INTEGRATING GREEN INFRASTRUCTURE FOR URBAN RESILIENCE: CASE AREA OF LUCKNOW

A Thesis Submitted

in Partial Fulfilment of the Requirements

for the Degree of

MASTER

In

Planning(Urban)

by

SIDDHANT SHANKAR

(Roll No.- 123502018)

Under the Guidence of

Prof. MOHIT KUMAR AGARWAL

BABU BANARSI DAS UNIVERSITY
LUCKNOW

2024-25

BABU BANARSI DAS UNIVERSITY, LUCKNOW

Report of M. Tech./ M. Pharma/ M. Arch. Thesis/ Dissertation Evaluation

Name of student:_____ Roll No.:_____

Department:_____

Thesis Title:_____

(in capital)_____

Thesis Supervisor(s):_____

Remarks: Satisfactory/Not Satisfactory (in case of not satisfactory give comments)

_____

_____

_____

_____ _____

Sign of Thesis Supervisor Sign of External Examiner

_____ _____

Sign of Head of Department Sign of Dean of School

_____

Convener

BABU BANARASI DAS UNIVERSITY, LUCKNOW

CERTIFICATE OF THESIS SUBMISSION FOR EVALUATION

(Submit in Duplicate)

1. Name : Siddhant Shankar

Enrollment No. : **123502018**

2. Thesis title: INTEGRATING GREEN INFRASTRUCTURE FOR URBAN RESILIENCE: CASE AREA OF LUCKNOW
3. Degree for which the thesis is submitted: Masters in Planning(Urban)
4. Faculty of the University to which the thesis is submitted School of Architecture and Planning

6. Thesis Preparation Guide was referred to for preparing the thesis.	YES	NO
7. Specifications regarding thesis format have been closely followed.	YES	NO
8. The contents of the thesis have been organized based on the guidelines.	YES	NO
9. The thesis has been prepared without resorting to plagiarism.	YES	NO
10. All sources used have been cited appropriately.	YES	NO
11. The thesis has not been submitted elsewhere for a degree.	YES	NO
12. Submitted 2 spiral bound copies plus one CD.	YES	NO

(Signature of the Candidate)
Name: SIDDHANT SANKAR

Roll No **123502018**

BABU BANARASI DAS UNIVERSITY, LUCKNOW

CERTIFICATE OF FINALTHESIS SUBMISSION

(To be submitted in duplicate)

1. Name : Siddhant Shankar
Enrollment No. : **123502018**

2. Thesis title: **INTEGRATING GREEN INFRASTRUCTURE FOR URBAN RESILIENCE: CASE AREA OF LUCKNOW** Degree for which the thesis is submitted: **Masters in Urban Planning**

3. School (of the University to which the thesis is submitted)

School of Architecture and Planning

6. Thesis Preparation Guide was referred to for preparing the thesis.	YES	NO
7. Specifications regarding thesis format have been closely followed.	YES	NO
8. The contents of the thesis have been organized based on the guidelines.	YES	NO
9. The thesis has been prepared without resorting to plagiarism.	YES	NO
10. All sources used have been cited appropriately.	YES	NO
11. The thesis has not been submitted elsewhere for a degree.	YES	NO
12. All the corrections have been incorporated.	YES	NO
13. Submitted 4 hard bound copies plus one CD.		

(Signature(s) of the Supervisor(s))
Name(s):……...…….

(Signature of the Candidate)
Name:……...…….
Roll No …….
Enrollment No.:……

SUMMARY

This thesis, titled "Integrating Green Infrastructure for Urban Resilience: A Case of Chowk, Lucknow Inspired by Singapore," explores the role of green infrastructure (GI) in enhancing the resilience, sustainability, and livability of densely populated historic neighborhoods in India.

The study focuses on the urban precinct of Chowk in Lucknow, a congested and heritage-rich area severely affected by the Urban Heat Island (UHI) effect, inadequate green cover, and environmental degradation. The objective is to draw strategic and context-sensitive lessons from Singapore's globally acclaimed green infrastructure model to frame implementable solutions for Chowk.

The research begins with a comprehensive literature review of green infrastructure theories, ecosystem services, and sustainable urbanism. It highlights best practices in global cities including Singapore, Rotterdam, and New York. Case studies of Singapore's ABC Waters Program, vertical gardens, and green plot ratio policies are critically analyzed.

Primary data was collected from Chowk through GIS analysis, heat mapping, NDVI studies, pollution data, and field surveys. The data shows an alarming lack of green infrastructure, high surface temperatures, narrow roads, and insufficient open spaces. Rooftops and courtyards emerged as viable micro-intervention zones.

Key proposals include rooftop gardens, vertical greening, bioswales along streets, shaded walkways, and micro-parks in temple courtyards. Policy recommendations suggest zoning reforms, FAR incentives, green audits, CSR involvement, and PPP models for implementation. A pilot-to-scaling roadmap is envisioned with performance metrics such as green cover ratio, temperature drop, and community satisfaction.

The thesis concludes that integrating nature-based solutions in dense, heritage precincts is not only feasible but essential for urban climate resilience. The proposed framework for Chowk, termed the "Chowk Green Revival Framework (CGRF) 2035," blends ecological restoration with socio-cultural inclusivity, creating a scalable model for Indian cities.

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to the individuals who have contributed to the completion of my Master's thesis in Planning (Urban). Their unwavering support and encouragement have played a crucial role in my academic journey.

First and foremost, I am immensely grateful to my thesis guide, **Dr. Mohit Kumar Agarwal**. His invaluable guidance, expertise, and unwavering support throughout this research endeavour have been instrumental in shaping the direction and quality of my work. His continuous encouragement, insightful feedback, and patience have truly been a source of inspiration for me.

Furthermore, I would like to acknowledge the role of my **faculty and mentors at the School of Architecture and Planning, Babu Banarasi Das University — Prof. Sumit Wadhera, Ar. Ankita Gupta, Ar. Ghanshyam Yadav, Ar. Varsha Verma, and Ar. Shalini Diwakar**. Their extensive knowledge, constructive criticism, and valuable insights have significantly contributed to the development of my research. Their unwavering dedication and support have been invaluable, and I am deeply grateful for their mentorship.

I would also like to express my gratitude to my **friends and loved ones** who have been there for me throughout this journey. Their unwavering support, understanding, and encouragement have provided me with the strength and motivation to overcome challenges and persevere. Their presence has brought joy, laughter, and solace during the demanding times of thesis work.

Lastly, I would like to extend my appreciation to all the individuals who have directly or indirectly contributed to my growth as a researcher and planner. Your collective efforts have played an integral role in shaping my academic and personal development.

To everyone mentioned above and to those not mentioned individually but who have been a part of my journey, please accept my heartfelt gratitude for your unwavering support, guidance, and encouragement. This thesis would not have been possible without each and every one of you. Thank you for being a part of this significant milestone in my academic life.

UNDERTAKING

I, **Mr. Siddhant Sankar**, the author of the thesis titled
"INTEGRATING GREEN INFRASTRUCTURE FOR URBAN RESILIENCE: CASE AREA OF LUCKNOW",

hereby declare that this is an independent work of mine, carried out towards the fulfilment of the requirements for the award of the **Master's in Planning(Urban)** at the **Department of Architecture and Planning, Babu Banarasi Das University (BBDU), Lucknow**.

This work has not been submitted to any other organization or institution for the award of any degree or diploma.

Siddhant Shankar
Roll no. 1230152018
M.Plan 2nd Year

Table of Contents

1. **Undertaking** i
2. **Acknowledgment** ii
3. **Summary** iii
4. **Chapter 1: Introduction** 4
   1.1 Urban Heat Island (UHI)
   1.2 Benefits of Green Infrastructure
   1.3 Aim and Objectives
   1.4 Scope
   1.5 Research Methodology
5. **Chapter 2: Literature Review** 14
   2.1 Key Theories and Frameworks
   2.2 Key Studies and Research Findings
   2.3 Research Gaps
   2.4 Summary
6. **Chapter 3: Case Study** 16
   3.1 Singapore
   3.2 Netherlands
7. **Chapter 4: Research Context – Lucknow** 21
   4.1 City Overview
   4.2 Existing Green Infrastructure
   4.3 Goals and Comparative Aims
8. **Chapter 5: Site Analysis – Chowk, Lucknow** 23
   5.1 Land Use, Density, and Connectivity
   5.2 Heat Map and Green Space Coverage
9. **Chapter 6: Data Collection** 26
   6.1 Study Area Overview
   6.2 Sources of Data
   6.3 Observations
   6.4 Summary
10. **Chapter 7: Data Analysis** 28
    7.1 SWOT Analysis
    7.2 GIS and Thermal Mapping
    7.3 Urban Morphology and Accessibility
    7.4 Mobility and Street Conditions
    7.5 Socio-Spatial Behavior
    7.6 Summary of Findings
11. **Chapter 8: Comparison** 32
12. **Chapter 9: Proposals and Policies** 33
    9.1 Proposed GI Interventions
    9.2 Planning and Zoning Reforms
    9.3 Fiscal Incentives
    9.4 PPP Models and Community Engagement
    9.5 Technology and Smart Strategies
    9.6 Implementation Roadmap
    9.7 Expected Impacts
13. **References** 38

CHAPTER-1

INTRODUCTION

1.1 INTRODUCTION

Green infrastructure refers to a strategically planned network of natural and semi-natural systems that provide environmental, economic, and social benefits by integrating nature into urban and rural settings. It includes elements such as parks, green roofs, urban forests, rain gardens, wetlands, green walls, and permeable pavements.

