



The role of green infrastructure in sustainable urban planning: A geographical study of Lucknow City

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Abstract

The present research study, titled "The Role of Green Infrastructure in Sustainable Urban Planning: A Geographical Study of Lucknow City," effectively assesses the role of green infrastructure in sustainable urban planning in the context of Lucknow City. Due to Rapid industrialization and urbanization have had an unprecedented impact on the geographical and ecological structure of Indian cities. Rapid population growth, land use imbalances, and infrastructural pressures are leading to a continuous decline in green spaces. Consequently, air pollution, the urban heat island effect, drainage problems, and health challenges among urban residents are increasing. In these circumstances, the concept of sustainable urban planning assumes significance, striving to strike a balance between development and environmental protection. During the present research study, it was found that only 4.45% of the city's total geographical area is covered by green infrastructures such as parks, gardens, green belts, water bodies, riverfronts, and open spaces, whereas according to urban planning standards, green infrastructure should be at least 20-25%. As a result of this lack of green infrastructure, the city is facing problems such as increased pollution levels, temperature imbalances, encroachment on water bodies, and degradation of ecological services. This research study attempts to elucidate the role of green infrastructure through social, economic, environmental, and cultural dimensions. The present research study is descriptive and analytical in nature. Both primary and secondary data were used as data collection methods. Techniques such as remote sensing and geographical information system were used to collect and analyze spatial data. Research studies have concluded that preserving and enhancing green infrastructure is essential for sustainable urban planning in Lucknow city. It is recommended that at least 20-25% of the city's land be reserved for green spaces. Green belts should be developed around rivers and ponds, and environmental awareness should be increased among citizens. Thus, green infrastructure can play a central role in Lucknow's sustainable urban development.

Keywords: Green Infrastructure, sustainable development, urban planning, environment conservation, SDG-11, urban ecosystem

Introduction

Today, rapid industrialization and urbanization have transformed the geographical, social, economic, and cultural structure of most cities worldwide. Rapid population growth, industrialization, and urbanization have placed immense pressure on urban areas, resulting in significant challenges such as environmental imbalance, environmental pollution, chaotic transportation systems, drainage problems, and the urban island effect. In these circumstances, sustainable urban planning has emerged as a concept that balances development and environmental protection, making cities more livable. The fundamental objective of sustainable urban planning is not merely the expansion of physical infrastructure, but the creation of an urban structure that is socially, economically, environmentally, and culturally balanced and sustainable. Green infrastructure plays a crucial role in this regard. Green infrastructure includes components such as parks, gardens, groves, rivers, lakes, wetlands, green belts, and urban agriculture, which enhance the quality of urban life while also maintaining environmental balance. Lucknow, the capital of Uttar Pradesh and a rapidly developing urban center, is currently facing the challenges of unplanned urbanization, imbalances in land use, and increasing pressure on natural resources. The proportion of green cover here is steadily declining compared to population growth

and infrastructure expansion. Consequently, problems such as air pollution, temperature rise, and ecological imbalance are emerging. In this scenario, studying the status and role of green infrastructure in a city like Lucknow is not only environmentally relevant but also essential for sustainable urban planning. The present research paper has been written with this objective in mind.

Research Problem: A general survey of the research area reveals that due to rapid urbanization and industrialization in the research area, increasing population pressure, road and building construction, the expansion of industrial units, and unplanned land use and land cover changes have affected the green cover in Lucknow. As a result:

1. Air pollution levels in the city are continuously increasing.
2. The urban heat island effect is clearly visible in the city.
3. Stormwater drainage is being obstructed in the city.
4. The health of urban residents is being adversely affected.

The above problems are a result of the lack of green infrastructure.

Research Objectives: The main research objectives of the current research study are:

1. To analyze the current distribution pattern of green infrastructure in Lucknow.
2. To clarify the role of green infrastructure in sustainable urban planning.
3. To analyze the relationship between green cover and population density in Lucknow.
4. To assess the importance of green infrastructure from environmental, social, economic, and cultural perspectives.
5. To provide suggestions for conservation and promotion of green infrastructure in Lucknow city.

