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Strategies To Mitigate Urban Heat Island In Pune Through Comparative Analysis: Case Studies Of Singapore And Copenhagen

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Abstract
Urban areas face a growing challenge in the form of Urban Heat Islands (UHIs), a prominent consequence of climate change exacerbated by urbanization. Pune, a rapidly developing city in India, is no exception to this issue. UHIs contribute to elevated temperatures, air pollution, and increased energy consumption, which collectively impact the environment and human well-being. To address these challenges, this study reviews and assesses various Urban Heat Island (UHI) mitigation strategies, including green infrastructure, and their effectiveness in cooling the urban environment of Pune.
The mitigation strategies include green infrastructure which plays a pivotal role in this research.By examining the current state of Pune's urban infrastructure and environmental conditions, this research identifies the most promising mitigation approaches that could significantly lowerurban temperatures and mitigate the UHI effect, with a particular focus on the integration of green infrastructure. It also provides a set of recommendations that can guide local policymakers and government authorities in implementing effective UHI mitigation policies inPune, ultimately contributing to a more sustainable and climate- resilient urban future.
Keywords: *Urban Heat Island, Pune, Green Infrastructure, Singapore, Copenhagen,Temperature*

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I. Introduction

The urbanization of our planet is a relentless force reshaping landscapes, lives, and the global environment. Urban areas have become the epicentres of human civilization, engines of economic growth, and hubs of innovation. According to the United Nations, 68% of the world's population will live in cities by the year 2050, up from more than half in 2021. While cities offer unparalleled opportunities for progress, they also pose unprecedented challenges, the most daunting of which is climate change. Climate change is unequivocally one of the most pressing issues of our time. Its effects are discernible and omnipresent, from the melting glaciers in the Arctic to the intensification of hurricanes and prolonged droughts. At the heart of this global crisis lies the undeniable fact that cities are both major contributors to climate change and the first to bear its brunt. Urban areas, though occupying a mere 2% of the world's land, are responsible for a staggering 75% of global greenhouse gas emissions, as reported by the World Bank. In parallel, cities are experiencing more frequent and severe heatwaves, floods, and air quality issues that put their inhabitants at risk.

Among the myriad challenges associated with climate change, urban heat islands and deteriorating air quality are becoming increasingly prominent. Urban heat islands (UHIs) are regions within a city that exhibit significantly higher temperatures than their rural surroundings. These localized hotspots are primarily the result of urban infrastructure such as buildings, roads, and pavements absorbing and re-radiating heat. Inhabitants of cities like Pune, India, understand the discomfort and health hazards that extreme heat can cause. Urban air quality, or rather the lack thereof, is another salient issue. The World Health Organization estimates that 90% of the global population lives in areas with poor air quality. Urban pollution poses severe health risks, leading to respiratory diseases, cardiovascular problems, and premature deaths. Pune, a thriving metropolis with a rich history, has not remained immune to these challenges. The city's growth and urbanization have led to increased air pollution levels and the formationof urban heat islands.

Pune's burgeoning population, driven by a surge in educational institutions, the presence of global IT companies, and a vibrant cultural scene, has transformed it into a bustling city. However, this urban transformation comes at a cost, as the city's green cover has been sacrificed for concrete structures and roadways. This rampant urbanization and environmental degradation have resulted in heat pockets within the city, soaring temperatures, and air quality concerns. In light of these challenges, it is evident that Pune stands at a crossroads. As it continues to urbanize and grow, decisions made today regarding urban development and

environmental management will significantly influence the city's future. These decisions will not only shape Pune's environmental resilience but also have far-reaching consequences for the well-being of its residents, the sustainability of its economy, and its ability to tackle the profound challenge of climate change.

To address the intertwined issues of urban heat islands and deteriorating air quality in Pune, and indeed in cities worldwide, innovative and sustainable solutions are required. Our research endeavours to investigate the potential of green infrastructure and urban forestry as effective strategies to mitigate urban heat islands, enhance air quality, and foster climate resilience in Pune. This research acknowledges that green infrastructure and urban forestry are integral components of sustainable urban planning and environmental management, offering multifaceted benefits for cities and their inhabitants.

Significance of Research

The significance of our research extends beyond Pune. As urbanization accelerates worldwideand cities grapple with the twin challenges of climate change and environmental sustainability,our study can offer valuable insights and practical recommendations. By demonstrating the potential of green infrastructure and urban forestry to address urban heat islands and air qualityconcerns, our research contributes to the broader discourse on sustainable urban development. Pune serves as a microcosm of the global urban experience, exemplifying both the challengesand opportunities faced by cities in an era of rapid urbanization. The lessons learned from Punecan guide other cities as they confront similar environmental challenges, and the policy recommendations generated from our research can inform and inspire urban planners and policymakers across the world. The urgency of addressing climate change and its localized impacts in cities is unequivocal. As we embark on this research journey to explore the potentialof green infrastructure and urban forestry in Pune, we are cognizant of our role in contributingto a more sustainable and resilient urban future. In the following sections, we will delve into the research methodology, the planned timetable, and the expected outcomes of this study, aiming to provide a comprehensive framework for our research endeavor.