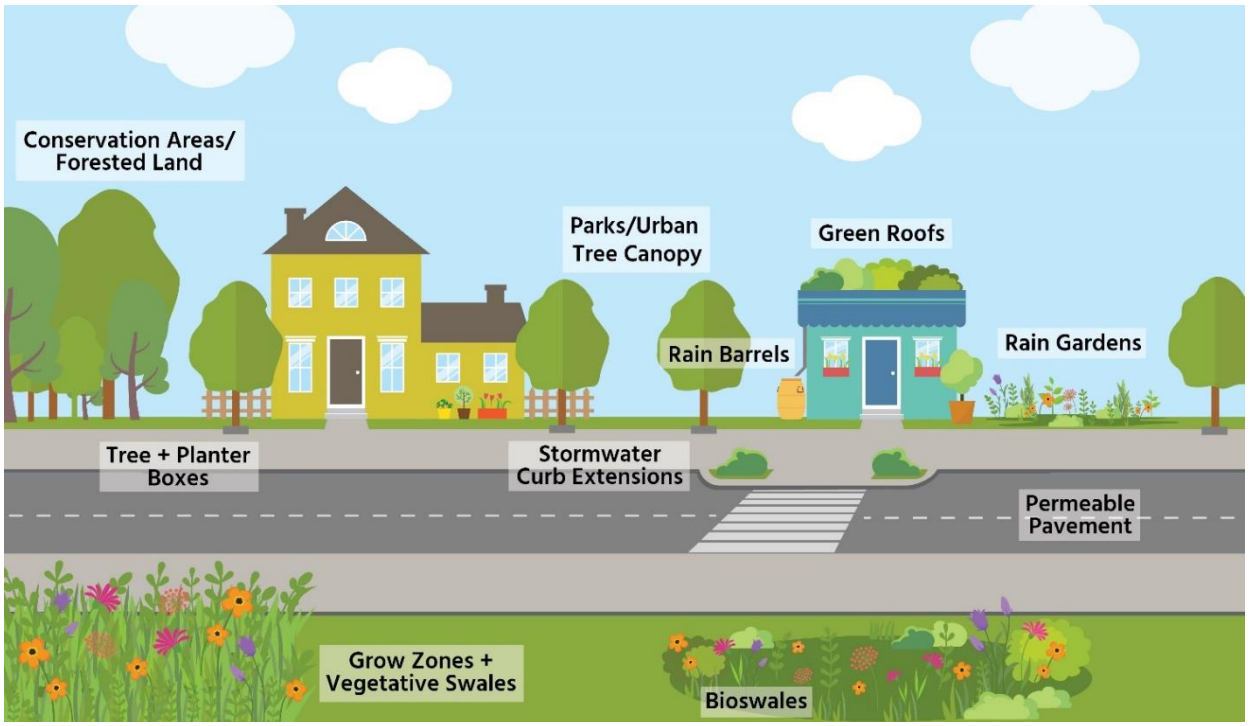
Unlike traditional "grey" infrastructure (such as roads and drainage systems), green infrastructure harnesses the power of ecosystems to deliver services like stormwater management, air purification, temperature regulation, and biodiversity enhancement.

As cities face growing challenges from climate change, rapid urbanization, and environmental degradation, green infrastructure offers a sustainable and adaptive approach to urban development. It helps reduce the urban heat island effect, improve water quality, enhance aesthetic and recreational value, and promote healthier living environments for communities. Thus, integrating green infrastructure is essential for building resilient, livable, and climate-responsive cities.

Urbanization is reshaping the world, bringing with it both opportunities and challenges. One of the most pressing environmental challenges faced by cities today is the Urban Heat Island (UHI) effect, where densely built-up urban areas record significantly higher temperatures than surrounding rural regions. This temperature differential is primarily driven by the excessive use of impervious materials, loss of green cover, and heat-retaining infrastructure. As climate change intensifies and urban populations swell, cities like Lucknow are increasingly vulnerable to heat stress, pollution, and ecological degradation.

Green Infrastructure (GI) has emerged as a pivotal tool in addressing these urban challenges. Unlike conventional “grey” infrastructure that primarily focuses on engineered solutions, GI integrates natural processes into the built environment. Parks, green roofs, rain gardens, vertical gardens, bioswales, and permeable pavements represent just a few of the components of GI. These systems offer multifaceted benefits — they reduce surface temperatures, absorb rainwater, improve air quality, foster biodiversity, and enhance community well-being.

This thesis focuses on the integration of green infrastructure to enhance urban resilience, particularly targeting Chowk, one of the most congested and historically rich neighborhoods of Lucknow. By drawing insights from global exemplars, particularly Singapore’s well-established green urbanism model, this research explores how densely populated and ecologically degraded zones like Chowk can be retrofitted with sustainable, multifunctional, and heritage-sensitive green infrastructure strategies.



SOURCE - www.brec.org

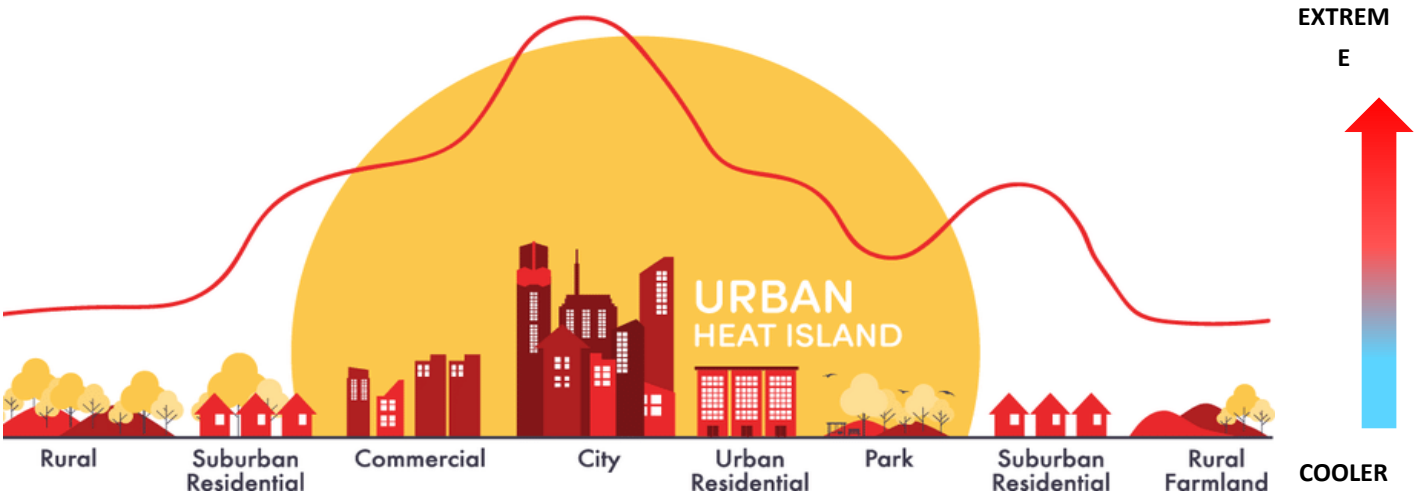
URBAN HEAT ISLAND (UHI)

Urban Heat Island (UHI) is a phenomenon where urban or metropolitan areas experience significantly higher temperatures than their surrounding rural areas.

This temperature difference is primarily caused by human activities, dense infrastructure, and reduced natural vegetation in cities. Surfaces like concrete, asphalt, and buildings absorb and retain heat during the day and release it slowly at night, leading to a sustained increase in urban temperatures.

As cities face growing challenges from climate change, rapid urbanization, and environmental degradation, green infrastructure offers a sustainable and adaptive approach to urban development. It helps reduce the urban heat island effect, improve water quality, enhance aesthetic and recreational value, and promote healthier living environments for communities. Thus, integrating green infrastructure is essential for building resilient, livable, and climate-responsive cities.

The UHI effect not only contributes to increased energy consumption (due to higher demand for air conditioning) but also exacerbates air pollution, negatively impacts human health, and affects local weather patterns. As urbanization continues to grow globally, understanding and mitigating the UHI effect has become a crucial component of sustainable urban planning and climate resilience strategies.



SOURCE - community.wmo.int

BENEFITS OF GREEN INFRASTRUCTURE

Green infrastructure provides a wide range of environmental, social, and economic benefits that contribute to sustainable and resilient urban development. Key benefits include:

Environmental Benefits

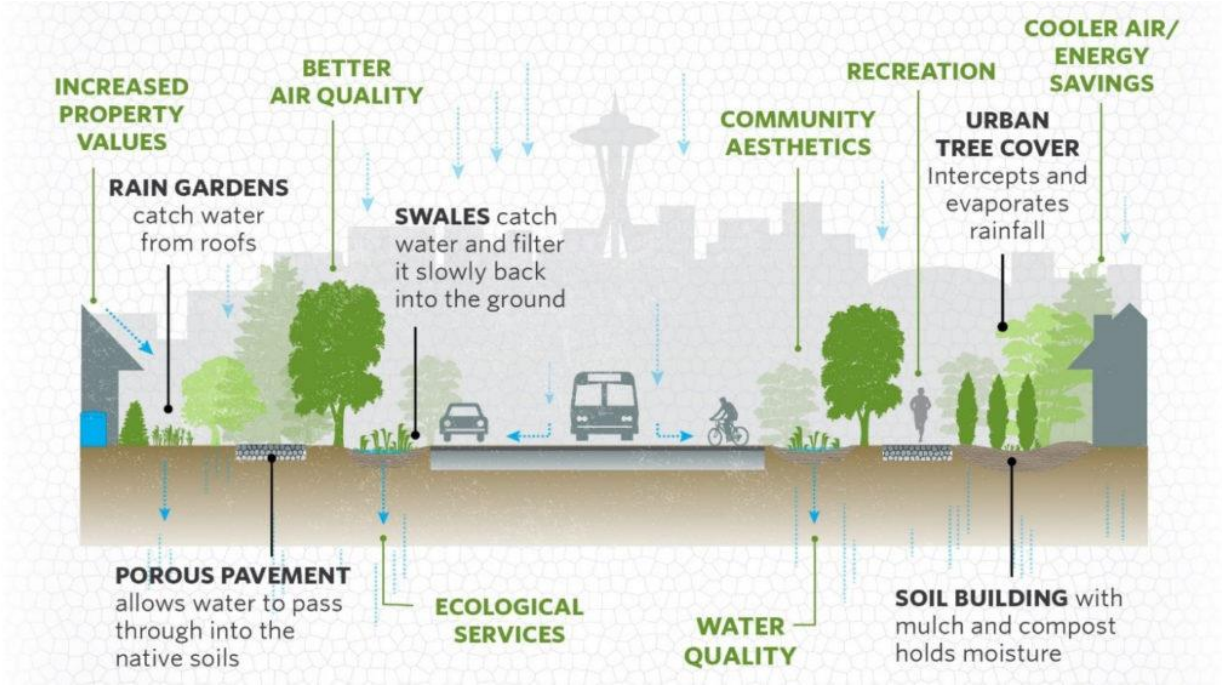
- Urban Heat Island Mitigation: Vegetation and green surfaces lower urban temperatures by providing shade and promoting evapotranspiration.
- Improved Air Quality: Plants filter pollutants and particulate matter, enhancing the overall air quality.
- Stormwater Management: Features like green roofs and rain gardens absorb and filter rainwater, reducing runoff and preventing urban flooding.
- Biodiversity Enhancement: Green spaces support local wildlife by providing habitats and ecological corridors.


SOURCHE - media.licdn.com

Social Benefits

- **Improved Public Health:** Access to green spaces promotes physical activity, reduces stress, and lowers risks of heat-related illnesses.

- **Enhanced Aesthetic Value:** Green infrastructure improves the visual appeal of urban areas, contributing to a better quality of life.
- **Social Cohesion:** Parks and green corridors encourage community interaction and foster a sense of belonging.



SOURCE - delphi.ca

Economic Benefits

- **Energy Savings**: Trees and green roofs provide insulation, reducing the need for artificial heating and cooling.
- **Increased Property Value**: Proximity to green spaces often leads to higher property prices and attractiveness for investment.
- **Job Creation**: Designing, installing, and maintaining green infrastructure supports green jobs in landscaping, environmental services, and urban planning.

