendations regarding sustainable land use management in Prayagraj, with an emphasis on maintaining green areas and water bodies, encouraging urban planning practices that limit environmental degradation, and ecological sustainability.

Scope and Significance

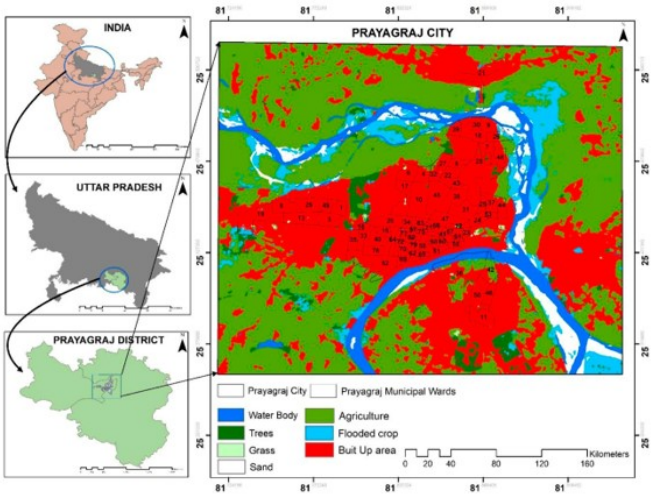
- **Urban Planning and Development**: Prayagraj, similar to most other fast-developing cities, has problems in controlling urban sprawl and achieving sustainable development. Knowing the dynamics of LULC change is important in order to come up with effective urban planning measures. Through the mapping of the expansion of built-up areas, conversion of agricultural land, and degradation of natural resources, this research gives information on how urban expansion can be controlled in a sustainable manner.
- **Environmental Impacts**: The swift growth of urban settlements is usually at the expense of environmental degradation, such as deforestation, agricultural land loss, and depletion of natural resources like water and soil. Through the examination of LULC trends in Prayagraj, the research enables one to comprehend the environmental implications of urbanization, which is essential for putting in place efforts to counteract adverse effects like water scarcity, air pollution, and biodiversity loss.
- **Sustainability and Resource Managemen**t: With increasing growth of the city, the pressure on resources such as land, water, and energy mounts. Proper land use practices are important to make available these resources for generations to come. This study's findings will assist policymakers, urban planners in making well-informed decisions regarding land use zoning, conservation, and sustainable development policies.
- **Technological Integration**: The significance of applying current technologies like remote sensing and GIS in land use change monitoring and management is brought out in this study. These technologies offer a cost-saving, efficient method for analyzing extensive spatial data, thus making them valuable tools in urban and environmental research. The application of satellite imagery in this study illustrates how these technologies can be utilized in actual urban planning applications.
- **Contribution towards Urban Sustainability Study**: This study will add value to the large body of knowledge in urban studies, providing in-depth examination and insight into Prayagraj's land use dynamics. Outcomes will serve other cities having similar issues, arising from exponential growth and concern for the environment.
- **Urbanization Pressure**: As Prayagraj expands further, encroachment by the urban area over agricultural land, vegetation, and water bodies is on the rise. Quantification and observation of these changes are important in order to plan for the effective management of the urban environment.
- **Environmental Impact:** Changes in LULC may cause problems such as deforestation, loss of biodiversity, more surface runoff, urban heat islands, and pollution of water. Identifying such changes can facilitate environmental management planning.
- **Urban Planning and Policy Making**: The right information about land use dynamics is crucial to enable urban planners and policymakers in making informed decisions regarding efficient management of land resources and planning for sustainable urban growth.
- **Resource Management**: Identification of LULC changes facilitates proper management of natural resources, check on urban sprawl, and balanced development.

Study Area: Prayagraj City: Knowledge of the study area is the basis of any geographical or urban study, particularly while interpreting Land Use and Land Cover (LULC) patterns. Prayagraj city, being one of the prominent urban hubs of Uttar Pradesh and North India, has witnessed tremendous transformations in the last few decades. This chapter gives a comprehensive description of Prayagraj's geographical, demographic, socio-economic characteristics, and existing land use patterns.

Geographical Location and Features: Prayagraj, previously referred to as Allahabad, is situated geographically in the southern region of Uttar Pradesh at the meeting point of the Ganga, Yamuna, and the legendary Saraswati rivers. The city is of religious, cultural, administrative, and educational significance.

