

# The Integration of Green Roofs into Urban Sustainability: The Insights for Implementation in Pakistan

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***Abstract-*** Urban areas face escalating challenges such as climate change, resource depletion, and environmental degradation. This study explores green roof technology as a crucial component of green infrastructure to address these issues. With a focus on Pakistan, the research investigates green roofs' environmental, social, and economic benefits and evaluates their role in sustainable urban development. Case studies and literature review provide actionable insights for integrating green roofs into policy and planning frameworks. This article highlights the potential of green roofs to mitigate urban heat, manage stormwater, and enhance biodiversity while addressing challenges in implementation.

***Indexed Terms-*** Urban Resilience, Sustainability, Ecosystem Services, Green Roof, Green Infrastructure, and Pakistan Urban Planning

## I. INTRODUCTION

### 1.1 Background and Problem Statement

As urbanization accelerates, cities face significant environmental challenges, including reduced green spaces, increased impermeable surfaces, and heightened vulnerability to climatic events. Buildings contribute approximately 40% of global energy consumption and 33% of greenhouse gas emissions. Urban sprawl has led to deforestation, increased pollution, and loss of biodiversity, compounding these challenges. Recent climate events, such as record-breaking heatwaves in Europe, floods in South Asia, and wildfires in Australia, underscore the urgent need for innovative urban solutions.

In the context of Pakistan, urban centers like Karachi, Lahore, and Islamabad are particularly vulnerable due

to rapid population growth, unregulated urban expansion, and inadequate infrastructure. Heatwaves in Karachi have resulted in significant loss of life, while urban flooding disrupts essential services and damages property annually. These issues are exacerbated by a lack of green spaces, with per capita green space in major cities falling well below the World Health Organization's recommendation of 9 square meters per person.

Green infrastructure, particularly green roofs, emerges as a vital approach to address these challenges. Green roofs enhance urban sustainability by leveraging unused rooftop spaces for ecosystem services, including energy efficiency, carbon sequestration, and biodiversity enhancement. In cities where horizontal space is limited, rooftops represent an untapped resource with immense potential for transformation. The integration of green roofs into urban planning offers a multifaceted solution to environmental degradation while simultaneously improving urban aesthetics and quality of life.

The United Nations' Sustainable Development Goals (SDGs), especially SDG 11 (Sustainable Cities and Communities), emphasize the importance of sustainable urban development. Incorporating green roofs aligns with these goals by fostering resilient, inclusive, and environmentally friendly cities. Moreover, as cities expand, the need for innovative architectural and urban planning approaches grows exponentially, positioning green roofs as an essential component of future urban design.

### 1.2 Aim and Scope

This study focuses on green roof implementation in Pakistan, examining its feasibility, benefits, and alignment with global best practices. The scope

includes:

- **Environmental Benefits:** Urban heat island mitigation, storm water management, and air purification.
- **Social Benefits:** Improved urban aesthetics, health outcomes, and recreational spaces.
- **Economic Benefits:** Energy savings, increased property values, and job creation.

Additionally, the research explores the technical and financial challenges of green roof adoption, such as structural retrofitting requirements and initial investment costs. By addressing these aspects, this study aims to provide insights into advancing sustainable urban development in Pakistan through the widespread adoption of green roofs. This research also highlights the adaptability of green roofs to Pakistan’s specific climatic and socio-economic conditions, making it a pivotal strategy for urban resilience.

## II. LITERATURE REVIEW

### 2.1 Green Infrastructure: Principles and Applications

Green infrastructure emphasizes connectivity and multi-functionality, enabling cities to integrate natural systems into urban planning. It includes features like green roofs, urban forests, and rain gardens, which collectively address challenges like climate change and biodiversity loss. By bridging ecological, social, and economic objectives, green infrastructure offers a transformative framework for sustainable urban development. A multi- scale approach, ranging from individual buildings to entire city regions, ensures that green infrastructure delivers benefits at all levels.

### 2.2 The Concept of Green Roofs

Green roofs have evolved from being simple aesthetic features to becoming pivotal components of sustainable urban development. Historically, their origins trace back to ancient civilizations, including the famous Hanging Gardens of Babylon, which served both functional and ornamental purposes. Today, green roofs represent an innovative response to the pressing environmental challenges faced by modern cities.