II. Literature Review

Climate change is a pervasive global phenomenon with far-reaching and interconnected effects that are reflected in all sectors of society. One of the most striking features of climate change is its ability to trigger a domino effect, where the consequences of a single environmental change can have profound and often unexpected effects on multiple dimensions of our world. For example, the increase and intensity of drought not only threatens food production due to depletion of water resources, but also endangers human health by contributing to water scarcity and crop failure. Floods of various magnitudes occur in many land (especially low-lying) areas, causing enormous annual damage and disruption to economic livelihoods, businesses, infrastructure, services, and public health. Historical data spanning a century underscores that floods and storms, frequently associated with inundation events, have consistently ranked as the predominant sources of natural disasters on a global scale. Also, the reverse of the coin, flooding, not only damages ecosystems and infrastructure, but can also promote the spread of disease and threaten public health (Few, Ahern, Matthies, & Kovats, 2004)

The consequences of climate change also extend to human well-being. Health problems exacerbated by climate change can lead to higher mortality, reduce food availability due to crop losses, and hinder worker productivity. It's a cascading effect that touches almost every aspect of our lives. Increasing crop production to meet the increasing demands of population growth in the face of climate change threats is a difficult task (Gupta, Sonkar, & Mall, 2017) However, it is important to note that climate change does not affect everyone in the same way. It has a disproportionate impact on underserved and vulnerable communities, exacerbating existing socioeconomic inequalities. Because most of the the developing nations' economies are in temperature-volatile sectors and their ability to adapt is constrained by a lack of labor, monetary, and natural resources as well as infrastructure and technological competence, there are some "less developed" nations that are particularly vulnerable (Ravindranath & Sathaye, 2002).

In the Indian context, climate change significantly impacts Earth's natural resources. India has observed heightened seasonal temperature variations, with winters growing warmer than summers. The country has also experienced longer heat waves with rising nighttime and daytime temperatures, a trend set to continue. Projections indicate an anticipated temperature change of 2.33-4.78°C with a doubling of CO2 concentrations, which influences the variability of India's summer monsoon rains, significantly affecting the agricultural sector. (Kumar & Gautam, 2014).

India is particularly vulnerable to change in climatic conditions due to its economy's heavy reliance on climate-volatile sectors like agriculture and forestry, coupled with its densely populated, low-lying coastline vulnerable to potential sea-level rise. Coal remains the primary fossil fuel for electricity generation in the country, contributing over 60% to the increased greenhouse effect. India's existing climate and energy policies have demonstrated a degree of limited attention toward the environmental implications associated with the

processes of power generation, conversion, distribution, and consumption. Given the continued importance of coal in India's energy landscape, C02 emissions will persist as long as these fossil fuels are employed (Raghuvanshi, Chandra, & Raghav, March 2006).

Additionally, water resources in the Indian subcontinent are under growing pressure due to climate change. Climate impacts both the demand and supply of water, as well as its quality, particularly affecting arid and semi-arid regions. This intensifies competition for water across economic, social, and environmental domains. In the future, a rising population will escalate the demand for water resources, particularly for irrigation, potentially jeopardizing drinking water availability due to concurrent industrialization efforts. Disputes over water resources in a degraded environment marked by pollution and climate change can have significant social consequences. After 2025 AD, climate change may also worsen conditions because the amount of precipitation in the staple food is decreasing. The production areas and the evaporation rates will increase. If we want in the next 30 years, to prevent the nationwide water crisis that threatens at the end of the 21st century, quick and decisive action must be taken (Mall, Bhatla, & Pandey, 2007). Disputes over water resources can have significant social consequences in a degraded environment due to pollution and climate change. The second session of the United Nations Commission on Sustainable Development, New York, 1994, stated: "As the impending crisis draws nearer and the availability of water resources diminishes, the potential for heightened conflict is poised to escalate. After 2025, climate change may also worsen conditions because the amount of precipitation in the staple food is decreasing. The production areas and the evaporation rates will increase. If we want in the next 30 years, to prevent the nationwide water crisis that threatens at the end of the 21st century, quick and decisive action must be taken (Mall, Bhatla, & Pandey, 2007).

Urban areas play a pivotal role in the global landscape of carbon emissions, contributing significantly to the challenges of climate change. It is widely acknowledged that cities account for over 70% of global CO2 emissions, with a substantial proportion stemming from industrial activities and motorized transportation systems. The carbon-intensive infrastructure, reliant on fossil fuels and carbon-intensive materials, is emblematic of the urban environment. A concerted effort toward massive decarbonization of cities is imperative to mitigate the negative impacts of climate change and adhere to the imperative of limiting global warming to below the 1.5°C threshold (Sun, Zhang, Ma, Wu, & Wang, 2022).

Notably, older cities often bear the burden of inherited carbon-intensive infrastructure. Retrofitting and modernizing these structures are essential steps toward reducing their carbon footprint. The financial constraints of such efforts can be particularly challenging for cities with limited resources. In contrast, more populous cities, despite their higher emissions, may benefit from economies of scale in implementing emission-reduction measures (Chen, et al., 2022).

The economic profile of a city plays a crucial role in its carbon emissions. Higher-income cities tend to have fewer emissions-intensive heavy industries and stricter pollution regulations, resulting in comparatively lower carbon emissions. Nonetheless, they face unique challenges, including higher land costs and the need for targeted policies to reduce emissions associated with energy consumption for heating and cooling, especially in extreme climates (Xiaomin & Chuanglin, 2023).