1.2 AIM AND OBJECTIVES

To explore the role of green infrastructure in enhancing urban resilience with focus on mitigating Urban Heat Island effects in urban areas.

- **Conceptual Analysis:**

To critically analyze the concept of green infrastructure and its relevance to urban resilience.

To identify the key components and functions of green infrastructure in urban planning.

- **Strategy Development:**

To evaluate global best practices for integrating green infrastructure into urban development plans.

To identify scalable and context-specific strategies for implementing green infrastructure in urban areas.

- **Impact Assessment**:

To assess the socio-economic, environmental, and climate-related impacts of green infrastructure in selected case studies.

To examine the role of green infrastructure in mitigating urban challenges like flooding, heat islands, and biodiversity loss.

- **Stakeholder Analysis**:

To understand the role of policymakers, urban planners, and communities in the successful integration of green infrastructure.

To analyze the barriers and enablers of public-private partnerships in green infrastructure projects.

- **Policy Recommendations**:

To propose actionable recommendations for incorporating green infrastructure into urban resilience frameworks.

To develop guidelines for equitable and inclusive access to green infrastructure in urban settings.

The aim of this research is to explore and evaluate the role of green infrastructure (GI) in enhancing urban resilience, with a specific focus on mitigating Urban Heat Island (UHI) effects in densely populated and historically significant urban areas like Chowk, Lucknow. By drawing lessons from global best practices, especially the exemplary model of Singapore, this study intends to develop a context-sensitive and scalable GI framework suited to Indian cities.

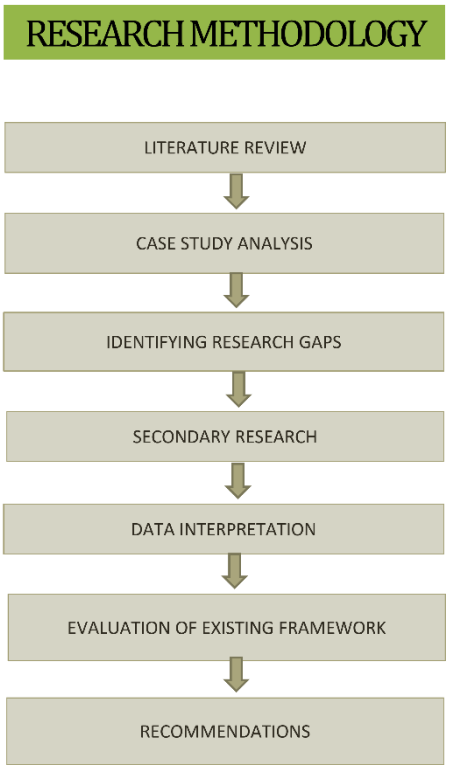
The specific objectives of the study are:

1. To critically analyze the concept of green infrastructure and its role in urban resilience and sustainable urban planning.
2. To identify and classify the various components of green infrastructure relevant to dense urban environments.
3. To examine global case studies, particularly Singapore, to extract scalable strategies for GI integration.
4. To evaluate the socio-economic, environmental, and climatic impacts of green infrastructure using qualitative and quantitative data.
5. To analyze existing conditions in Chowk, Lucknow in terms of land use, thermal mapping, green cover, and urban form.
6. To develop strategic proposals for retrofitting green infrastructure in Chowk, maintaining sensitivity to its heritage and social fabric.
7. To formulate policy-level recommendations, financial models, and community-driven strategies for implementing GI in historic urban contexts.
8. To promote inclusive, equitable, and participatory approaches in the planning and maintenance of green infrastructure in Indian cities.

SCOPE

- **Geographical context:**
  Focuses on urban areas where green infrastructure (GI) has been or is being implemented.
  Includes both global best practices and specific case studies, such as those in rapidly urbanizing countries like India.
- **Thematic coverage:**
  Explores the integration of green infrastructure with urban planning for resilience against environmental and socio-economic challenges.
  Addresses climate adaptation, biodiversity conservation, water management, and urban heat mitigation through gi.
- **Stakeholder engagement:**
  Examines the role of policymakers, urban planners, private developers, and communities in the implementation of GI.
  Analyzes public-private partnerships and community-driven initiatives for equitable access to green spaces.
- **Evaluation metrics:**
  Assesses the socio-economic and ecological impacts of GI projects, including cost-effectiveness, ecosystem service delivery, and equity.
- **Policy recommendations:**
  Provides actionable insights for policymakers and planners to incorporate GI into urban resilience frameworks.

1.3 RESEARCH METHODOLOGY



RESEARCH PAPERS

1. *Comprehensive Performance of Green Infrastructure Through a Life-Cycle Perspective: A Review*
Source:MDPI,*Sustainability*
Summarizes life-cycle environmental and economic outcomes of integrated grey-green systems, exploring green roofs, infiltration basins, and permeable pavements.

2. *Green Infrastructure Designed Through Nature-Based Solutions for Sustainable Urban Development*
Source: MDPI, *International Journal of Environmental Research and Public Health*
Examines health, wellbeing, hydrological performance, and green–grey system integration; includes green roof cooling and roadside vegetation impacts.

3. *Green Infrastructure in the Urban Environment: A Systematic Quantitative Review*
Source:MDPI,*Sustainability*
Based on 171 papers, analyses environmental, social, and economic GI benefits, including cost, energy savings, wellbeing, crime reduction, and ecosystem services.

4. *Green Urban (RE)Generation: Methodology to Better Implement Urban GI*
Source:MDPI,*Land*
Offers a global classification of GI (e.g., green roofs, façades, permeable pavements, swales, rain gardens) and discusses scale-based implementation strategies.

ANALYSIS

📗 1. "Nature-Based Solutions for Climate Change Mitigation and Adaptation" – European Environment Agency (EEA)

- Source: EEA Website
- Summary: This article highlights the role of green infrastructure in Europe for climate adaptation, biodiversity, and urban well-being.
- Example Case: Sponge Cities in China and green corridors in Germany.

📙 2. "Singapore: A City in a Garden" – Centre for Liveable Cities, Singapore

- Source: CLC Publication
- Summary: A deep dive into Singapore's approach to integrating green infrastructure through vertical gardens, green buildings, and stormwater-sensitive parks.
- Highlights:
    - ABC Waters Programme
    - Bishan-Ang Mo Kio Park
    - Green Plot Ratio system

📓 3. "Green Infrastructure: Planning and Design for Sustainable Cities" – American Society of Landscape Architects (ASLA)
Source: ASLA Website
Summary: Covers design strategies and project examples showing how landscape architects use GI to enhance liveability and ecological performance in cities.
Includes: Visual diagrams, design briefs, urban integration methods.

JOURNALS

🔍 Academic Journal Articles (You can find these on Google Scholar or academic databases like JSTOR, ResearchGate):

- "Green Infrastructure: Linking Landscapes and Communities" – Benedict & McMahon (2006)
- "The Effectiveness of Green Infrastructure in Stormwater Management—A Review" – Environmental Science & Policy
- "Urban Green Infrastructure for Climate Change Mitigation" – Nature-based Solutions Journal

CASE STUDY ANALYSIS

SINGAPORE

Population and Density

Total Population (2025): Approximately 5.87 million people.

Land Area: About 71000 hectare.(710 Sq.km.)

Population Density: Approximately 142.5 du/ha.

Green Space Coverage

Green Space: Around 20% of Singapore's land area is designated as green space, encompassing parks, nature reserves, and urban greenery.

Ratio of Population to Green Space

With 5.87 million residents and 140 square kilometers of green space (20% of 700 km²), there are approximately 41,929 people per square kilometer of green area.

Urban Planning Initiatives

Singapore's "City in Nature" vision aims to enhance green spaces and biodiversity, ensuring that every resident lives within a 10-minute walk of a park. This approach demonstrates how high-density urban living can coexist with substantial green coverage.

AIMS AND OBJECTIVES

To propose a comprehensive and context-sensitive green infrastructure framework for Chowk, Lucknow, by drawing comparative insights from Singapore's successful green infrastructure strategies, with the goal of enhancing urban resilience, environmental quality, and livability in dense, historic Indian cities.

- Examine key projects like vertical gardens, ABC Waters Program, green roofs, green corridors, and park connectors.
- Understand policy tools, governance models, public-private partnerships, and design principles used.
- Consider local heritage sensitivity, informal economic activity, narrow lanes, encroachments, and socio-economic diversity.
- Identify barriers (e.g., funding, governance, space constraints) and potential enablers.
- Use parameters such as density, climate, land values, administrative mechanisms, and public engagement.
- Highlight scalable and adaptable strategies from Singapore that are contextually relevant to Chowk.
- Design multifunctional green elements: rooftop gardens, shaded walkways, green walls, rain gardens, and micro parks.
- Integrate ecological design into urban conservation and regeneration plans.

CASE AREA IDENTIFICATION

CHOWK, LUCKNOW

Population and Density

Total Population (2025): Approximately 6000 people.

Land Area: About 10 hectare.

Population Density: Approximately 120 du/ha.

Green Space Coverage

Green Space: Around 12.9% of land area is used as green space, parks, nature reserves, and urban greenery.

Ratio of Population to Green Space

With 1625 residents and 1.29 hectare of green space (12.9% of 10.06 hectare).

DATA COLLECTION AND ANALYSIS

📊 Data Collection:

- Land use maps (LU/LC data)
- Built density & FSI (from municipal records)
- Traffic volume & congestion data
- Heat island data (temperature surveys or satellite thermal imagery)
- Air and water quality reports (CPCB/UPPCB)
- Green cover percentage (NDVI analysis or GIS mapping)
- Photographic survey of public spaces, streets, parks

📈 Data Analysis:

- SWOT analysis of environmental conditions
- Urban morphology mapping
- GIS-based heat map overlay of pollution, green space, and congestion
- Space syntax analysis for movement and accessibility

DATA INTERPRITATION

Collected Data:

- Satellite imagery shows <5% green cover
- Air quality index consistently >150 (poor)
- Narrow roads (avg. 6 m), high pedestrian congestion
- Lack of formal open spaces; informal use of religious courtyards as gathering zones

Interpretation:

- Chowk is critically underserved in formal green infrastructure.
- Existing courtyards, rooftops, and abandoned spaces offer micro-intervention opportunities.
- High pedestrian density offers potential for linear green corridors or shaded walking routes.

EVOLUTION AND RECOMMENDATION

📘 1. Global Evolution

- Pre-20th Century: Green spaces were ornamental or religious (e.g., Mughal gardens, European royal parks).
- 1960s–1980s: Environmental crises (e.g., pollution, floods) led to eco-centric urban planning in Europe and the US.

- 1990s: Introduction of the term *Green Infrastructure (GI)* as an ecological approach to urban planning.
- 2000s–present: GI became integral to *sustainable*, *resilient*, and *climate-adaptive* city frameworks (e.g., EU GI Strategy, Singapore's ABC Waters Programme, New York's Green Streets).