Importance or Significance: The role of green infrastructure in sustainable urban planning is highly relevant in today's era of rapid urbanization and environmental crises. In rapidly growing metropolitan cities like Lucknow, green infrastructure has become an essential element towards achieving sustainable development. The main utility or significance of the present research study is as follows:

Environmental Significance: The environmental significance of green infrastructure is as follows:

1. Green infrastructure helps in improving urban air quality.
2. Green spaces control the urban heat island effect.
3. Green cover in urban areas help in water harvesting and groundwater recharge.
4. Green infrastructure helps in biodiversity conservation in urban areas.
5. Green infrastructure in urban areas helps in soil erosion and flood control.
6. Urban green infrastructure controls environmental pollution.

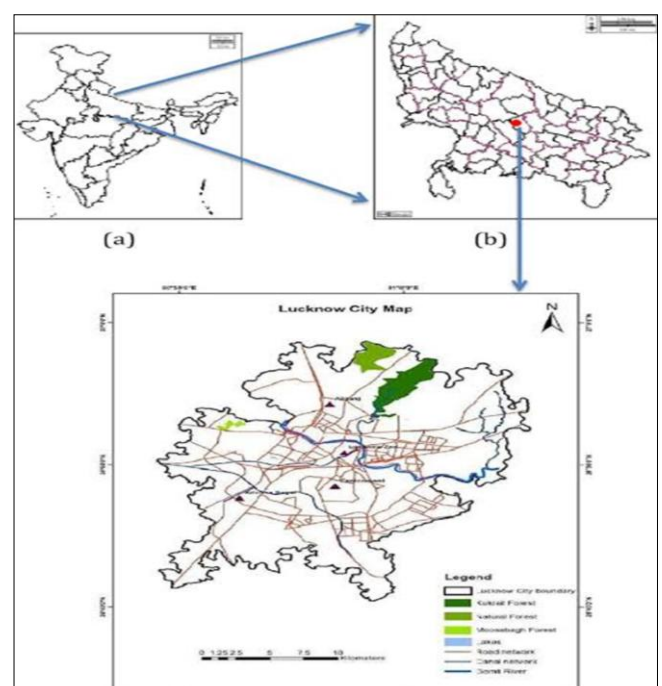
Social and Health Significance: Green infrastructure found in Lucknow city, such as parks, gardens, playgrounds, and open spaces, provide mental and physical health benefits to urban citizens. These spaces help in increasing community cohesion in cities. Urban green infrastructure provides citizens with a suitable environment for exercise, yoga, recreation, and social activities, resulting in a reduction in stress, anxiety, and depression among citizens.

Economic Significance: Green spaces located in Lucknow city, such as Janeshwar Mishra Park, Gomti Riverfront, and the zoo, promote tourism and increase the real estate value of residential areas located near these green spaces. They also provide employment opportunities to local people in areas such as horticulture, park management, ecotourism, and nursery development. The presence of green infrastructure in urban areas reduces temperatures, thereby decreasing the need for air conditioning and saving energy.

Contribution to Urban Planning: Green infrastructure strengthens the concept of the Smart City Mission. It aligns with the 'Green and Clean' goals of the Smart City Mission. Green infrastructure makes urban areas more resilient and livable and helps in tackling problems such as floods, waterlogging, and urban pollution. This research study assists the Municipal Corporation, Lucknow Development Authority, and other institutions in formulating appropriate policies.

Academic and Research Significance: This research study contributes to geographical and environmental studies. This topic will be extremely useful for students of urban geography and medical geography, environmental management, and sustainable development. This research study, which focuses on Lucknow city, can serve as a guide for the development of green infrastructure in other Indian cities.