Urbanization has a complex impact on carbon emissions. It can accelerate carbon emissions by stimulating economic growth and increasing the proportion of residential energy consumption. However, it can also mitigate carbon emissions by enhancing energy efficiency and reducing the proportion of energy consumption in industrial sectors. Notably, these effects tend to diminish as the rate of urbanization increases, ultimately leading to the prevalence of what is known as the "agglomeration effect" over the "consumption effect" in the long-term trajectory of urbanization. Furthermore, the rapid pace of urbanization introduces a significant "scale effect" that contributes to a temporary decoupling of carbon emissions from the urbanization process. Consequently, in the context of developing countries, it becomes imperative to actively promote urbanization while harnessing the benefits of the agglomeration effect. This can be achieved through measures aimed at improving energy efficiency, optimizing the structure of final energy consumption, and reducing carbon intensity (Wang, Liu, Liao, & Wei, 2021).

Green spaces and urban forestry refer to the intentional integration of natural elements within urban areas. These include parks, gardens, street trees, green roofs, and more. Green spaces offer numerous benefits to urban environments, such as enhancing aesthetics, providing recreational opportunities, and promoting biodiversity. However, their impact on mitigating heat islands and enhancing air quality is the central focus of this review.

Urban heat islands, denoted as UHIs, denote localized urban areas within cities characterized by elevated temperatures in comparison to their adjacent rural environment. This review emphasizes the significant impact of urban heat islands on climate, biology, and economics while underscoring the importance of research in unraveling their causes and developing sustainable adaptation strategies. It highlights the need for improved communication of scientific knowledge to urban planners and the faster implementation of technologies like greenroofs to address this pressing issue (Yow, 2007).

Climate change has led to the emergence of Urban Heat Islands (UHIs) in urban areas, characterized by increased temperatures due to heat-absorbing surfaces, leading to elevated energy consumption and greenhouse gas emissions (Yang, Qian, Song, & Zheng, 2016). The study analyzes various UHI mitigation strategies, emphasizing the effectiveness of multiple measures in cooling urban environments, and provides recommendations for Indian policymakers to address the UHI effect at the government level (Khare, Vajpai, & Gupta, 2021). Urban areas often face air quality issues due to high levels of pollution, which can have detrimental effects on the health of city residents. Green spaces and urban forestry can play a crucial role in enhancing the quality of air by removing particulate matter from the atmosphere (Zupancic, Westmacott, & Bulthuis, 2015). This illustrates how urban greenery, particularly urban forests, can act as sinks for pollutants like particulate matter (PM) and gaseous contaminants. Trees and plants capture and retain these pollutants through a range of mechanisms, improving overall air quality in urban regions. Urban vegetation, including green spaces and urban forests, has a significant impact on urban climate. By evaluating multiple scenarios in various cities correlations between increased green infrastructure and reduced ambient temperatures is established (Santamouris & Osmond, 2020). The expansion of green infrastructure leads to decreased peak daily and nighttime temperatures. This reduction in temperature can be crucial in mitigating heat-related mortality and complex relationshipbetween increased greenery and urban pollutant concentrations can be highlighted.

Another critical aspect of urban green infrastructure's impact on air quality is its ability to remove particulate matter. Trees and vegetation have been shown to accumulate PM through sedimentation, interception, and impaction. The efficiency of PM removal varies with tree species, leaf characteristics, and environmental conditions (Henderson, 2013).

Understanding the intricate relationship between urban greenery and PM removal is crucial for addressing air quality concerns. By enhancing green infrastructure, cities can reduce airborne particle concentrations, resulting in improved air quality for residents.

The economics of urban green infrastructure emphasizes that green spaces are not just environmental assets but also economic drivers. In the context of heat island reduction and improved air quality, the paper underscores the economic value of public urban green spaces.

The study of Bishan-Ang Mo Kio (AMK) Park in Singapore reveals that green infrastructure provides substantial economic benefits. Enhanced urban greenery contributes to improved human well-being, attracting tourists, consumers, and investments. These economic advantages underscore the potential of green infrastructure to tackle urban environmental challenges (Lim& Xenarios, 2021).

Employing the hedonic price method to assess the economic value of urban green spaces in Kuala Lumpur is one of the aspects seen here. Analysis of house prices demonstrates how proximity to green spaces affects property values. The results reveal the significant economic value associated with specific green spaces in the city (Samad, Abdul-Rahim, Yusof, & Tanaka, 2020). The economic benefits of reduced distances to parks and increased park sizes, emphasizing the link between green spaces and property values. This economic perspective offers insight into the tangible financial benefits that green infrastructure can bring to cities.

The increasing body of research dedicated to green infrastructure, predominantly spearheaded by European and American nations, is underscored through a bibliometric analysis of the subject, underscoring its significance in achieving sustainable development. The construction, evaluation, and management of green infrastructure, as well as aspects like climate change, stormwater management, ecosystem services, and biodiversity protection can all be identified by looking at the co-cited literature. Other key themes within the field of green infrastructure research include its relationship with ecosystems and human health. Green infrastructure has become a vital strategy for achieving sustainability and harmonizing human- nature coexistence (Jun Ying & Bilan, 2022).