🔷 Urban Design Recommendations

1. Micro Green Pockets: Convert dead spaces, temple grounds, and historic courtyards into shaded mini-parks or edible gardens.
2. Rooftop Greening: Incentivize green roofs on heritage-compatible buildings (e.g., public schools, religious institutions).
3. Vertical Greening: Use blank facades of markets and flyovers for vertical gardens using low-maintenance native species.
4. Shaded Walkways & Green Corridors: Line narrow lanes with climbers and potted plants; promote shaded pedestrian streets.

CHAPTER-2
LITERATURE REVIEW

Green infrastructure (GI) has evolved into a cornerstone of modern urban planning, offering a nature-based solution to urban environmental, social, and economic challenges. This chapter provides an in-depth review of key theories, frameworks, and studies related to GI and urban resilience.

Key Theories and Frameworks

a. Urban Resilience Theory:
Urban resilience refers to the capacity of cities to absorb, recover, and prepare for future shocks, whether they are economic, environmental, social, or institutional. Holling's (1973) ecological resilience theory laid the foundation for applying adaptive systems thinking to urban environments.

b. Green Infrastructure Concept:
Benedict and McMahon (2002) defined green infrastructure as a network of natural landscapes that supports biodiversity, improves air and water quality, and provides cultural and recreational benefits. It emphasizes integration with the built environment.

c. Ecosystem Services Framework:
According to the Millennium Ecosystem Assessment (2005), GI delivers provisioning, regulating, supporting, and cultural services that are essential for human well-being and sustainable urban life.

d. Livability and Sustainability Paradigms:
Green infrastructure is closely aligned with sustainable development goals (SDGs) and urban livability, promoting walkability, climate adaptation, and public health (Beatley, 2011).

Key Studies and Research Findings

a. Climate Adaptation and Urban Cooling:
Research by Bowler et al. (2010) confirms that urban greenery significantly mitigates UHI through shading and evapotranspiration. Green roofs and parks reduce surface temperatures by up to 5°C.

b. Water Management:
Green infrastructure aids stormwater infiltration, reduces runoff, and prevents urban flooding.

Studies in cities like Copenhagen and Portland (Kleerekoper et al., 2012) show effective use of bioswales and rain gardens.

c. Social and Economic Impacts:
Kabisch et al. (2016) highlight improved mental health, physical activity, and social interaction from access to green spaces. GI also leads to higher property values and job creation in green sectors.

d. Biodiversity Conservation:
Tzoulas et al. (2007) argue that urban green corridors and native planting schemes enhance habitat connectivity and species richness, particularly in high-density zones.

e. Policy and Governance:
Hansen et al. (2015) illustrate how European cities like Rotterdam, Stockholm, and Berlin integrate GI into master plans and resilience strategies. Governance structures play a critical role in enabling GI initiatives.

f. Technology Integration:
Emerging studies emphasize the potential of smart GI—using IoT-based sensors and AI—for real-time monitoring of vegetation health, irrigation needs, and air quality (EEA, 2020).

Research Gaps

Despite the progress, several challenges persist:
- Lack of quantifiable long-term data on GI performance.
- Insufficient inclusion of vulnerable communities in GI planning.
- Need for integrative approaches combining grey and green infrastructure.
- Limited studies from developing country contexts, including dense Indian cities.

Summary

The literature underscores the multifunctionality and adaptability of GI, particularly in the context of rapid urbanization and climate risk. However, the translation of global best practices into local, heritage-sensitive contexts like Chowk, Lucknow requires tailored strategies that respect historical identity and spatial constraints.

(Citations: Holling, 1973; Benedict & McMahon, 2002; Millennium Ecosystem Assessment, 2005; Bowler et al., 2010; Kabisch et al., 2016; Tzoulas et al., 2007; Hansen et al., 2015; Beatley, 2011; EEA, 2020)

CHAPTER-3
CASE STUDY

SINGAPORE

Key Green Infrastructure Initiatives

✅ **Park Connector Network (PCN)**

- Over 300 km of green corridors linking parks and nature reserves.
- Encourages walking, cycling, and ecological connectivity across urban areas.

✅ **ABC Waters Programme (Active, Beautiful, Clean)**

- Transforms utilitarian canals and drains into vibrant green-blue spaces.
- Examples: **Bishan-Ang Mo Kio Park**, **Kallang River at Lower Peirce**, which combine flood control with recreation and biodiversity.

SOURCE - www.greenplan.gov.sg

✅ **Skyrise Greenery (Green Roofs and Walls)**

- Incentivized through the **Skyrise Greenery Incentive Scheme (SGIS)** by NParks.
- Prominent examples: **Parkroyal on Pickering**, **CapitaGreen**, **Marina One** – buildings that integrate extensive greenery into their architecture.

✅ **Vertical and Roadside Greening**

- The **LUSH programme (Landscaping for Urban Spaces and High-Rises)** mandates greenery replacement and encourages vertical gardens in high-rise developments.
- Roadside trees and median planting enhance thermal comfort and air quality.

SOURCE - www.greenplan.gov.sg

✅ Key Features of Green Infrastructure in Singapore

1. Comprehensive Policy Framework

- **National Parks Board (NParks)** oversees biodiversity conservation and urban greenery.
- Initiatives like the **Skyrise Greenery Incentive Scheme** promote green roofs and green walls in private and public developments.
- **Singapore Green Plan 2030** includes nature-based solutions as part of climate resilience efforts.

SOURCE - www.greenplan.gov.sg

2. Green Buildings and Skyrise Greenery

- **Over 110 hectares** of rooftop gardens and green walls have been installed (as of 2020).
- Iconic projects:
  - **Marina One**: Features a biodiversity-rich "Green Heart" with tiered gardens.
  - **Parkroyal Collection Pickering Hotel**: 15,000 m^2 of green terraces and vertical greenery.

3. Park Connector Network (PCN)

- Over **300 km of green corridors** link parks, residential areas, and waterways.
- Encourages cycling, walking, and biodiversity movement within the city.

SOURCE - www.greenplan.gov.sg

4. ABC Waters Program (Active, Beautiful, Clean)

- Led by **PUB (Singapore's National Water Agency)**.
- Transforms concrete canals into naturalized, multi-functional blue-green corridors.
- Example: **Bishan-Ang Mo Kio Park** – a successful case where a concrete canal was replaced with a meandering river integrated into a public park.
  - Benefits: Stormwater management, flood control, biodiversity, and recreation.

SOURCE - www.greenplan.gov.sg

5. Climate Resilience and UHI Mitigation

- GI helps mitigate the **urban heat island effect** through increased vegetative cover and evapotranspiration.
- GIS mapping and modeling are used to target GI installations in heat-prone zones.

📈 Outcomes and Impact

- **Temperature Reduction**: Studies show green roofs and trees reduce local temperatures by 2–4°C.
- **Improved Livability**: High green space accessibility contributes to better public health and wellbeing.
- **Global Recognition**: Singapore ranks highly in sustainability indices and is often cited in global urban ecology research.

NETHERLANDS

SOURCE - www.kimkim.com

🌿 Green Infrastructure Initiatives in the **Netherlands**

The **Netherlands** is internationally renowned for its innovative and integrated approach to **green infrastructure (GI)**, especially due to its geographic vulnerability to climate change and sea-level rise. Dutch urban planning combines **ecological restoration**, **water-sensitive design**, and **community-based solutions** to create sustainable and resilient cities.

✅ Key Green Infrastructure Initiatives

1. Room for the River Programme

- **Objective**: Restore natural river floodplains to reduce flooding.
- **Approach**: Relocate dikes, deepen river beds, and create green river parks.
- **Example**: *Nijmegen Lent* project—transformed a floodplain into a recreational green park and eco-zone.
- **Impact**: Increased biodiversity, recreational value, and flood resilience.

2. Green Roofs and Urban Greening

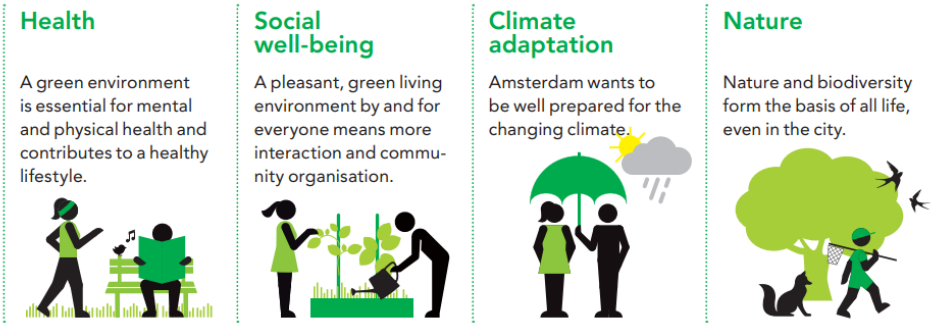
- Cities like **Rotterdam**, **Amsterdam**, and **Utrecht** offer **financial incentives** for green roofs.
- **Rotterdam Green Roof Programme**: Over 400,000 m² of green roofs installed.
- Benefits: Improves thermal comfort, reduces runoff, and promotes biodiversity in dense urban areas.

3. Sponge City Techniques

- **Rotterdam** and **Amsterdam** are adopting nature-based solutions to absorb and slow stormwater.
- Includes **rain gardens**, **water plazas**, **permeable pavements**, and **bioswales**.
- **Benthemplein Water Square (Rotterdam)**: Multifunctional public space that collects and stores rainwater during heavy storms.

4. National Ecological Network (EHS/NEN)

- A strategic GI initiative connecting fragmented ecosystems across the country.
- Aims to link **core natural areas** via **green corridors**, enabling species migration and landscape connectivity.
- Covers forests, wetlands, and coastal areas.