Study Area: Lucknow: The location of Lucknow is in the state of Uttar Pradesh in India. Situated on the northern Gangetic plains of India, Lucknow is the capital city of Uttar Pradesh. Geographically, it lies between 26°30' N to 27°10' N latitude and 80°30' E to 81°13' E longitude. Lucknow is located at an elevation of 123 meters above sea level. This city was known by the name of Awadh during ancient times, situated in the heart of the great Gangetic plain. Lucknow city is surrounded by its rural towns and villages like the orchard town of Malihabad, historic Kakori, Mohanlal Ganj, Gosainganj, Chinhat, and Itaunja. On its eastern side lies Barabanki District, on the western side is Unnao District, on the southern side Raebareli District, and on the northern side the Sitapur and Hardoi districts. The Gomti River, the main geographical feature, meanders through the city, dividing it into the Trans-Gomti and Cis-Gomti regions. Lucknow city is located in the seismic zone III. Lucknow's location is responsible for the diverse weather patterns and climatic changes. It does not have a uniform weather throughout the year and experiences extreme summers and extreme winters. The total geographical area of Lucknow district is 2528 square kilometers, out of which the total area of Lucknow City is 631 square kilometres. According to the Census 2011, the total population of the Lucknow City is 2,817,105 in which the male population is 1,460,970 and the female population is 1,356,135 and density of 8000 persons/sq. km. Lucknow city contributes 6.33% of urban population in total of state's Urban population. Lucknow city is divided into six zone and further subdivided into 110 administrative wards. Lucknow is also referred as "Golden City of the East"



Research Methodology and Collection of Data:

Descriptive and analytical research methods were used in this paper. Primary and secondary data sources, as well as spatial geographic collection techniques such as remote sensing and GIS, were used to collect geographic data. Geographical analysis of the research area involved GIS-based mapping and satellite imagery obtained through remote sensing. Changes in tree cover and built-up area were analyzed using geospatial technical analysis.

Concept of Sustainable Urban Planning: Sustainable urban planning refers to a development model that balances environmental protection, social equity, and economic development. This concept is linked to the Brundtland Report of 1987, which states that "Sustainable development is development that meets the needs of the present, without compromising the ability of future generations to meet their own needs." The main objectives of sustainable urban planning are balancing land use pattern, energy conservation, pollution control, preservation of green infrastructure, and ensuring a better quality of life for citizens.

Concept of Green Infrastructure and Types: Green infrastructure refers to the set of natural and semi-natural systems that provide ecological services in urban areas. These include trees, parks, gardens, rivers, lakes, water bodies, agricultural areas, green corridors, biosphere reserves, etc.

Types: The following are the major types of green infrastructure:

- Urban green spaces: Parks, gardens, playgrounds.
- Natural water bodies: Lakes, ponds, riverside green areas.
- Green corridors: Roadside tree lines, canal banks.
- Urban agriculture: Rooftop gardening, community gardens.
- Biodiversity reserves: Reserved forests, zoos, natural reserves.

Current Status of Green Infrastructure in Lucknow City:

There is no definitive figure available for the total extent of green infrastructure in Lucknow City, as it encompasses various types of green infrastructure, including parks public and private. According to data from 2004-05, the total area of recreational parks, playgrounds, and open spaces in the Lucknow Development Area was approximately 435 hectares. When 176 villages are included in the Lucknow Development Area, in 2021, recreational parks, play ground, and open spaces covered a total of 1384.87 hectares of land use, representing 4.45% of the total urban developed area. The total number of developed, undeveloped, and open spaces within the Lucknow Municipal Corporation is approximately 2,466. The major recreational parks of Lucknow metropolis include Janeshwar Mishra Park, Begum Hazrat Mahal Park, Daya Nidhan Park, Surajkund Park, Shaheed Smarak Park, Buddha Park, Hathi Park, Ambedkar Udyan and Lemon Park etc. There are also extensive open spaces under the Residency, Botanical Garden, and Zoo. Including all these, about 5366.49 hectares of land has been kept for parks and open spaces in the Master Plan 2031. The main open spaces of the city are concentrated along the Gomti River; there is a lack of parks and open spaces in the old developed area of the city. Lucknow Development authority, Awas Vikas Parishad and private developers develop parks and gardens with the city in different colonies and societies which are later transferred Lucknow Municipal Corporation. Lucknow city is very rich in terms of green infrastructure but most of the green infrastructure have now turned into barren lands due to lack of regular maintenance. As per Lucknow Municipal Corporation there are 2466 parks and gardens under the jurisdiction of LMC comprising to an area of about 435 hectares. Out of the total number of parks and gardens only 1881 of them are in good condition or developed, rest 428 parks and gardens are not developed and the remaining 157 parks and gardens are just open areas. Out of all the parks and gardens only 76.27% of them are fully developed with proper upkeep and maintenance.