Table 1: Literature Review Summary Evaluation Table

Sr. No.	Study	Title	Keywords	Research Question / Objective	Findings
1	(Raghuvanshi, Chandra,	Carbon dioxide emissions from coalbased power generation inIndia	Energy, C O2Emissions, Power, Greenhouse gases	discusses Indi a'svulnerability	Around three-quarters(68%) of electricity generation in India depends on coal. The verified coalreserves in India are estimated at 60.6 billion tonsas of 2018, ranking again as number three globally
2	(Mall, Bhatla,& Pandey,2007)	Water resources in India andimpact of climatechange	Water resources availability; climate chang eimpact; projected	highlights the growing pressure on waterresources in the Indiansubcontinent due to climate chan	The Indian region is verysensitive to climate change.Elements/sectors

			climate change	ge,impacting both demand and supply, aswell as water quality.	
3	(Sun, Zhang, Ma, Wu, & Wang, 2022)	The Impacts of Urban Form on Carbon Emissions:	carbon emission, urban for m,sustainability, land use, energy efficiency. Research stages: budding, development, maturity	acknowledges thaturban areas contribute significantly to global CO2 emissions and theimperative	1. Urban form-carbon correlation: literaturegrowth, global and regional focus, early attention in developed countries,emerging concern indeveloping nations. 2. Urban form's carbon impact: Land use, built environment, traffic affect emissions. Compactdevelopment is favoured foremission reduction.
4	(Wang, Liu,Liao, & Wei,2021)	Impacts	Urbanisation, CO2 Emissions,Energy Efficiency, Consumption	discusses how urbanization can both accelerate and mitigate carbon emissions, witha focus on promoting energy efficiency and reducing carb onintensity.	1. Urbanization reduces carbon dioxide emissions, but its effect is weak in OECD countries. 2.Developed economies have broken the link between urbanization and carbonemissions.
5	(Zupancic, Westmacott, & Bulthuis, 2015)	The impact of green space onheat and air	Air qualit y, Green spac e,heat, mitigation	The importance of urban green infrastructure, such as	1. Green areas from walls toforests relieve heat stress and air pollution, especially
		pollution		parks and urban forests, in mitigating urban heat islands andimproving air qualityin cities is a crucial point.	in densely populated areas. 2. Trees, which are crucial for cooling and reducing pollution, require site- specific considerations toprevent increased pollution. 3. Neighbourhood green spaces, if fair, reduce surface 4. The density of greenareas, species diversity and wind dynamics have asignificant impact on the effectiveness of cooling and pollution reduction.
6	(Lim Xenarios, 2021)	Economic assessment	Singapore; environmental; Economics, Biodiversity; Park; Economicvalue	The recognition ofgreen spaces not only as environmental assets but also aseconomic drivers, withexamples such as the Bishan-Ang Mo Kio Park in Singapore,highlights	1. BGI's reconstruction ofthe Bishan – AMK park in Singapore has increasedwater capacity, but there is no economic assessment of its benefits. 2. The economic importanceof urban green spaces in dense cities such as Singapore requires sophisticated valuationmethods to represent future investments.
7	(Samad, Abdul-Rahim, Yusof,& Tanaka, 2020)	Assessing the economic valueof urban greenspaces in KualaLumpur	Kuala Lumpur ,Economic Valuation; Ordinary Least Square Regression; Geographically Weighted Regression; Public Urban Green Space	The analysis of theeconomic v alue associated with specific green spacesin Kuala Lumpur, particularly in terms ofproperty valu es,underscores	This study highlights the economic value of public urban green spaces in KLCity by highlighting their hedonic value in mitigating urban heat island effects andincreasing climate change resilience using spatialanalysis techniques.

Source: Multiple Research Papers mentioned in the References section.

Research Gap

The research gap in this study is the limited understanding and application of effective UHI mitigation

strategies, especially green infrastructure, in the context of rapidly developing cities like Pune. While UHIs are a well-documented issue, there is a lack of comprehensive research that evaluates the most appropriate mitigation strategies for specific urban environments and provides actionable recommendations for local policymakers.

Furthermore, the existing literature often lacks a specific focus on the integration of green infrastructure as a UHI mitigation strategy. Pune, like many other urban areas in India, is undergoing substantial expansion and development, and there is a pressing need for tailored UHI mitigation approaches. Understanding the effectiveness of green infrastructure, along withother strategies, in mitigating UHIs in Pune and similar cities remains an underexplored area of research. This study aims to bridge this gap by conducting a thorough assessment of variousstrategies and highlighting the importance of green infrastructure as a sustainable solution tomitigate the UHI effect.

Research Questions

The Primary objectives of this research are to answer the following questions:

1. What is the current extent and quality of green spaces, parks, and urban forests in Pune,and how effectively do they mitigate urban heat islands and improve air quality?
2. What are the strategies that can be used to mitigate UHIs in Pune by taking inspiration from other cities that have done it according to global standards?
3. Based on the research findings, what specific recommendations can be proposed for urban planners and policymakers in Pune to optimize urban forestry practices, increase green space coverage, and promote sustainable urban development with a focus on reducing carbon emissions and improving environmental quality?

Justification of Research

Pune, as one of India's rapidly growing urban centres, represents a significant and dynamic urban landscape. The city is home to a large population and is witnessing substantial urbanization, which has a profound impact on C02 emissions. Understanding how urban forestry and green spaces can influence carbon emissions in such a sizable urban area is crucial. Despite the growing global interest in urban sustainability and the role of green spaces, there remains a noticeable gap in the existing literature, especially with regards to the specific context of Pune. This research aims to address these gaps by investigating the interaction between urban forestry, green spaces, and carbon emissions in a detailed and nuanced manner.