A green roof, at its core, is a rooftop system that

supports vegetation and plant growth, providing a range of ecological, economic, and aesthetic benefits. Modern green roofs are categorized into two primary types, based on their structure and purpose:

#### 1. Intensive Green Roofs:

- These roofs feature a deep soil layer (usually more than 20 cm), allowing for the growth of diverse and often heavy vegetation, such as shrubs, small trees, and even gardens.
- They are designed to support recreational activities and are comparable to ground- level parks.
- Intensive green roofs require substantial structural support, regular maintenance, and sophisticated irrigation systems.
- Example: The Namba Parks Mall Roof Garden in Osaka, Japan, exemplifies an intensive green roof. Spanning over eight levels, the roof garden incorporates walking paths, waterfalls, and lush greenery, providing an urban oasis in the heart of the city. This project demonstrates how green roofs can serve both ecological and social purposes in dense urban areas



FIGURE 1: NAMBA PARKS The Hanging Gardens in the Shopping Mall

#### 2. Extensive Green Roofs:

- These are lightweight systems with shallow soil layers (6–20 cm), intended for low- maintenance vegetation such as mosses, sedums, and grasses.
- They prioritize energy efficiency, stormwater management, and cost-effectiveness, rather than recreational use.
- Extensive roofs are ideal for retrofitting existing structures due to their lower weight and minimal maintenance requirements.
- Example: The Ford Motor Company’s Rouge Factory Roof in Michigan, USA, is one of the largest extensive green roofs in the world, covering 42,000 square meters. This roof reduces

stormwater runoff by 50% and provides insulation, significantly lowering energy costs for the facility.



Figure 2: Ford Plant Green Roof

Comparison Table: Types of Green Roofs

Feature	Intensive	Extensive	Semi-Intensive
Soil Depth	>20 cm	6–20 cm	12–25 cm
Vegetation Type	Diverse (trees, shrubs, lawns)	Low-maintenance (grasses, mosses, sedums)	Moderate (herbs, grasses, small shrubs)
Structural Support	High	Low	Moderate
Maintenance	Regular and intensive	Minimal	Moderate
Watering Requirements	High (requires irrigation)	Low	Moderate
Cost	High (installation and upkeep)	Low	Moderate
Primary Use	Recreation, aesthetics	Energy efficiency, stormwater management	Balanced approach (biodiversity, aesthetics, efficiency)
Examples	Namba Parks Mall (Japan)	Ford Rouge Factory Roof (USA)	Mixed-use rooftops in Europe

Table 1: comparison of Green roof

**Benefits of Green Roofs:**

Research indicates that green roofs significantly contribute to urban sustainability by addressing multiple challenges simultaneously:

- **Environmental Benefits:**

Green roofs reduce the urban heat island effect by cooling ambient air temperatures and insulating buildings. They also improve air quality by trapping

particulate matter and absorbing carbon dioxide. Furthermore, green roofs aid in stormwater management, reducing runoff and filtering pollutants.

- **Social Benefits:**

These systems enhance urban aesthetics and provide spaces for recreation, contributing to improved mental well-being. Green roofs also play a vital role in increasing urban biodiversity by creating habitats for birds, insects, and other wildlife.

- **Economic Benefits:**

Energy savings from reduced heating and cooling demands are among the most notable advantages. Additionally, green roofs increase property values and extend the lifespan of roofing materials by protecting them from harsh weather conditions.

**Modern Examples of Green Roofs:**

Green roofs have been adopted worldwide, with notable implementations such as the Chicago City Hall Roof Garden, which features over 20,000 plants and reduces the building's cooling needs. Similarly, Singapore’s Parkroyal on Pickering Hotel integrates green roofs as part of its "hotel in a garden" concept, blending luxury with sustainability. In arid regions like Dubai, innovative green roof systems use drought-resistant plants and advanced irrigation techniques to achieve sustainability goals.

In Pakistan, however, the concept remains underdeveloped. Challenges such as limited awareness, lack of policy support, and structural constraints have hindered the adoption of green roofs. Nonetheless, the increasing urban challenges, such as heatwaves and flooding, necessitate the integration of green roof technologies into urban planning frameworks.

**Future Directions:**

Green roofs are continuously evolving with new materials, technologies, and designs. Research into lightweight substrates, improved water retention systems, and native vegetation is paving the way for more efficient and cost-effective solutions. By addressing technical and financial barriers, green roofs can be mainstreamed as a key component of sustainable cities globally, including in developing regions like Pakistan.

2.3 Global Practices and Benefits

Examples from Developed Countries

Globally, green roofs have demonstrated their effectiveness in mitigating urban environmental challenges. In Singapore, the "City in a Garden" initiative mandates green roofs for new developments, showcasing their potential to combat urban heat islands while improving energy efficiency. Buildings such as the Parkroyal on Pickering Hotel integrate lush rooftop gardens and vertical greenery, significantly reducing cooling costs while enhancing urban biodiversity. Similarly, in New York City, the Javits Convention Center features an extensive green roof that spans over 6.75 acres, reducing indoor cooling costs by 25% and supporting a thriving habitat for birds and pollinators. In Malmö, Sweden, the Augustenborg neighborhood employs green roofs across residential and commercial buildings, reducing stormwater runoff by 20% and demonstrating their value in urban flood prevention.