5. Urban Forests and Green Corridors

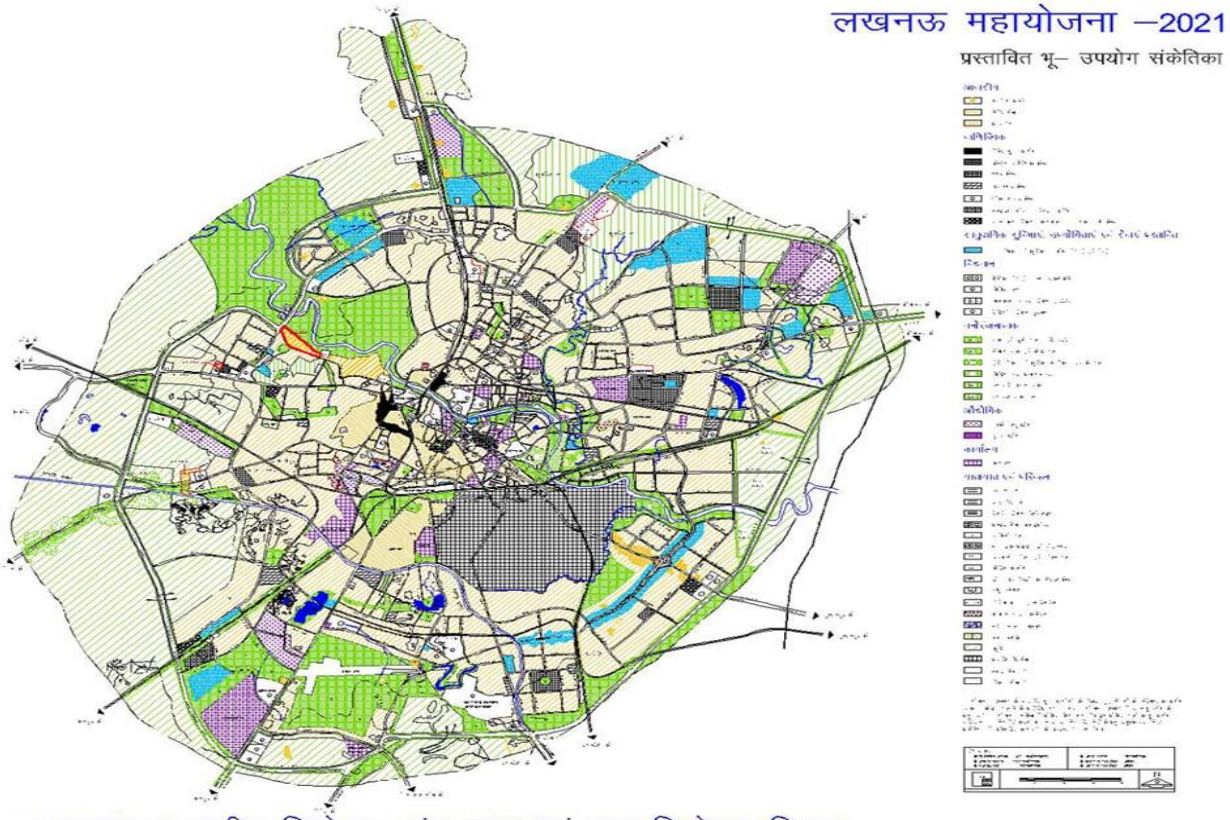
- Municipalities invest in **urban forests**, such as *Amsterdamse Bos* and *Utrecht's Gagelbos*.
- Encourage biodiversity, carbon sequestration, and public recreation.
- **Green cycling and pedestrian paths** connect urban and natural landscapes.

☑ Outcomes and Impacts

- **Climate Adaptation**: GI is core to the **Dutch Delta Programme** for future water security.
- **Increased Biodiversity**: Wetland restoration and corridors promote healthy ecosystems.
- **Community Involvement**: Public awareness campaigns and citizen-led gardening initiatives strengthen stewardship.
- **Urban Livability**: GI improves aesthetics, reduces noise and heat, and supports healthier lifestyles.

SOURCE - www.kimkim.com

CHAPTER-4
RESERCH

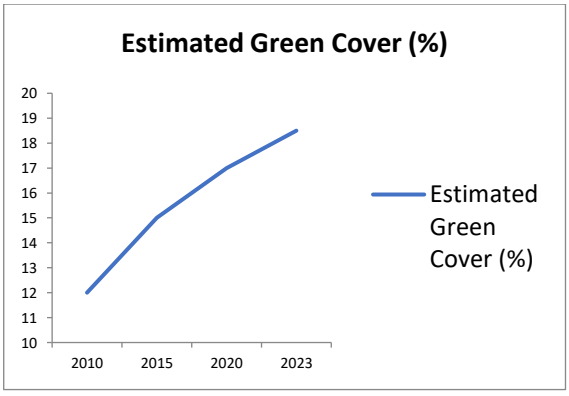


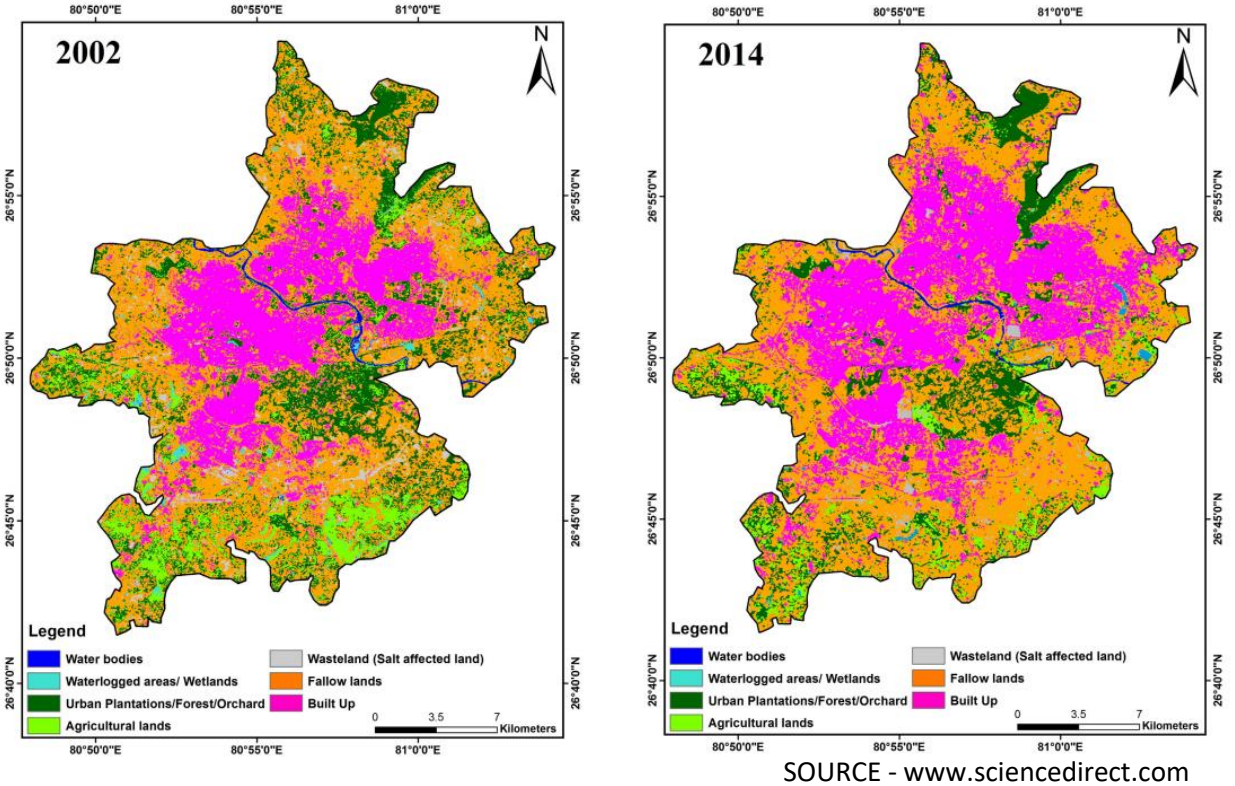
SOURCE - www.ghardhudho.com

City: Lucknow, Uttar Pradesh, India
Population (2021 est.): ~3.7 million
Total Area: ~631 km²
Green Cover Target (as per Urban Forest Policy): 33%

- **Janeshwar Mishra Park** – Asia's largest garden park (~376 acres)
- **Gomti Riverfront** – Landscaped green area along the Gomti river
- **Lohia Park** – ~80 acres of public park in Gomti Nagar
- **Kukrail Forest Reserve** – Urban forest and gharial breeding center

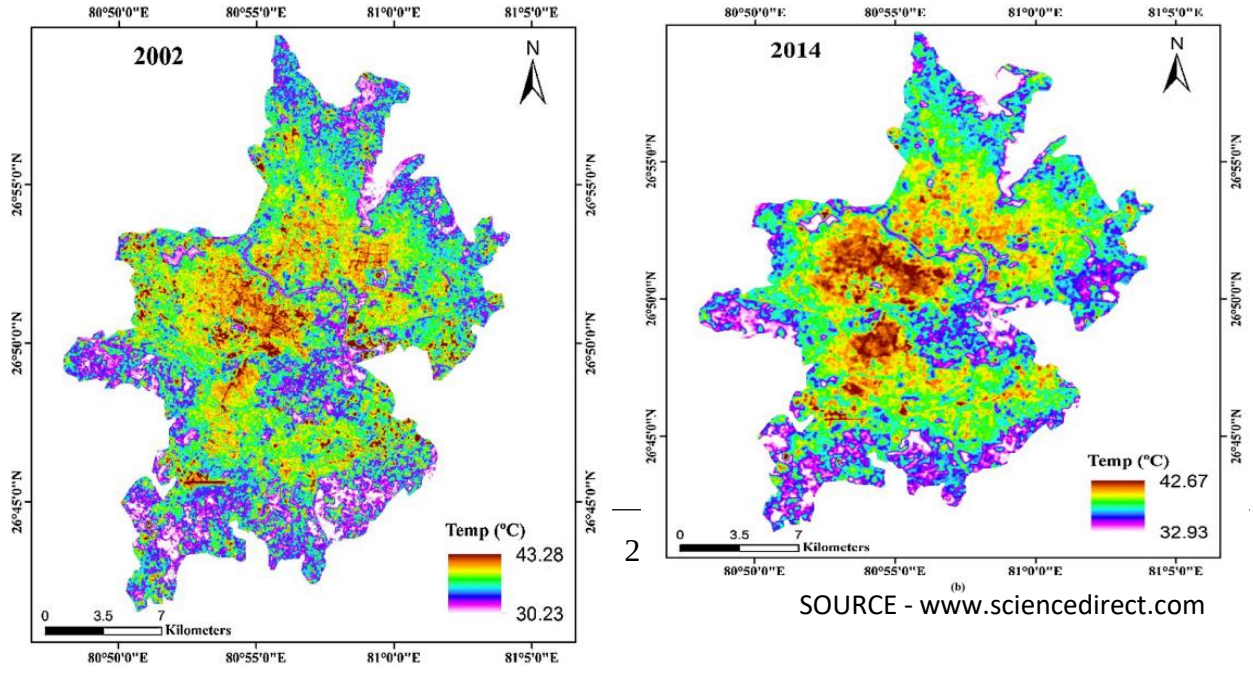
Category	Area (sq km)	Percentage of Total Area
Forest Area (Reserve + Open)	55	8.7%
Public Parks & Gardens	35	5.5%
Avenue/Street Trees		Estimated 1.5%
Private Green Spaces		Estimated 3.0%
Total Green Cover	63	~18-20%