Zone wise distribution of parks and gardens in Lucknow city: Year -2024

Zone	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Total (8)
Developed	53	229	317	390	42	60	410	380	1881
Not developed	09	45	130	19	08	25	87	105	428
Open Areas	00	38	12	01	02	00	51	53	157

Source: Lucknow Municipal Corporation



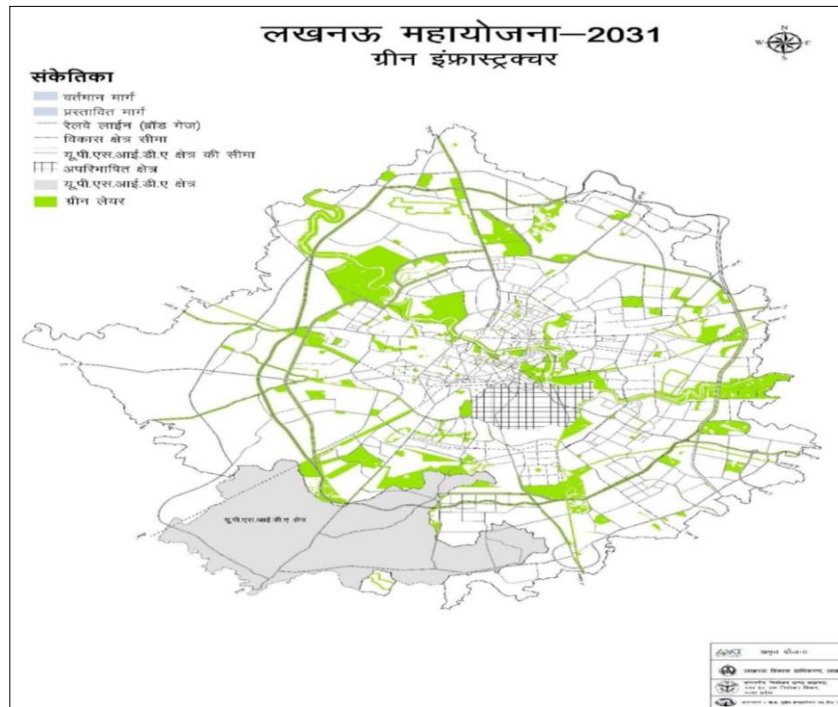
Example of Green Infrastructure

Below the details of parks and open spaces land uses (green infrastructure) In the Lucknow Master Plan -2031.

Category	Sub Category	Area (ha)	Percentage
	Parks and open spaces	4862.03	36.07
Green Infrastructure Or Parks and Open Spaces	Regional Parks and Playground	1761.09	13.06
	Historical and cultural/ Religious Importance Site or Buildings	131.14	0.97
	Zoo or Museum	28.44	0.21
	Botanical Gardens	23.47	0.17
	Environment Park	2374.61	17.62
	Exhibition/Fair and Conference Venue	18.24	0.87
	Green Belt	4176.80	30.99
	Total	13475.82	100

Source: Lucknow Master Plan -2031

Green Infrastructure Map of Lucknow City



Source: Master Plan -2031

Role of Green Infrastructure in Sustainable Urban Planning: Green infrastructure plays a crucial role in sustainable urban planning by enhancing environmental sustainability, improving community well-being and creating more liveable cities through the integration of natural elements such as parks, gardens, green spaces and open spaces into urban landscapes. It helps mitigate the adverse effect of urbanization and industrialisation, support biodiversity, promote social inclusiveness and contribute to overall urban resilience and quality of life. The key role of green infrastructure in sustainable urban planning are as follow: -

Environmental Benefits: According to a 2018 study, urban green infrastructure is the creative combination of natural and artificial (green + grey + blue) structures intended to achieve specific resilience goals (flood/drought management, public health, etc.) with broad public support and attention to the principle of appropriate technology. Investing in green infrastructure in urban areas offers significant environmental benefits, which make GI investments a valuable strategy for sustainable and resilient urban planning.