Turkey's Experience with Green Roofs

Turkey has also embraced green roof technology to address urbanization challenges. For example, the Zorlu Center in Istanbul features an intensive green roof system with walking paths, native vegetation, and recreational spaces spread over 72,000 square meters. This green roof not only mitigates the urban heat island effect but also provides a cooling effect for adjacent structures. In İzmir, the Municipality Building uses an extensive green roof system to enhance building insulation, reducing heating and cooling energy requirements by 15–20%. Additionally, Ankara's urban planning authorities have initiated green roof programs, encouraging semi-intensive systems in residential complexes to strike a balance between ecological benefits and economic feasibility.

Methodology Table 2: Green Roofs Research

Study Title	Study Objectives	Methodology	Study Outcomes	Significance
Green Roofs for Urban Sustainability in Pakistan	To analyze the feasibility and benefits of green roofs in mitigating urban environmental challenges.	Literature review and field observations	Identified key environmental, social, and economic benefits; highlighted barriers to adoption.	Provides foundational insights for green infrastructure in urban planning.
Global Practices in Green Roof Integration	To evaluate global practices and their relevance for Pakistan's urban planning.	Case study analysis	Presented successful examples from cities like Singapore, New York, and Malmö;	Highlights transferable strategies from developed countries to emerging economies.
			provided transferable strategies.	
Barriers to Green Roof Adoption	To assess technical, financial, and policy challenges in Pakistan.	Questionnaire surveys	Revealed economic constraints, lack of awareness, and policy gaps as major obstacles to	Addresses critical barriers to adoption and offers pathways for mitigation.

			green roof implementation.	
Potential Applications of Green Roofs in Pakistan	To identify practical applications of green roofs in urban areas.	Mixed-methods approach	Proposed strategies for integrating green roofs into residential and commercial developments; recommended incentives.	Emphasizes the potential for scalable solutions in dense urban areas.
Climate Resilience and Green Roofs	To explore the role of green roofs in enhancing urban resilience against extreme weather conditions.	Simulation studies and comparative analysis	Demonstrated the effectiveness of green roofs in mitigating heatwaves and managing stormwater.	Establishes green roofs as a critical component of climate adaptation strategies.

Table 2: Methodology of Green roof

IV. DISCUSSION

Green roofs play a pivotal role within the broader framework of green infrastructure, addressing multifaceted urban challenges such as climate adaptation, ecosystem restoration, and resource efficiency. Their integration into urban design strategies globally has demonstrated significant ecological, economic, and social benefits, which can serve as a guiding model for countries like Pakistan.

4.1 Global Perspectives on Green Roof Benefits

• Ecological Impact

Green roofs have emerged as a cornerstone of ecological restoration in urban areas. In New York City, public and commercial buildings with green roofs have reduced ambient temperatures by up to 2°C, significantly mitigating the urban heat island effect. Cities like Malmö, Sweden, have adopted green roof systems to manage stormwater runoff, with studies showing retention rates between 50% and 90%, which helps prevent flooding in regions prone to heavy rainfall. These roofs also reduce noise pollution by absorbing sound waves, an often-overlooked advantage in congested urban environments.

Moreover, green roofs contribute to biodiversity conservation by creating habitats for flora and fauna. Singapore’s "City in a Garden" initiative integrates green roofs and vertical gardens, resulting in urban ecological networks that attract pollinators, birds, and insects. Similarly, Berlin, Germany, has incorporated green roofs into its "Urban Biodiversity Strategy," enhancing habitats for rare species in dense metropolitan areas.

• Economic and Energy Benefits

Green roofs significantly reduce building energy demands by enhancing insulation. For instance, Ford’s Rouge Factory in Michigan saved 7% annually on cooling costs, thanks to its extensive green roof, which also reduced the building’s carbon footprint. Furthermore, green roofs prolong the lifespan of roofing materials by protecting them from UV radiation and temperature extremes, leading to reduced maintenance costs over time. Cities like Vienna, Austria, have implemented subsidy programs to encourage green roof installations, recognizing their potential for reducing urban energy consumption.

• Social Advantages

Socially, green roofs enhance urban quality of life by providing accessible recreational spaces and improving mental health. The Namba Parks Mall in

Osaka, Japan, features intensive green roofs with walking paths and seating areas, fostering community engagement and offering a natural retreat within a bustling city. Moreover, studies in London, UK, indicate that workers with access to green roofs report higher job satisfaction and lower stress levels.