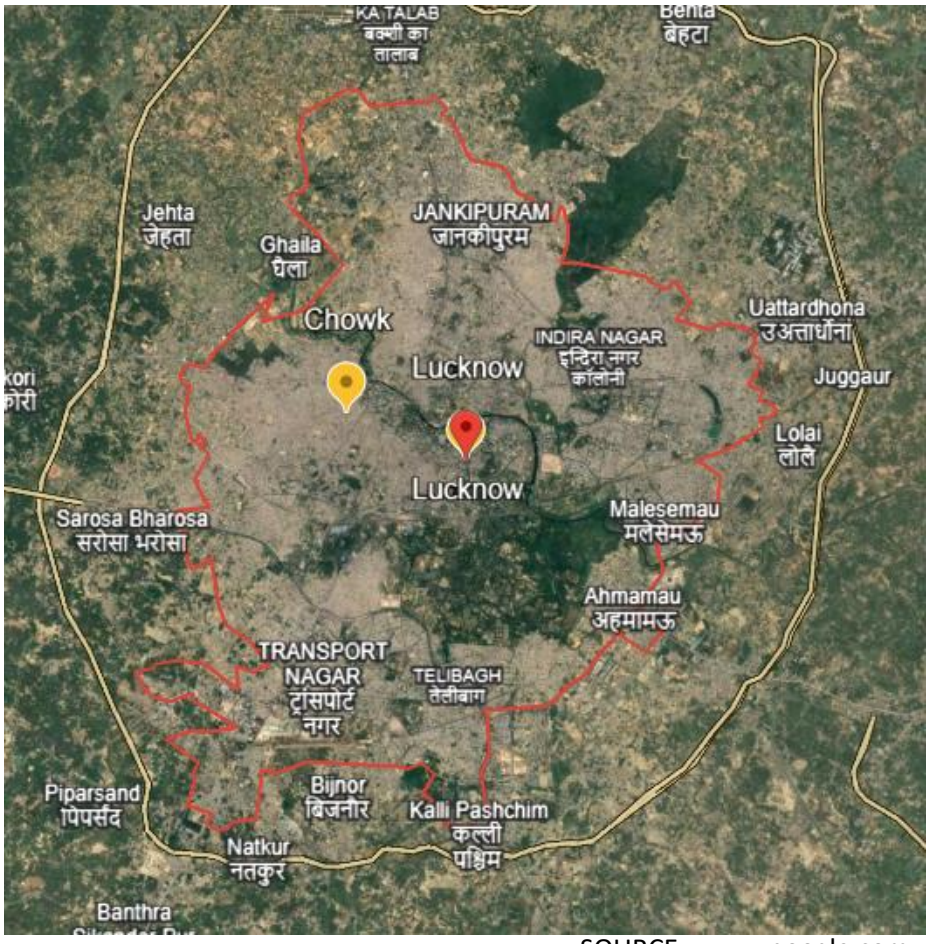
SOURCE - www.sciencedirect.com

LULC	30th September 2002	23rd September 2014
Built up area (urban and rural)	93.97	130.33
Waterlogged areas/wetlands	6.71	8.18
Wasteland (salt affected land)	14.68	12.11
Urban plantations and forest	75.97	50.27
Agricultural lands	32.37	25.03
Fallow lands	202.47	201.84
Water bodies	3.29	1.71



SOURCE - www.sciencedirect.com

CHAPTER-5
SITE ANALYSIS



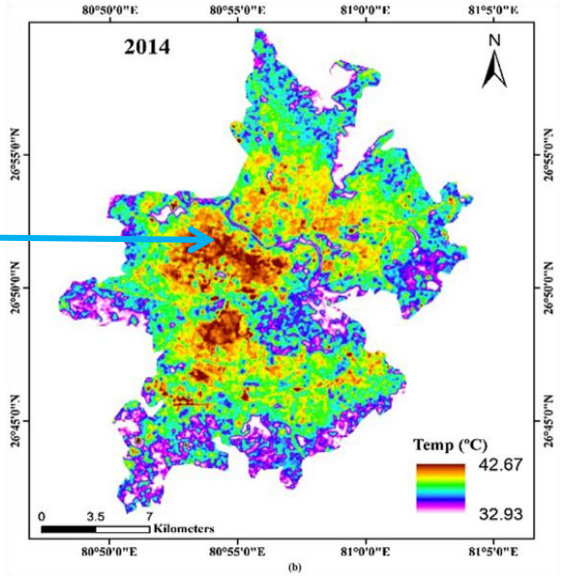
LUCKNOW SOURCE - www.google.com

SOURCE - www.google.com

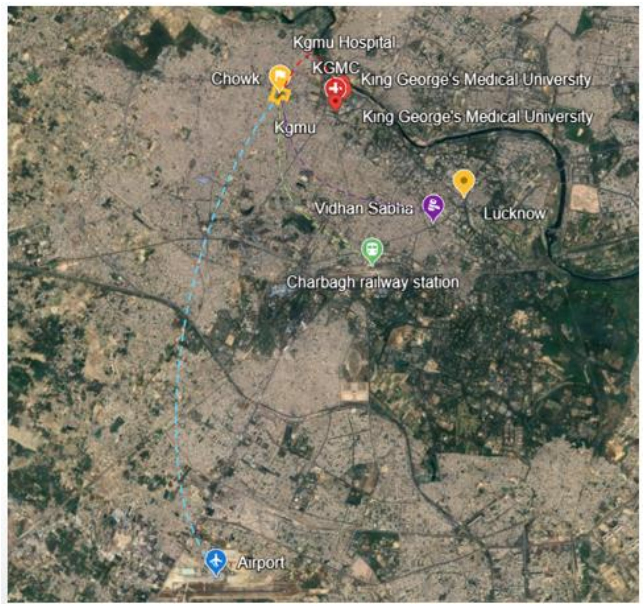
- **Survey area – 10.06 hectare (100615 sqm)**
- **No. Of houses – 396**
- **Green area – 1.289 hectare**
- **Green area percentage – 12.9%**
- **Latitude – 26.8697524**
- **Longitude – 80.9005344**

Maximum heat prone area

Chowk, lucknow



SOURCE - www.sciencedirect.com



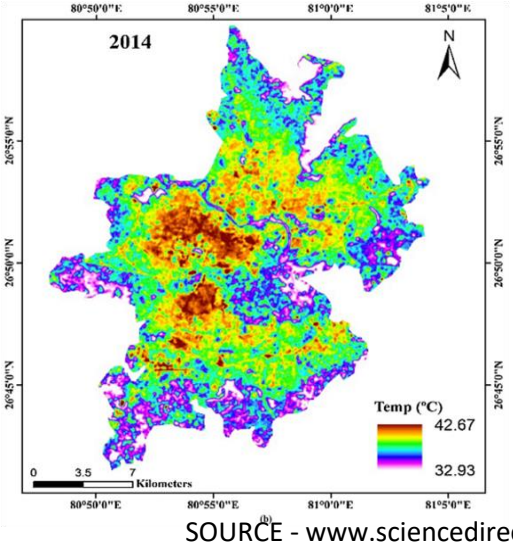
SOURCE - www.google.com

Connectivity

- 2 km from King George's medical university
- 6 km from Charbagh railway station
- 6 km from Vidhan Sabha
- 12 km from Chaudhary Charan Singh international airport

SOURCE - www.google.com

Chowk, Lucknow



SOURCE - www.sciencedirect.com

Heat map Lucknow

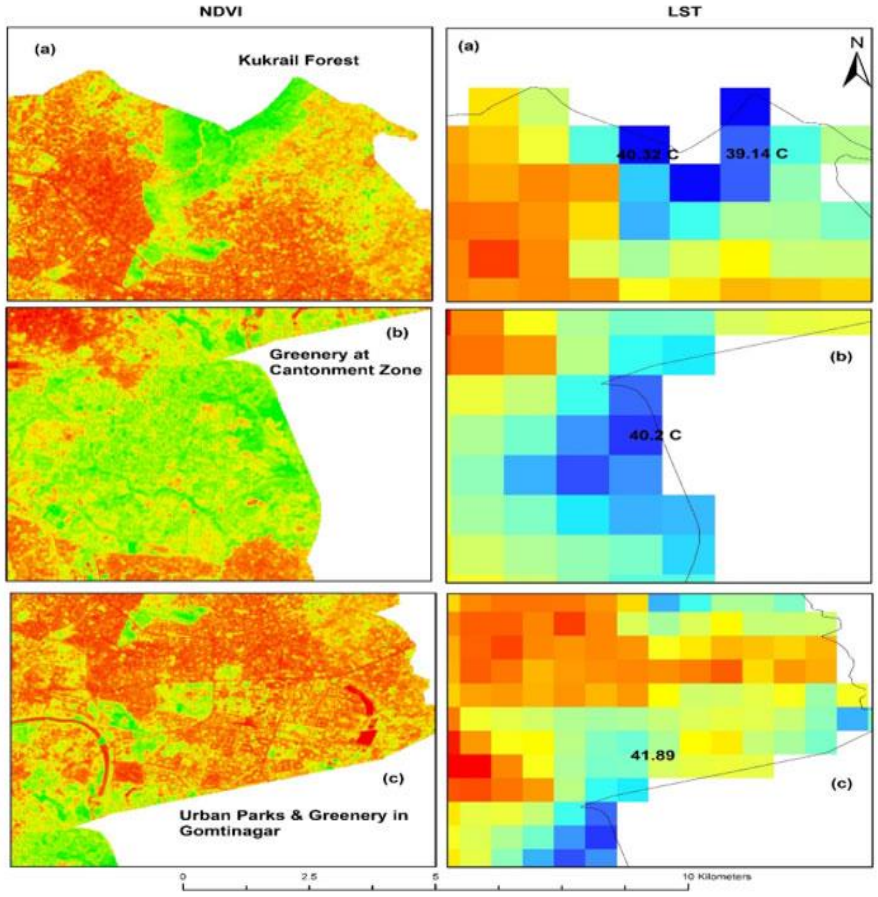


Figure 3: a-c. NDVI & LST of Lucknow

Source: Open-Source Satellite Data

SOURCE - www.google.com

CHAPTER-6
DATA COLLECTION

This chapter presents the data sources and collection methodologies employed to understand the environmental and infrastructural characteristics of Chowk, Lucknow. Given the objective to retrofit green infrastructure in a dense, historic neighborhood, both qualitative and spatial datasets were collected from secondary sources and interpreted with contextual sensitivity.

4.1 Study Area Overview: Chowk, Lucknow

Chowk is a historic core of Lucknow city characterized by a dense urban fabric, narrow lanes, high pedestrian density, and a mix of residential, religious, and commercial land uses. It covers an approximate area of 10.06 hectares with a population of around 6,000 residents.

SOURCE - www.google.com

4.2 Sources of Data

- **Satellite Imagery:** Used to analyze land cover, vegetation index (NDVI), and built-up density. Sources: Google Earth Pro, Bhuvan (ISRO), Landsat archives.
- **Land Use and Land Cover (LULC) Maps:** Maps from 2002 and 2014 were used to observe changes in land utilization.
- **Government Reports and Municipal Records:** FSI, housing density, traffic data, and regulations from Lucknow Development Authority.
- **Thermal Heat Maps:** Surface temperature data from thermal imagery assessed UHI-prone zones.
- **Environmental Data:** Air and water quality reports from CPCB and UPPCB.
- **Primary Surveys:** Field visits and photo documentation of roads, rooftops, courtyards, and parks.
- **Green Space Calculations:** GIS mapping revealed only 12.9% green coverage.