The outcomes of this research can provide practical guidance to urban planners, policymakers, and environmental organizations. It has the potential to inform the development and implementation of strategies aimed at reducing carbon emissions in urban areas, offering sustainable solutions for mitigating the impacts of climate change. This research will be instrumental in crafting evidence-based policies and practices, enabling Pune and other cities to leverage urban forestry and green spaces as integral tools in their carbon emissions reduction efforts.

III. Methodology

The methodology for our research aims to comprehensively assess the state of urban heat islands (UHIs), with a focus on the role played by green infrastructure and urban forestry in addressing these challenges. To achieve this, we will employ a multifaceted approach that integrates both qualitative and descriptive research methods. The methodology is structured into several key components:

Comparative Analysis:

Compare Pune's green infrastructure and urban forestry efforts with those of other cities known for their sustainable and green urban planning. Examples may include Singapore and European cities with robust green initiatives.

Data Collection:

i. Mapping: Obtain historical temperature data from Pune's meteorological stations, covering at least the past decade. This data will serve as the baseline for assessing UHIsin different parts of the city.
ii. Questionnaire Surveys: Conduct surveys through a questionnaire with residents of Pune to gather qualitative insights on perceived changes in climate, air quality, and green spaces in Pune.

Data Analysis:

Analyse the collected responses through questionnaire and find inference for the same which will further help in providing recommends.

Policy Recommendations

Based on the research findings, propose specific policy recommendations and interventions for Pune's municipal authorities. These should focus on optimizing green infrastructure, expanding urban forestry, and incorporating sustainable practices.

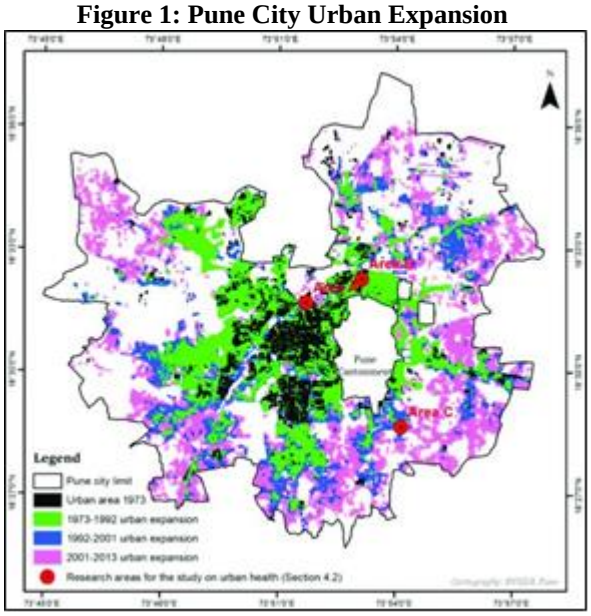
This comprehensive methodology will guide our research on mitigating urban heat islands and improving air quality in Pune through green infrastructure and urban forestry. By integrating data analysis, spatial mapping, surveys, and policy recommendations, we aim to provide a holistic understanding of the challenges and opportunities for Pune and offer actionable strategies for creating a more sustainable and climate-resilient urban environment.

Overview of Pune City

Pune, once known as Poona, has undergone significant growth and transformation over the past three decades, evolving from a city dominated by its universities and military presence to a bustling urban agglomeration (Butsch et al., 2017). This transformation has been fueled by various factors, including regional agricultural ties, national policies promoting industrial diversification, and the city's renowned educational facilities (Butsch et al., 2017).

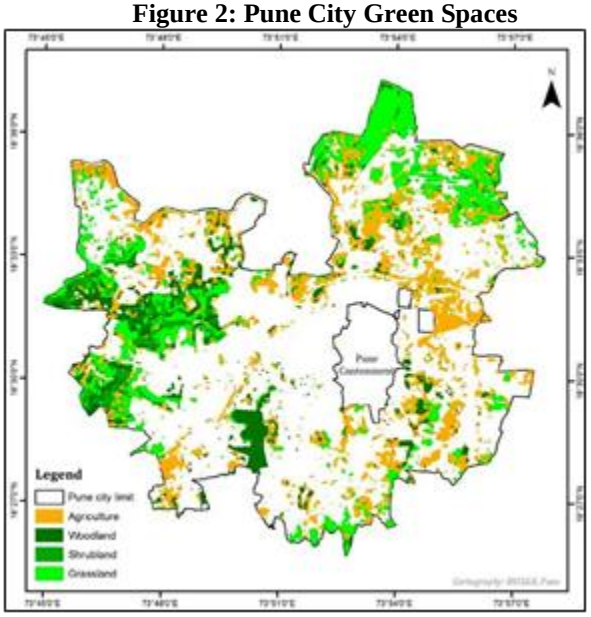
The city's vulnerability to climate change is compounded by its socio-economic dynamics and urbanization patterns (Deosthali, 2000). Social disparities, characterized by uneven wealth distribution and fragmentation along class and caste lines, intersect with climate vulnerabilities, magnifying the impacts on marginalized communities. Informal settlements, which house a significant portion of the population, are particularly susceptible to climate-related hazards due to their inadequate infrastructure and lack of access to basic services (Deosthali, 2000).