Latitude: 25°27′N to 25°45′N
Longitude: 81°50′E to 82°10′E
Elevation: About 98 meters above sea level

The city is situated in a strategic location in the Indo-Gangetic Plain, with fertile alluvial soil, hence being historically conducive to agriculture. Prayagraj has a subtropical climate with hot summers, moderate monsoons, and cold winters. The average rainfall per year is between 900 mm to 1100 mm, mostly during the monsoon months (June to September). Natural landscapes like rivers, wetlands, and green cover used to be the dominant land use pattern. But urbanization and infrastructural development in the past couple of decades have really changed the natural landscapes.



Demographic and Socio-Economic Profile: According to the Census of India 2011, the population of Prayagraj district was approximately 5.95 million, with an urban population of more than 1.12 million. Prayagraj city itself contributed a major portion of this urban population, making it among the fastest-growing cities in Uttar Pradesh. Population Density (City area): Roughly 4,000–6,000 people per sq. km. Literacy Rate: 83.98% (above the state average)
Sex Ratio: 875 females per 1,000 males

The city is also a prime center of learning, with places like Allahabad University, Motilal Nehru National Institute of Technology (MNNIT), and many management and law colleges. The city is also important administratively by virtue of housing the High Court of Uttar Pradesh. Economically, Prayagraj possesses a mixed profile with government administration, education, religious tourism, retail trade, small-scale industries, and agriculture being the crucial contributors. The Kumbh Mela, which occurs once in 12 years, has a significant effect on the socio-economic life of the city by adding to occasional peaks in infrastructure growth and land use transformation.

Prayagraj's Land Use Patterns: Agricultural fields, orchards, water bodies, open spaces, and religious complexes dominated Prayagraj's land use traditionally. Recent decades, though, have seen serious land cover shifts due to heightened urbanization, population pressure, and infrastructural growth.
Trends include:

- Conversion of agriculture lands and open spaces into residential colonies, commercial hubs, education institutions, and transport corridors.
- Reduction in green cover and water body deterioration of natural water bodies because of encroachment and pollution.
- Spread of urban built-up areas towards the periphery of the city, especially along transport routes such as NH-19 (Grand Trunk Road) and NH-30.
- Major increase in road networks, shopping centres, and recreational zones, with concomitant loss of agricultural land and wetlands.
- Seasonal and event-annual land use changes at events such as Kumbh Mela, with massive temporary settlements incurring land cover changes.

Recent research applying Remote Sensing and GIS applications suggests that urbanized areas increased by over 30% during the period between 2005 and 2020, with agricultural land and green cover gradually decreasing. Land use patterns constitute a challenge for sustainable urban planning, environmental control, and infrastructural planning in Prayagraj.

REVIEW OF LITERATURE

- **Singh, R., & Singh, S.(2008)** This study uses remote sensing data to analyze the changes in land use/land cover in Allahabad (now Prayagraj). The research identifies urban sprawl, agricultural land conversion, and deforestation as the key contributors to the region's transformation.
- **Jain, S.K., & Chauhan, A.K. (2014**). The study utilizes remote sensing techniques to monitor land use changes in Agra. The methodology and results of this research are comparable to those that can be applied to Prayagraj for analyzing the rapid urbanization and its impact on agricultural lands.
- **Kumar, P., & Sharma, P.(2015)..**This paper examines the land use and land cover dynamics in Delhi using GIS and remote sensing. The insights from this study help understand the urbanization processes in Prayagraj, particularly in terms of urban expansion, loss of open spaces, and increased infrastructure development**.**
- **Bhat, S.P., Mishra, S. (2015).**This study evaluates land use changes in Pune using remote sensing and GIS technologies. The approach and results in the context of urban sprawl and land cover change are useful for understanding similar patterns in Prayagraj.
- **Rao, P.S., & Saha, S. (2016).**This research analyzes the impact of urban sprawl on land use in various Indian cities, including Allahabad (Prayagraj). It emphasizes the shift from agricultural land to urban areas and the corresponding environmental effects.
- **Patel, R.M., & Choudhury, D.P. (2018).**The study analyzes urban growth and land use changes in Surat, India, using GIS and remote sensing tools. The methodologies and findings offer valuable insights for understanding the urban expansion in Prayagraj.
- **Sharma, A., & Gupta, R.(2019).**This study presents a detailed analysis of land use changes in Allahabad (Prayagraj) through remote sensing technology. It identifies key land use/land cover types and their transformations due to urban growth.
- **Sharma, P., & Verma, M. (2020).** Focusing on Lucknow, this study explores urban growth and land use changes using GIS and remote sensing. The analysis

methods used in this study can be applied to Prayagraj for detecting similar urbanization patterns.