4.3 Observations

- Green cover <5% in many subsectors.
- AQI consistently above 150.
- Narrow, congested roads without shaded infrastructure.
- Unused rooftops and religious courtyards indicate opportunity for greening.

4.4 Summary

The Chowk area lacks formal green infrastructure but holds strong potential in its informal open spaces and architectural elements for low-cost, effective green interventions.

SOURCE - www.google.com

CHAPTER-7
DATA ANALYSIS

This chapter analyzes the spatial, environmental, and social data collected for Chowk, Lucknow, to understand its existing conditions and the scope for green infrastructure (GI) integration. The analysis is structured around key themes: environmental vulnerability, land use, connectivity, urban heat mapping, and socio-spatial dynamics.

6.1 Environmental SWOT Analysis

Strengths	Weaknesses
- Presence of cultural landmarks	- Extremely low green cover (<13%)
- Dense mixed-use environment	- Air quality index remains consistently poor (>150 AQI)
- Walkability and compact urban form	- Narrow lanes prevent street tree plantation
Opportunities	**Threats**
- Rooftop greening and vertical gardens	- Rising temperatures and worsening UHI effect
- Conversion of courtyards into green nodes	- Waterlogging due to lack of stormwater infiltration
- Community engagement via heritage greening	- Encroachment and lack of urban planning enforcement

6.2 GIS and Thermal Mapping

- **NDVI (Normalized Difference Vegetation Index):**
  NDVI analysis confirmed vegetative cover below 5% in large parts of Chowk. Existing vegetation is fragmented and largely confined to temple backyards or narrow planters.
- **Thermal Imagery and Heat Island Mapping:**
  Chowk has one of the highest recorded surface temperatures within the city during pre-monsoon months, with readings exceeding 45°C in multiple pockets. These correspond to areas of dense built-up, high asphalt presence, and low ventilation.

6.3 Urban Morphology and Accessibility

- **Space Syntax Analysis:**
  Conducted to study pedestrian accessibility and connectivity between public spaces and underutilized zones. Chowk scores high on pedestrian movement but low on formal recreational and green public spaces.
- **Built Density and FSI:**
  Floor Space Index in several pockets exceeds 2.0, with high built-to-plot ratios. Rooftop spaces remain underutilized, providing strong potential for vertical greening and rooftop gardens.

6.4 Mobility and Street Conditions

- **Street Width and Congestion:**
  More than 80% of internal streets are <6 meters in width. These are frequently congested, with limited tree cover or shaded infrastructure, exacerbating the local UHI effect.
- **Pedestrian Volume:**
  High pedestrian activity, especially around temples and markets, makes shaded walking corridors and bioswales viable interventions.

6.5 Socio-Spatial Behavior and Public Space Usage

- **Religious Courtyards:**
  Used informally as gathering points for small events and social interactions. These offer great potential for integration as “green social nodes.”
- **Vacant Plots & Back Alleys:**
  Many narrow alleys and dead-ends are underutilized and can be transformed into pocket parks or linear bioswale corridors.

6.6 Summary of Key Findings

- Chowk exhibits acute UHI effects and lacks adequate green spaces.
- GIS and spatial analysis reveal viable greening opportunities in:
  - Rooftops
  - Side alleys
  - Courtyards
  - Blank facades
- Community and religious infrastructure offer points for decentralized GI interventions.
- Urban morphology supports linear interventions due to street continuity and walkability.

This chapter analyzes the spatial, environmental, and social data collected for Chowk, Lucknow, to understand its existing conditions and the scope for green infrastructure (GI) integration. The analysis is structured around key themes: environmental vulnerability, land use, connectivity, urban heat mapping, and socio-spatial dynamics.

6.1 Environmental SWOT Analysis

Strengths:

- Presence of cultural landmarks and religious institutions
- Dense mixed-use environment fosters walkability
- Compact built form supports decentralized interventions

Weaknesses:

- Extremely low green cover (<13% of the area)
- Poor air quality index (AQI >150 regularly)
- High pedestrian congestion and absence of shaded streets
- Lack of formal recreational or public green spaces

Opportunities:

- Rooftop and vertical greening on public and religious buildings
- Conversion of courtyards into shaded, social green nodes
- Public-private partnerships for greening dead spaces and narrow alleys

Threats:

- Rising surface temperatures and worsening UHI effect
- Encroachments and lack of enforceable urban green policy
- Climate change intensifying water scarcity and heat stress

6.2 GIS and Thermal Mapping

- NDVI (vegetation index) confirms vegetation below 5% in most subsectors.
- Thermal imagery reveals extreme heat zones exceeding 45°C during summer, mostly over markets, roads, and rooftops.

6.3 Urban Morphology and Accessibility

- Chowk's historic grid layout has narrow streets (avg. 6m width).
- Space syntax analysis highlights high pedestrian volume but low access to recreational green space.
- Floor Space Index (FSI) varies from 1.5 to 2.5, offering rooftop greening potential.

6.4 Mobility and Public Space

- High footfall recorded near temples and markets.
- Streets lack canopy, resulting in heat stress and poor walkability.
- Temple courtyards and lanes used as informal gathering zones present key intervention opportunities.

6.5 Summary of Key Findings

- Chowk suffers from severe ecological stress and lacks integrated green space.
- Rooftops, alleys, and courtyards are underutilized assets for introducing green infrastructure.
- Shaded walkways, vertical greening, and rooftop gardens are contextually feasible and impactful strategies.

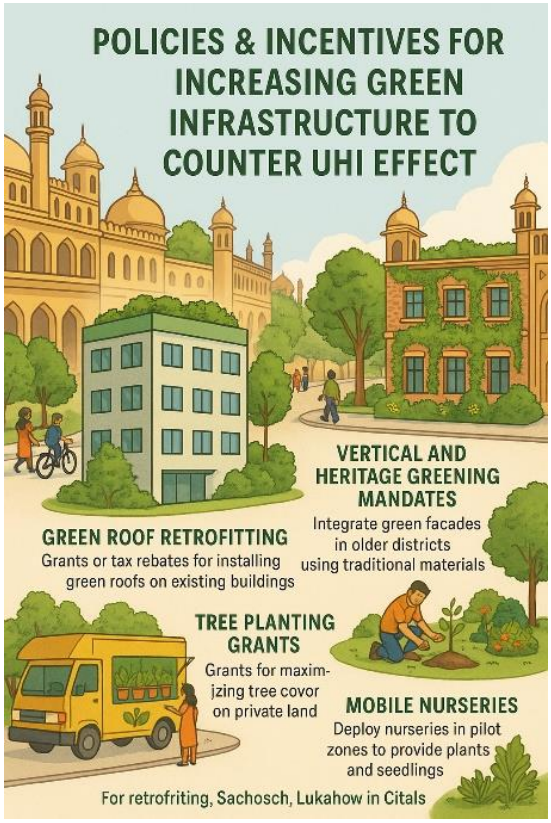
CHAPTER-8
COMPARISION

Aspect	Singapore	Lucknow, Uttar Pradesh
Urban Planning Approach	Long-term, integrated urban and environmental planning (e.g., "City in Nature" vision)	Traditional city layout; green infrastructure planning is limited and scattered
Policy Support	Strong national support via NParks, URA, PUB, and the Singapore Green Plan 2030	Policies under Smart Cities Mission and AMRUT, but with limited focus on integrated GI
Implementation Model	Centralized, with government funding and incentives (e.g., LUSH, ABC Waters)	Decentralized efforts with some state-funded parks and lakes; limited coordination
Types of Green Infrastructure	- Green roofs, green walls - Park connector network - Stormwater canals as public spaces - Rain gardens, vertical gardens	- Public parks and gardens (e.g., Janeshwar Mishra Park, Lohia Park) - Riverfront redevelopment - Roadside tree plantation
Blue-Green Integration	High: e.g., Bishan-Ang Mo Kio Park integrates flood control and recreation	Limited: Riverfront projects like Gomti Riverfront but often lack ecological design
Biodiversity Conservation	Integrated with urban design—ecological corridors, urban forests	Biodiversity is less prioritized; fragmented green zones lack ecological continuity
Community Engagement	High: Programs like Community in Bloom, citizen gardening, guided trails	Low to moderate; most GI is government-driven with limited community ownership
Technology Use	GIS mapping, sensors, remote monitoring for irrigation and maintenance	Mostly manual monitoring; technology integration is minimal or project-specific
Impact on UHI (Urban Heat Island)	Significant reduction through dense tree cover and vegetated buildings	Limited impact; high impervious surface and sparse tree cover in older, denser areas like Chowk
Maintenance Practices	Well-funded, systematic maintenance regimes	Often irregular; lack of dedicated staff or maintenance budget
Educational Integration	GI integrated into school curricula and public awareness campaigns	Minimal; green awareness campaigns are rare and not integrated with education

SUMMARY

Category	Singapore	Lucknow
Planning Level	Strategic, policy-driven	Localized and reactive
Green Infrastructure Type	Diverse and multi-functional	Basic green areas, limited multifunctionality
Effectiveness	High (climate resilience + livability)	Moderate to low (aesthetic + limited UHI reduction)
Community Role	Strong, incentivized participation	Low involvement, mostly top-down projects

CHAPTER-9
PROPOSAL AND POLICIES



Proposal for Green Infrastructure in Chowk, Lucknow Inspired by Singapore

The proposal aims to transform Chowk, one of the most densely populated and historic neighborhoods of Lucknow, through a green infrastructure strategy modeled after Singapore's successful urban greening initiatives. Recognizing the intense urban heat island effect, poor stormwater management, and limited ecological space in Chowk, the plan focuses on integrating vertical gardens on existing buildings, green rooftops on residences and markets, and narrow bioswales along roads to manage runoff. Underutilized alleys and courtyards can be converted into micro-parks and rain gardens, offering both cooling and recreational relief. Rooftop farming cooperatives and community gardening projects would promote participation, modeled after Singapore's "Community in Bloom" initiative. Green corridors can be introduced along heritage streets to connect existing parks like Chhota Imambara greens with newly proposed green nodes. These interventions would help cool the neighborhood, improve air quality, reduce waterlogging, and enhance overall urban livability, while respecting Chowk's rich cultural and architectural fabric.

1. **Urban Planning and Zoning Policies**

a. Mandatory Green Roof and Cool Roof Regulations

- Require new developments and major renovations to include green or reflective (cool) roofs.
- Provide design guidelines for green roofs to ensure sustainability and effectiveness.

b. Vertical Greening Mandate

- Mandate vertical gardens or green facades in commercial corridors or public buildings.

c. Open Space Ratio Modification

- Modify building regulations to include minimum on-ground or rooftop green space requirements.

d. Heat-Resilient Zoning

- Introduce zoning overlays for UHI hotspots with stricter green cover mandates.