#### 4.2 Implications for Pakistan

While green roofs have gained traction globally, their adoption in Pakistan remains limited. However, the country stands to benefit significantly from their integration into urban planning.

1. **Climate Resilience** Pakistan faces acute challenges from climate change, including heatwaves, flooding, and air pollution. Green roofs can mitigate these impacts by cooling urban areas, reducing peak energy demand, and managing stormwater. For example, implementing green roofs in Karachi could alleviate the effects of heatwaves and improve air quality by filtering industrial emissions.
2. **Urban Aesthetics and Social Well-being** The lack of accessible green spaces in urban centers like Lahore and Islamabad has contributed to declining mental well-being among residents. Green roofs can transform rooftops into vibrant recreational spaces, fostering community interaction and providing relief from urban congestion. Integrating green roofs in schools, hospitals, and office buildings can also enhance productivity and mental health.
3. **Economic Feasibility** Energy efficiency is a critical concern in Pakistan due to frequent power outages and rising electricity costs. Green roofs can reduce energy consumption for cooling and heating by up to 30%, providing long-term economic benefits. Moreover, they increase property values and extend roof lifespans, making them an attractive investment for both residential and commercial sectors.
4. **Integration with Urban Infrastructure** As part of a broader green infrastructure strategy, green roofs can complement urban forests, rain gardens, and permeable pavements. For instance, connecting green roofs with Islamabad's existing green belts could create an integrated ecological network, enhancing biodiversity and resilience against climate change.

#### 4.3 Overcoming Barriers in Pakistan

Despite their potential, the adoption of green roofs in Pakistan is hindered by high installation costs, lack of technical expertise, and limited public awareness. These barriers can be addressed through:

- **Policy Incentives:** Tax rebates, subsidies, and grants for green roof installations.
- **Capacity Building:** Training programs for architects, urban planners, and engineers.
- **Public Awareness Campaigns:** Highlighting the environmental, economic, and social benefits of green roofs through media and community initiatives.

### V. RECOMMENDATION

To promote the adoption of green roofs as a critical component of sustainable urban development, several strategic measures are essential. First, governments should introduce mandatory green roof policies for new urban developments, complemented by financial incentives such as tax rebates, subsidies, and low-interest loans for retrofitting projects.

Capacity-building initiatives, including specialized training programs and certifications for architects, planners, and contractors, are vital to ensure technical expertise. Public awareness campaigns that highlight the environmental, economic, and social benefits of green roofs through media outreach and community engagement can drive grassroots support. Pilot projects on public buildings, such as schools and hospitals, can serve as demonstration models, showcasing the feasibility and advantages of green roofs. Investment in research and development should focus on locally adapted materials, lightweight substrates, and drought-resistant vegetation, ensuring cost-effective and climate-appropriate solutions. Integrating green roofs into urban planning frameworks, in collaboration with city planners, can create synergies with other green infrastructure elements, such as rain gardens and urban forests.

Finally, fostering international collaborations to learn from global best practices and implementing monitoring systems using advanced technologies can ensure the long-term success and optimization of green roof projects. Together, these measures can

unlock the full potential of green roofs in mitigating urban challenges and enhancing resilience in Pakistan and beyond.

### CONCLUSION

Green roofs represent a transformative approach to tackling the pressing environmental, social, and economic challenges posed by rapid urbanization and climate change. As a cornerstone of green infrastructure, they offer multi-faceted benefits, including reducing urban heat islands, enhancing biodiversity, managing stormwater, and providing insulation to buildings, leading to significant energy savings. The global adoption of green roofs in cities such as Singapore, Malmö, and New York demonstrates their potential to create more resilient, sustainable, and livable urban environments. These case studies highlight that green roofs are not merely aesthetic additions but essential tools in mitigating climate impacts, fostering urban biodiversity, and contributing to sustainable development goals. The integration of green roofs with other green infrastructure elements, such as urban forests and rain gardens, further underscores their importance in holistic urban planning strategies.

In the context of Pakistan, green roofs hold immense potential to address critical urban issues, including heatwaves, flooding, air pollution, and the lack of accessible green spaces. However, widespread adoption will require overcoming significant barriers, such as high installation costs, limited technical expertise, and policy gaps. By implementing targeted policies, fostering capacity-building initiatives, and raising public awareness, Pakistan can unlock the full potential of green roofs. Moreover, research into cost-effective and locally adapted solutions, combined with international collaborations and demonstration projects, can pave the way for their scalability. If prioritized, green roofs could become an integral part of Pakistan's urban planning framework, helping to create climate-resilient cities while improving the quality of life for their residents.

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