- **Singh, A., & Yadav, R.(2021**).The study discusses spatial dynamics of urban growth in Allahabad (Prayagraj) and its relationship with land use/land cover changes. It uses satellite imagery for detection and identifies the causes of urban expansion.
- **Singh, D., & Agarwal, P.(2022).** This paper investigates the land use changes in Prayagraj using satellite imagery and GIS techniques. It provides insights into urban sprawl, the loss of agricultural land, and the development of built-up areas.
- **Verma, R., & Tiwari, M. (2022).** This study explores the application of remote sensing data for detecting land use/land cover changes in Prayagraj. It focuses on the transition from agricultural land to urbanized areas and identifies the ecological implications of such changes.
- **Ali, M., & Prasad, M.(2021).** This research applies GIS and remote sensing to study urban expansion in Allahabad. The findings contribute to understanding how rapid urbanization is altering the landscape, which is applicable to Prayagraj as well.
- **Mishra, S.K., & Soni, P. (2020).**This study evaluates urban growth dynamics in several Indian cities, including Allahabad. The paper applies remote sensing and GIS to assess the transformation of land use patterns, which is crucial for urban planning in Prayagraj.
- **Chandra, P., & Choudhury, A. (2019**).This paper examines the role of GIS and remote sensing in mapping urban expansion and its effects on land use in Prayagraj, highlighting the shift from rural to urban landscapes.
- **Reddy, A., & Rao, R. (2021).**This study utilizes remote sensing data to detect temporal changes in land use and land cover in Prayagraj, documenting the city's urbanization and the transformation of agricultural and natural areas into urbanized zones.

RESEARCH METHODOLOGY

The research technique employed in this study is a blend of remote sensing, GIS, and manual interpretation of satellite imagery. The technique can be separated into a number of important phases: data collection, pre-processing, classification, change detection, and interpretation.

Study Area: Prayagraj City: Prayagraj, in the state of Uttar Pradesh, India, at the confluence of rivers Ganges, Yamuna, and Sarasvati, is a city of great historical and cultural importance. The urban spread of the city has been increasing at a very high rate following socio-economic development, infrastructural development, and population growth. The study region includes the whole urban area of Prayagraj, both its core and peripheral areas. The spatial analysis is centered on identifying and measuring the land cover and use changes between the year 2005 and 2020.

Data Collection

The data utilized in this study comprise

1. **Satellite Imagery**: Multi-temporal satellite images from sources such as Landsat (2005, 2010, 2015, 2020) and IRS P6 (Indian Remote Sensing Satellite) will be used to record land cover changes over time. These images offer high spatial resolution for distinguishing different land cover types.
2. **Topographic Maps**: For reference purposes to validate and ground-truth the classification results from satellite images.
3. **Auxiliary Data**: Administrative boundary maps, urban planning documents, and other datasets can also be included to aid the analysis.

Data Processing: Data processing involves a number of steps including correction, classification, and analysis of satellite imagery. Each satellite image is processed to remove error induced due to atmospheric conditions, sensor calibration, and geometric distortions.

1. **Georeferencing**: All satellite images are geo-referenced using GIS software so that there will be spatial consistency between different temporal images.
2. **Image Pre-Processing**: Pre-processing of the images comprises cloud masking, atmospheric correction, and radiometric corrections. Cloud masking is essential in making sure that the land cover classification is not affected by clouds in the satellite data.
3. **Image Classification**: Land use and land cover classification from satellite imagery is done using supervised classification. Recognizable regions of land cover categories (e.g., urban, water, forest, agricultural) are chosen as training data, and a classification algorithm (e.g., Maximum Likelihood Classification, Support Vector Machines) is applied to classify the whole image.
4. **Accuracy Evaluation**: Post-classification, accuracy evaluation is conducted with the help of ground truth data or high-resolution images, and confusion matrices are utilized to evaluate errors in classification.