Manage Water and Air Quality: Green infrastructure projects like permeable pavements and green roofs can effectively manage stormwater by absorbing and filtering rainwater. This reduces the risk of flooding, prevents water pollution, and helps maintain healthier aquatic ecosystems. Green infrastructure improves stormwater quality by reducing the load of sediment, unwanted minerals and other contaminants that are carried with runoff from impermeable surfaces. Lucknow city's Air Quality Index (AQI) frequently exceeds 150 to 200. Trees and green infrastructure play a crucial role in regulating air quality levels. Areas in Lucknow with more greenery tend to have better air quality; for example, the areas around Janeshwar Mishra Park, the

Gomti Riverfront, and the zoo have better air quality compared to other parts of the city.

Provide Habitat and Biodiversity: Green infrastructure initiatives introduce more green spaces into cities, promoting urban biodiversity by providing habitats for various species. This supports urban wildlife conservation efforts and enhances overall ecological balance. Native vegetation is better suited to the rainfall of the local area. Enhancement of biodiversity in cities can increase environmental awareness among urban residents. The Kukrail area and the zoo in Lucknow are home to a large variety of flora and fauna. These green spaces contribute to the sustainability of biodiversity.

Mitigate Urban Heat Island Effect: Green infrastructure contributes to climate resilience by mitigating the urban heat island effect. The presence of green infrastructure provides shade and cooling effects, reducing energy consumption for air conditioning and improving overall urban climate comfort. A general survey of Lucknow city reveals that urban temperatures are, on average, 2-3 degrees Celsius lower near the Gomti riverfront and large parks, which helps mitigate the urban heat island effect.

Control Soil Erosion: Retaining runoff in landscaped areas and slowing the rate of flow from the catchment area reduces the risk of erosion of the soil bed. Slower flow rates reduce stress on downstream waterways as well. Where local soils are suitable, rain gardens are used to treat stormwater before it permeates the groundwater. Directing stormwater to irrigate the planting reduces the need for manual watering and increases soil moisture.

Social and Health Benefits: Green infrastructure offers a range of social and health benefits to urban residents.

Amenity and Landscape Design: landscape design contributes to a city's character and identity. Planting complements to built environment, softens appearance of hard surfaces, and provides a visual screen. It can have a positive impact on mental health by providing urban dwellers with access to green spaces, parks, and natural environments. These accessible green areas can help reduce feelings of stress, anxiety, and depression among urban residents.

Encourage Outdoor Activity: Green infrastructure promotes physical health by offering opportunities for activities like walking, jogging, and recreational pursuits within urban spaces. These activities contribute to lower rates of obesity and related health problems. Green cover in urban areas encourages outdoor activity, including walking, cycling and other recreation.

Promote Socialism: Green infrastructure plays a crucial role in creating communal areas where residents can interact, socialise, and develop stronger community bonds. These communal spaces often serve as venues for gatherings, events, and neighbourhood activities, fostering a sense of unity among urban dwellers."

Urban Cooling and Air Quality: Trees and green infrastructure provide significant reductions in urban temperatures. Large trees with good soil moisture can reduce local temperatures through shading and evapotranspiration. Trees can reduce air temperatures in parks and green areas by as much as 2-8°C, and they have been linked to the prevention of unnecessary loss of life during heatwaves. Vegetation improves air quality and reduces greenhouse gases. Trees remove carbon dioxide, nitrous oxides, sulphur dioxide, carbon monoxide and ozone from the atmosphere. The most effective species in trapping pollutants are those with large leaf surface areas and high transpiration rates.

Economic Benefits

Investing in Green infrastructure brings a variety of economic benefits.