Figure 1: Pune City Urban Expansion



Source: (Butsch et al., 2017)

Figure 2: Pune City Green Spaces



Source: (Butsch et al., 2017)

In response to these challenges, efforts have been made to integrate climate resilience into urban planning and development strategies (Parishwad & Shinkar, 2017). Initiatives like the Smart Cities Mission aim to address climate vulnerabilities by promoting sustainable infrastructure and enhancing adaptive capacity. However, there is a need for greater coordination and holistic approaches to effectively tackle the multifaceted impacts of climate change on Pune's urban landscape (Parishwad & Shinkar, 2017). Government of Maharashtra recognised Pune as a vulnerable region for energy and infrastructure but has not recommended any policies regarding green infrastructure for the same (TERI, 2014).

Pune's history of rapid urbanization and economic growth has intersected with the complex challenges posed by climate change, underscoring the importance of integrated and proactive measures to build resilience and sustainability in the face of environmental uncertainties.

Table 2: Green Spaces (per ward) in Pune

Green Spaces in Pune			
Sr. No.	**Wards**	**Total number of gardens (with areaover 1 acre)**	**Area of gardenscovered in acres**
1	Aundh	3	7
2	Bhavanipeth	4	7.5
3	Bibvewadi	1	4
4	Dhole patil	8	20.5
5	Ghole Road	9	33.5
6	Hadapsar	3	12.5
7	Sahakarnagar / Dhankawadi	10	153.5
8	Sangamwadi	6	14.75
9	Tilak Road	3	19.5
10	Vishrambagwada	6	19
11	Warje / Karve	5	11.5
12	Yerwada	8	14
	Total	**66**	**317.25**

Source: (Vijayalakxmi & Mahajan, 2021)

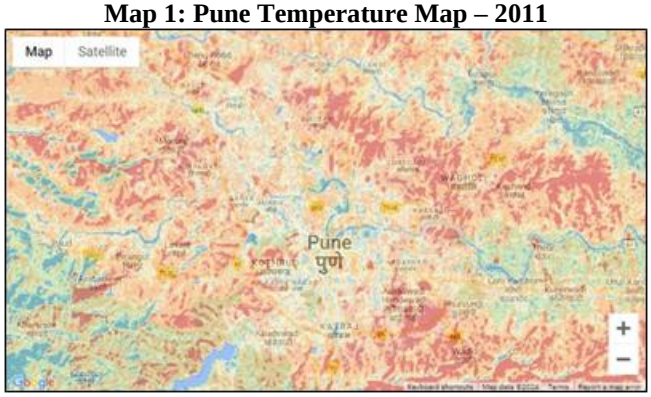
Temperature Map Analysis of Pune City

Land Surface Temperature (LST) refers to the temperature of the Earth's surface as sensed by a satellite looking through the atmosphere. It differs from the air temperature usually presentedin weather forecasts, because it shows the actual temperature of different surfaces such as snow,grass, roofs or vegetation.

LST data is collected by instruments such as the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite, which provides a temperature range of -25 degrees Celsius to 45 degrees Celsius.

LST monitoring is important for understanding the effects of the landscapes of the Earth due to the influence of weather and climate models. Scientists analyse LST to assess the impact of rising greenhouse gases on temperature fluctuations and how rising temperatures affect glaciers, ice sheets, permafrost and vegetation in ecosystems. In addition, commercial growers use LST maps to manage crop water needs during hot summers to avoid heat stress and to identify freeze-prone areas in winter to protect crops such as citrus. In urban areas, LST data isimportant. in measuring the effects of urban heat islands (UHI).

Map 1: Pune Temperature Map – 2011

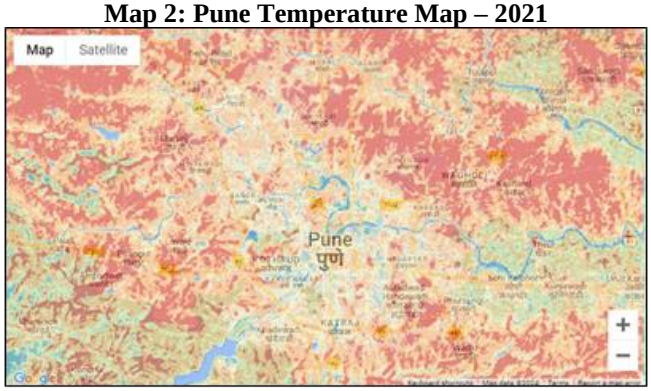


Source: Ross Southern Laboratories

The temperature is significantly higher in the city than the surrounding rural areas. By analyzing LST maps of urban areas, researchers can identify UHIs, assess temperature changes,and develop strategies to mitigate urban heat problems. Understanding LST in urban environments is important for urban planning, climate change resilience, and public health initiatives aimed at combating the adverse effects of heat islands on urban residents. The maps were obtained from RSLabs.com through their LST database. The files were downloaded fromthe website, then imported into QGIS for illustrating the temperature overlay.

As we can see, there has been an expansion in the red areas of the map. This signifies an increase in the UHI presence in Pune. Although not extreme, the expansion of the red areas illustrates the increase in the surface temperature of the city.

Map 2: Pune Temperature Map – 2021



Source: Ross Southern Laboratories

We can observe that the mean temperature for 2016 was 34℃, but in 2021, in a span of only 5 years, has increased to 39℃. This shows basically a 1 degree increase per year, which is not at all sustainable in the long run.