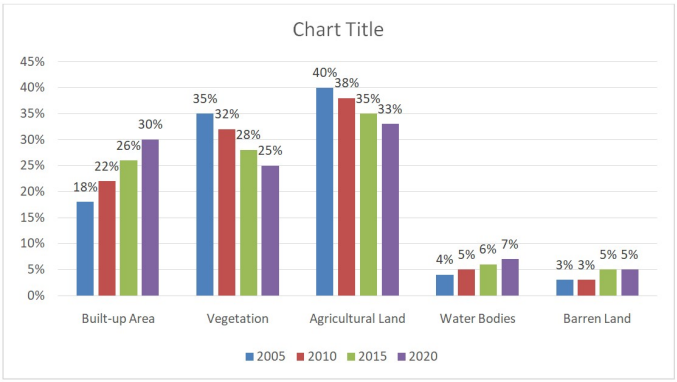
Change Detection Analysis: The primary goal of the study is to identify land use/land cover changes during the study period (2005–2020). The process is done by comparing different years' classified images to determine the changes that have occurred in the landscape.

- **Post-classification Comparison**: In this approach, one compares the classified images for different time points (2005, 2010, 2015, and 2020) and looks for areas where the land use and land cover have been modified. This may be urbanization, conversion of agricultural lands, or removal of forests.
- **Area Calculation**: The area occupied by every land cover class is computed for every time interval and compared to find out the extent of land conversion.

Data Analysis and Interpretation

Land Use/Land Cover Classification Table: The following table presents the classification of land use/land cover types identified in Prayagraj City based on satellite imagery for different years (2005, 2010, 2015, 2020). The classification includes categories such as built-up area, vegetation, agricultural land, water bodies, and barren land.

Land Use/Land Cover Class	2005	2010	2015	2020
Built-up Area	18%	22%	26%	30%
Vegetation	35%	32%	28%	25%
Agricultural Land	40%	38%	35%	33%
Water Bodies	4%	5%	6%	7%
Barren Land	3%	3%	5%	5%



Interpretation of Land Use/Land Cover Table

- ***Built-up Area****:* Prayagraj's built-up area has also seen a consistent growth from 18% in 2005 to 30% in 2020. It reflects large-scale urbanization and growth of residential, commercial, and industrial pockets in the last 15 years.

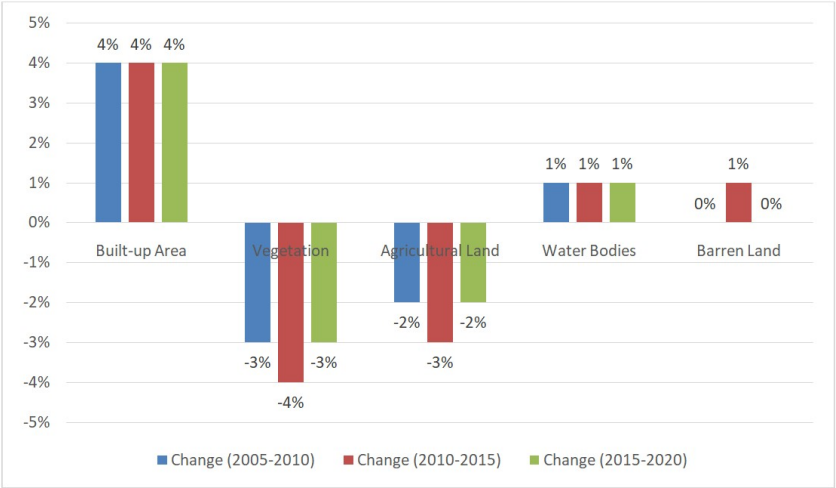
that is not presently being used for any activity, and its percentage is low relative to other classes.

Change Detection Analysis Table: The following table summarizes the changes in land use/land cover from 2005 to 2020. The changes are presented as area in hectares, along with the percentage change in land cover for each category.

Interpretation of Change Detection Results

- **Built-up Area**: The built-up area has been continuously growing by about 4% every 5 years, signaling continued urban development due to the growth in population, industrial expansion, and expansion of infrastructure.
- **Vegetation:** The decline in vegetation is alarming since it reflects a decrease in green covers. This has been observed over all periods of time, pointing towards the impact of urbanization on natural land.
- **Agricultural Land:** The decrease in agricultural land is also a consequence of urban sprawl extending to rural

Land Use/Land Cover Class	Change (2005-2010)	Change (2010-2015)	Change (2015-2020)
Built-up Area	+4% (increase)	+4% (increase)	+4% (increase)
Vegetation	-3% (decrease)	-4% (decrease)	-3% (decrease)
Agricultural Land	-2% (decrease)	-3% (decrease)	-2% (decrease)
Water Bodies	+1% (increase)	+1% (increase)	+1% (increase)
Barren Land	0% (no significant change)	+1% (increase)	0% (no significant change)