Energy Saving: Strategically placing green elements such as trees, parks, gardens and green roofs would lower energy consumption by providing shade and insulation to buildings. This means cost savings on utility bills. By reducing local temperatures and shading building surfaces, green infrastructure reduces the cooling demand of buildings, thus cutting energy needs.

Property Values and Marketability: Green infrastructure leads to better public health, which translates to lower healthcare costs for individuals and governments. It also raises property values when well-maintained, contributing to higher tax revenue for local governments. Green spaces attract visitors, benefiting local businesses and the economy. These projects create jobs in various fields such as landscaping and urban planning. Moreover, it helps manage stormwater naturally, reducing the need for expensive traditional infrastructure.

Provide Relaxation of Workers: Access to green spaces during breaks can boost worker productivity and job

satisfaction, benefiting employers and the economy as a whole.

Water System: The impacts on drainage system and the cost of managing erosion in waterways can be significant. Streets with green infrastructure slow the rate of runoff, reducing the pressure on these systems and lowering maintenance costs.

Cultural and Aesthetic Benefits:

Lucknow city has many historical gardens, such as Sikandar Bagh, Moti Mahal Garden, and Dilkusha Garden. These gardens are all part of Lucknow city's ancient heritage and act as a bridge between ancient and modern urban culture. Green infrastructure located in any urban area enhances the city's cultural identity and beauty.

Challenges and Problems: Green infrastructure in Lucknow city is the backbone of the city's ecological stability, citizen welfare, and sustainable urban development. The lack of green infrastructure in urban areas gives rise to various problems. Rapid population growth, unplanned construction, unplanned urbanization, unplanned industrialization, and administrative apathy are continuously increasing the pressure on the city's green spaces. The city's green cover has been reduced to less than 10%, while the ideal standard from an environmental perspective should be around 20-25%. This state of green infrastructure is affecting both the environmental quality and the standard of living in the city. The major challenges or problems related to green infrastructure in Lucknow city are as follows:

1. Rapid urban expansion and imbalance in land use.
2. Increase in encroachment and illegal construction.
3. Increase in climate change and urban heat island effect.
4. Gap between policy formulation and implementation.
5. Lack of public awareness.
6. Degradation and pollution of water bodies.

Suggestions and Recommendations: The following suggestions or recommendations can be made regarding the role of green infrastructure in the sustainable urban planning of Lucknow city-

1. Policy reforms and green planning should be promoted to ensure the sustainability of green infrastructure in Lucknow city.
2. Encroachments should be removed from water bodies in the urban area of Lucknow, and these water bodies should be revitalized.
3. Tree plantation and urban agriculture should be promoted in the urban area of Lucknow. Tree plantation should be institutionalized along roadsides, in schools, and in government complexes.
4. Community participation and public awareness should be encouraged for the maintenance and enhancement of green infrastructure in Lucknow city.
5. Technologies such as remote sensing and Geographic Information Systems (GIS) should be used for monitoring and managing green infrastructure in Lucknow city.
6. Environmental tourism should be promoted in Lucknow city.
7. The accountability of all implementing agencies responsible for the maintenance of green spaces in Lucknow city should be established.

8. Rules and policies related to urban planning and development should be made sustainable and viable.

Conclusion: The geographical location of Lucknow city, rapid population growth, rapid urban expansion, rapid industrialization, and rapid urbanization clearly indicate the need for robust green infrastructure to address the city's environmental challenges. Natural resources such as parks, gardens, urban agriculture, horticulture, riverbanks, and ponds not only maintain environmental balance but also play a crucial role in improving the quality of social life.

This research study reveals that the development of green infrastructure in many areas of Lucknow city has progressed positively; however, problems such as urban sprawl, encroachment, and shortcomings in policy formulation and implementation limit its full potential. If green spaces are placed at the center of urban planning, water bodies are conserved, and citizens are actively involved in conservation campaigns, Lucknow city can become cleaner, more sustainable, healthier, and climate-resilient. This is because green infrastructure is not merely a part of the city's aesthetics but the foundation upon which a sustainable, safe, and more livable Lucknow of the future will be built.

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