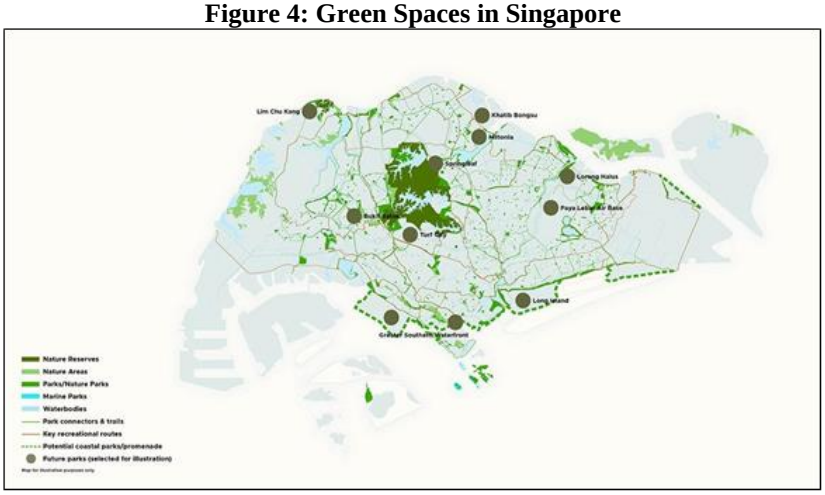
Case Study (I): Singapore

Singapore, a city-state with a tropical climate and high building density, has recognized the urgent need to address the issue of urban heat islands (UHIs) and has implemented various strategies to mitigate their impact. Studies utilizing the Weather Research and Forecasting (WRF) model have played a crucial role in assessing UHI mitigation scenarios in Singapore (Mughal et al., 2020). Through these simulations, the potential effectiveness of cool roofs and green vegetation in reducing UHI intensity has been identified (Li & Norford, 2016). Cool roofs, in particular, have shown promising results, providing a significant reduction in near- surface air temperature during the daytime, especially in large low-rise areas.

The deployment of green infrastructure, such as urban forests and green roofs, has also been a key aspect of Singapore's UHI mitigation strategy (Li & Norford, 2016). These green spaces not only help mitigate UHI effects but also contribute to reducing building energy consumption and enhancing biodiversity. Studies have shown that green vegetation deployment can lead to reductions of over 1 ℃ in near-surface air temperature during nighttime, particularly in intensive industrial regions in western Singapore (Jusuf et al., 2007).

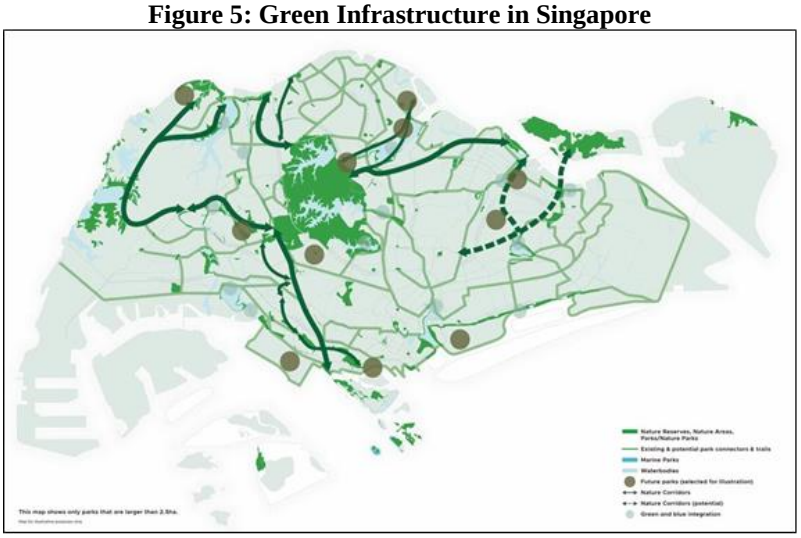
In addition to green infrastructure, Singapore has been proactive in addressing the impact of waste heat released from air-conditioning systems on UHI intensity. Efforts to reduce waste heat discharge from air-conditioning units have been considered as part of the city's overall UHI mitigation strategy (Mughal et al., 2020). Studies have suggested that increasing the thermostat set temperature and implementing water-cooled AC systems could significantly reduce air temperature and UHI intensity.

Figure 4: Green Spaces in Singapore



Source: Urban Redevelopment Authority, Government of Singapore

Figure 5: Green Infrastructure in Singapore



Source: Urban Redevelopment Authority, Government of Singapore

Singapore's comprehensive approach to UHI mitigation, including the deployment of cool roofs, green vegetation, and measures to reduce waste heat from air-conditioning systems, demonstrates its commitment to creating a sustainable and resilient urban environment. These efforts serve as a valuable case study for other cities facing similar challenges in mitigating the impacts of urbanization on local climates. Through a combination of innovative strategies and scientific modelling, Singapore continues to lead the way in urban climate resilience and sustainability.

Learnings and Inference: Case (I)

Singapore's successful mitigation of urban heat islands (UHIs) through green infrastructure offers valuable insights and emphasizes the pivotal role of nature-based solutions in urban climate resilience:

Green Infrastructure as a Sustainable Solution

The adoption of green infrastructure, including urban forests, green roofs, and vegetated areas, underscores Singapore's commitment to sustainable urban development. Unlike traditional grey infrastructure, green solutions harness the power of nature to mitigate UHIs while simultaneously providing a range of co-benefits such as improved air quality, enhancedbiodiversity, and aesthetic value.

Cooling Effect of Vegetation

Studies have demonstrated that green vegetation can significantly reduce near-surface air temperatures, particularly during nighttime when UHI intensity is high. Vegetation, through evapotranspiration and shading, helps to cool urban microclimates and create more comfortableoutdoor environments for residents.