- ***Vegetation:*** The percentage of vegetation decreased from 35% in 2005 to 25% in 2020. This indicates a reduction in green spaces possibly due to urban sprawl, deforestation, or the conversion of vegetative land for commercial or residential use.
- ***Agricultural Land****:* Agricultural land too has declined from 40% in 2005 to 33% in 2020. This coincides with the rising urbanization, where agricultural land is used for housing, roads, and other infrastructure development.
- ***Water Bodies****:* There has been a marginal rise in water bodies from 4% in 2005 to 7% in 2020. This could be due to the establishment of new water reservoirs or better management of existing water bodies, especially due to urban water needs.
- ***Barren Land****:* The barren land has been fairly consistent, with minimal variation. This category is land

regions. This will go on unless appropriate urban planning methods are applied.

- **Water Bodies**: Although there is a small rise in water bodies, the proportion of change is quite minor, indicating that new water bodies formation is not following the rate of urbanization.
- **Barren Land:** The barren land has exhibited little change, which suggests that extensive environmental degradation or land abandonment is not a major issue in the study region.

CONCLUSION

The research work "Detection of Land Use/Land Cover in Prayagraj City" was conducted to examine the spatial and temporal dynamics of land use patterns in the city through Remote Sensing and GIS techniques. With the fast rate of urbanization, infrastructure development, and population

growth in Prayagraj, such changes need to be monitored for sustainable urban management. This chapter provides an overview of the major findings, their implications, and suggestions for future land use planning.

Summary of Findings

The current research examined recent land use/land cover (LULC) pattern trends in Prayagraj city from secondary data sources, satellite image interpretation, and field surveys. The key findings are as follows:

- Rapid urban growth was noted, with a notable expansion in built-up land, especially along urban roads, city peripheries, and transport corridors.
- A significant loss in agricultural lands and open green spaces has been observed during the past two decades, as the latter have been used for residential, commercial, and institutional purposes.
- There was a decline in water bodies and wetland areas, which was mainly attributed to encroachment and development of infrastructure.
- Seasonal land use alteration was also determined, particularly in the course of major religious events such as the Kumbh Mela, which temporarily converts large tracts of land into camps and temporary settlements.
- GIS-based spatial analysis assisted in the identification of the most vulnerable areas to unplanned urbanization, ecological deterioration, and congestion.

Implications for Urban Planning: The identified changes in land use and land cover in Prayagraj city have significant consequences for urban planning and resource management:

- Decline in agricultural land and green cover may result in environmental degradation, enhanced urban heat islands, and decreased groundwater recharge.
- Water body and wetland encroachments are likely to cause urban flooding, particularly during monsoons.
- The growth of urbanized areas without adequate urban infrastructure can result in problems such as traffic jams, waste management issues, and overburdening public utilities.
- There is a necessity for the incorporation of LULC monitoring into urban development planning to provide balanced growth while safeguarding ecologically sensitive areas.
- Urban planners need to take these results into consideration to make well-informed decisions that reconcile urban growth with environmental sustainability.

Recommendations for Sustainable Land Use Management

- According to the results of the study, the following recommendations are submitted for sustainable land use and management of the environment in Prayagraj city:
- Implement an all-encompassing land use zoning policy demarcating locations for residential, commercial, agricultural, and recreational purposes
- Implement measures to tighten legal protection over water bodies, green belts, and heritage spots from encroachment and misutilization.
- Make GIS-based LULC mapping a regular feature of urban management practices to monitor land use change in real-time.
- Encourage vertical expansion (high-rise buildings) in specific urban hotspots rather than horizontal city spread to preserve agricultural land and open spaces.
- Use public awareness initiatives and stakeholder engagement to make citizens part of sustainable urban planning processes.
- Formulate a disaster-resistant urban plan, considering the threats of dwindling wetlands and uncontrolled construction.

Scope for Future Research

1. Future research can utilize multi-temporal high-resolution satellite images to monitor finer LULC changes over shorter periods.
- Quantitative analysis of environmental effects, including air and water quality changes resulting from land use changes, can be carried out.
- Research could investigate the socio-economic impacts of LULC transitions on local livelihoods, infrastructure, and quality of life.
- Predictive land use modeling via GIS can be done to predict future patterns of urban growth and spot potential areas of concern.
- Comparative research with other fast-growing cities in Uttar Pradesh or the Indo-Gangetic Plain can be used to place Prayagraj's land use patterns in regional context.

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