2. Fiscal and Financial Incentives

a. Green Infrastructure Subsidy Program

- Offer **grants or subsidies** for installing green roofs, permeable pavements, rain gardens, or vertical greens.

b. Property Tax Rebates

- Provide **tax rebates or reductions** for buildings that meet minimum green infrastructure criteria.

c. FAR Bonuses (Floor Area Ratio)

- Allow extra construction floor area in exchange for integrating green infrastructure (e.g., rooftop gardens or shaded sidewalks).

d. Green Maintenance Credits

- Offer annual rebates for maintaining rooftop gardens, community green spaces, or street tree cover.

3. Public-Private Partnership (PPP) Models

a. Adopt-a-Green-Space Program

- Let private organizations adopt parts of public land (e.g., medians, sidewalks, parks) to maintain and green them.

b. Rooftop Leasing

- Municipalities can lease public building rooftops to private firms or NGOs to install and maintain green roofs.

c. Corporate Social Responsibility (CSR) Incentives

- Encourage corporate entities to fund green infrastructure through CSR, with fast-track permissions or recognition.

4. Community-Based & Educational Policies

a. Community Gardening Initiatives

- Encourage residents to convert unused plots or rooftops into community gardens with seed grants.

b. Environmental Education and Awareness Drives

- Regular workshops on DIY greening (planter boxes, window gardens, composting) for residents and RWAs.

c. Citizen Green Champions

- Introduce annual awards or recognition for residents or societies contributing to greening efforts.

5. Regulatory and Monitoring Framework

a. Green Infrastructure Audit

- Make it mandatory for all buildings to undergo a green audit every 5 years, with penalties for non-compliance.

b. UHI Mapping and Monitoring Units

- Create a city-wide UHI and vegetation cover heat map, updated annually, to identify priority intervention areas.

c. Integrated Climate Resilience By-laws

- Revise building bye-laws and development control regulations to integrate urban resilience standards.

6. Smart Technology and Innovation Incentives

a. Smart Irrigation Systems Subsidy

- Incentivize IoT-enabled irrigation for rooftop or public green spaces to promote water-efficient greening.

b. GIS-Based Urban Greening Portal

- Use digital platforms for the public to report barren plots or suggest greening zones with real-time tracking.

- **Examples of Successful Global Policies**

City	Policy/Program
Singapore	Landscaping for Urban Spaces and High-Rises (LUSH) program
Toronto	Mandatory Green Roof Bylaw with financial incentives
New York City	Cool Neighborhoods NYC plan with tree planting, cool roofs, and green corridors
Melbourne	Urban Forest Strategy offering grants to residents to plant trees on private land

Recommendations for Implementation in Dense Indian Cities like Lucknow (e.g., Chowk)

- Start with **pilot zones** for green roof retrofitting on public buildings.
- Create a **Heritage Greening Scheme** for integrating green facades in historic urban fabrics using traditional materials.
- Develop **mobile nurseries** and **green design handbooks** for residents and builders.

Recommendations

Based on the collected data, literature review, and comparative analysis, this chapter proposes a strategic framework for integrating green infrastructure (GI) into Chowk, Lucknow. These interventions are inspired by Singapore's successful GI model but adapted for Chowk's dense, heritage-rich, and socio-economically diverse context.

7.1 Vision Statement

To transform Chowk into a climate-resilient, culturally vibrant, and ecologically inclusive neighborhood by integrating context-sensitive green infrastructure that enhances thermal comfort, public health, and heritage preservation.

7.2 Proposed Green Infrastructure Interventions

A. Micro-Greening Strategies

1. **Vertical Gardens**
    - Install native plant-based green walls on blank façades of markets and public buildings.
    - Use hydroponic systems or modular vertical panels.
    - Partner with local nurseries and artisans to create heritage-compliant green facades.
2. **Rooftop Gardens**

    - Convert underutilized rooftops into community gardens, especially on religious and public buildings.
    - Provide insulation, reduce indoor temperatures, and increase food security via rooftop farming cooperatives.
3. **Courtyard Revitalization**
    - Reclaim temple grounds and community courtyards as shaded mini-parks using native vegetation.
    - Introduce seating, shade structures, and bio-retention pits.
4. **Potted Plant Corridors**
    - Line narrow alleys with climbers, hanging pots, and painted planters for shade and visual relief.
    - Encourage residents to maintain them through local competitions.

B. Linear Interventions

1. **Shaded Walkways**
    - Introduce trellises, green canopies, or vertical planting structures along high-footfall lanes.
    - Combine with solar-powered lighting and water misters.
2. **Bioswales and Rain Gardens**
    - Install bioswales along road edges to manage stormwater and reduce flooding.
    - Use permeable pavements wherever feasible.

7.3 Urban Planning and Policy Proposals

A. Zoning and Regulatory Reforms

- Mandate **green roofs** or **cool roofs** on all new public and institutional buildings.
- Designate Chowk as a **heritage green overlay zone**, with relaxed FAR for buildings adopting GI.

B. Financial Incentives

- Offer **property tax rebates** for implementing GI.
- Launch a **Green Grant Scheme** for community rooftop farming or school greening projects.
- Enable **CSR funding** and NGO participation in GI development.

C. Public-Private Partnerships

- Launch "**Adopt-a-Plot**" initiatives for businesses to green courtyards, dead ends, and sidewalks.
- Allow **rooftop leasing** of public buildings for vertical farming or green energy/greenery combo projects.

7.4 Community and Capacity Building

1. **Environmental Education**
   - Workshops in schools, temples, and market areas on low-cost greening and composting.
   - Create awareness materials in Urdu and Hindi tailored to local populations.
2. **Citizen Engagement Programs**
   - "Green Champion" awards for households and businesses maintaining public greenery.
   - Use mobile apps or WhatsApp groups for reporting greening ideas or vacant land.

7.5 Technology and Innovation

- Develop a **GIS-based portal** to map heat zones and greenery coverage, updated annually.
- Use **IoT-based smart irrigation systems** for rooftop gardens and green corridors.
- Integrate **real-time AQI monitors** in high-traffic zones.

7.6 Implementation Roadmap

Phase	Timeline	Key Actions
Phase 1: Pilot	Year 1–2	Start with 3 rooftops, 2 courtyards, and 1 shaded corridor
Phase 2: Expansion	Year 3–5	Introduce bioswales, PPP gardens, and 10 more rooftops
Phase 3: Scaling	Year 5–10	Policy integration, GI audits, smart monitoring systems

7.7 Expected Impacts

- **Temperature reduction** of up to 2–4°C in key hotspots
- **Stormwater absorption** increase via bioswales and permeable zones
- **Community well-being** enhancement through shaded, social green areas
- **Improved air quality** and local biodiversity

REFERENCES

Academic Books & Journals

- Benedict, M. A., & McMahon, E. T. (2006). *Green infrastructure: Linking landscapes and communities*. Island Press.
- Beatley, T. (2011). *Biophilic cities: Integrating nature into urban design and planning*. Island Press.
- Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning*, 97(3), 147–155.
- Kabisch, N., Qureshi, S., & Haase, D. (2015). Human–environment interactions in urban green spaces—A systematic review of contemporary issues and prospects for future research. *Environmental Impact Assessment Review*, 50, 25–34.
- Kleerekoper, L., van Esch, M., & Salcedo, T. B. (2012). How to make a city climate-proof, addressing the urban heat island effect. *Resources, Conservation and Recycling*, 64, 30–38.
- Tzoulas, K., Korpela, K., Venn, S., Yli-Pelkonen, V., Kaźmierczak, A., Niemelä, J., & James, P. (2007). Promoting ecosystem and human health in urban areas using green infrastructure: A literature review. *Landscape and Urban Planning*, 81(3), 167–178.
- Hansen, R., Frantzeskaki, N., McPhearson, T., Rall, E. L., Kabisch, N., Kaczorowska, A., ... & Pauleit, S. (2015). The uptake of the ecosystem services concept in planning discourses of European and American cities. *Ecosystem Services*, 12, 228–246.

Reports and White Papers

- European Environment Agency. (2020). *Nature-based solutions in Europe: Policy, knowledge and practice for climate change adaptation and disaster risk reduction*. https://www.eea.europa.eu/
- Centre for Liveable Cities, Singapore. (2020). *A City in Nature: Singapore's green plan*. https://www.clc.gov.sg/
- Dasgupta, S., Laplante, B., Murray, S., & Wheeler, D. (2017). *Mangroves as Protection from Storm Surges in a Changing Climate*. The World Bank.

Case Study Sources

- Singapore Urban Redevelopment Authority. (2021). *Landscaping for Urban Spaces and High-Rises (LUSH) Programme*. https://www.ura.gov.sg/
- American Society of Landscape Architects. (2018). *Green Infrastructure: Planning and Design for Sustainable Cities*. https://www.asla.org/
- City of Toronto. (2020). *Green Roof Bylaw*. https://www.toronto.ca/
- City of New York. (2019). *Cool Neighborhoods NYC*. https://www.nyc.gov/

Thesis Data Sources

- Lucknow Development Authority (2024). *Urban Development Control Regulations and Green Space Guidelines.*
- Central Pollution Control Board. (2024). *Air Quality Reports: Uttar Pradesh.* https://cpcb.nic.in/
- ISRO Bhuvan Portal. (2025). *LU/LC and NDVI Mapping Tools*. https://bhuvan.nrsc.gov.in/
- United Nations Environment Programme. (2019). *Green Infrastructure Handbook.* https://www.unep.org/

Reports and White Papers

- European Environment Agency. (2020). *Nature-based solutions in Europe*. https://www.eea.europa.eu/
- Centre for Liveable Cities. (2020). *A City in Nature: Singapore's green plan*. https://www.clc.gov.sg/
- Dasgupta, S., et al. (2017). *Mangroves as Protection from Storm Surges*. The World Bank.

- Kleerekoper, L., van Esch, M., & Salcedo, T. B. (2012). Climate-proofing cities. *Resources, Conservation and Recycling*, *64*, 30–38.
- Tzoulas, K., et al. (2007). Urban green infrastructure: A literature review. *Landscape and Urban Planning*, *81*(3), 167–178.
- Hansen, R., et al. (2015). Ecosystem services in urban planning. *Ecosystem Services*, *12*, 228–246.

Thesis Data Sources

- Lucknow Development Authority. (2024). *Development Control Regulations*.
- CPCB. (2024). *Air Quality Reports: UP*. https://cpcb.nic.in/
- ISRO Bhuvan Portal. (2025). *LU/LC and NDVI Tools*. https://bhuvan.nrsc.gov.in/
- UNEP. (2019). *Green Infrastructure Handbook.* https://www.unep.org/