Enhanced Thermal Comfort

By incorporating green spaces into urban areas, Singapore enhances thermal comfort for its residents and mitigates the adverse effects of extreme heat events. These green spaces serve as cool refuges where people can seek relief from high temperatures, promoting outdoor activity and social cohesion.

Biodiversity Conservation

Beyond temperature regulation, green infrastructure contributes to biodiversity conservation and ecosystem resilience in urban environments. Urban forests and green corridors provide habitat for native flora and fauna, supporting biodiversity conservation efforts and enhancing urban ecosystems' capacity to adapt to climate change.

Promotion of Urban Health and Well-being

Green spaces have been linked to numerous health benefits, including stress reduction, mental well-being, and physical activity promotion. By integrating green infrastructure into its urban fabric, Singapore invests in the health and well-being of its residents, fostering a more livable and resilient city.

Long-Term Sustainability

Green infrastructure offers long-term sustainability compared to conventional cooling technologies,

which may require significant energy inputs and maintenance. As Singapore continues to urbanize, prioritizing green infrastructure ensures that the city remains resilient to climate change while minimizing its ecological footprint.

Temperature Regulation and Microclimate Modification

Through the strategic placement of green spaces and vegetation, Singapore effectively regulates microclimates, mitigating the urban heat island effect and reducing local temperatures. Urban forests, in particular, act as natural air conditioners, cooling the surrounding areas through evapotranspiration and providing shade to reduce heat absorption by built surfaces.

Singapore's emphasis on green infrastructure as a key component of its UHI mitigation strategy highlights the importance of nature-based solutions in creating climate-resilient cities. By harnessing the cooling and ecosystem services provided by vegetation, Singapore demonstrates a commitment to sustainable urban development that prioritizes both environmental protection and human well-being. These lessons can serve as inspiration for cities worldwide seeking to address the challenges of urban heat islands and build resilient urban futures.

Comparative Analysis: Singapore and Pune

Selecting Singapore for comparative analysis with Pune in mitigating Urban Heat Islands (UHIs) through green infrastructure is prudent. Both cities face rapid urbanization and share tropical climates, accentuating heat island effects. Their proactive investments in green spaces, exemplified by Singapore's Gardens by the Bay, offer valuable lessons for Pune. Similar socio- economic and demographic challenges further justify this comparison. By distilling insights from Singapore's experiences, Pune can craft effective UHI mitigation strategies suited to its context, fostering sustainable urban development.

Despite its Tier 1 status in India, Pune has an opportunity to harness its untapped potential towards global standards. Pune possesses considerable scope for growth and development, making it conducive for benchmarking against Singapore's exemplary urban infrastructure. Both cities share similarities in population density and area, amplifying the relevance of this comparison. By initiating this comparative study now, Pune can begin cultivating strategies to leverage its potential for sustainable urban development, aligning itself with global standards while addressing pressing challenges such as Urban Heat Islands.

Table 3: Comparative analysis of Singapore and Pune through strategies and objectives.

UHI Mitigation Strategies	Singapore	Pune	Potential Strategies for Pune
Green Spacesand Parks	Singapore has extensivegreen spaces, such as Gardens by the Bay and the Singapore Botanic Gardens, which helpabsorb heat and provide cooling effects.	Pune has some green spaces, but there is potential for increasing green cover to mitigate UHI effects.	Pune can increase the number of parksand green spaces, especially in urban heat island hotspots, to enhance cooling effects and improve urban microclimate.
Green Roofsand Walls	Singapore promotes green roofs and walls in buildings to reduce heat	Pune has limitedimplementation of greenroofs and walls.	Pune can incentivize the adoption of green roofs and walls in building regulations and provide subsidies or
	absorption and enhancethermal comfort.		tax incentives to encourage propertyowners with existing buildings.
Cool Pavement Technology	Singapore utilizes coolpavement technology, such as permeable pavements and light- colored materials, toreduce surfa cetemperatures a	Pune's pavemen tinfrastructure primarilyconsists of traditionalmaterials, but there is anopportunity to explore cool pavemen ttechnologies for new road construction andmaintenance projects.	Pune can pilot cool pavement technologies in selected areas and assess their effectiveness in reducing UHI effects. If successful, these technologies can be scaled up for wider implementation across the city.
Urban Greening Programs	Singapore implementsurban greening programs,such as the Skyrise Greenery Incentiv eScheme, to encourage the adoption of greenery inbuildings and publicspaces.	Pune has limited urban greening initiatives compared to Singapore but can benefit from similar programs to enhance green cover andmitigate UHI effects.	Pune can establish urban greening incentives and partnerships withprivate developers to incorporate greenery into building designs and public infrastructure projects. Additionally, community engagementprograms can be implemented to involve residents in tree planting and maintenance activities.

Heat Resilient Urban Planning	Singapore incorporatesheat-resilient ur banplanning principles, such as strategic tree planting and building orientation, to minimize heat exposure and enhance thermal comfort in urban areas.	Pune's urban planning practices may notprioritize heatresilience, but there is an opportunity to integrate heat-resilient designprinciples into future development projects.	Pune can integrate heat-resilient urbanplanning guidelines into city master plans and zoning regulations to ensurethat new developments prioritize shade provision, natural ventilation,and heat mitigation strategies. Public awareness to educate residents and stakeholders about the importance of heat-resilient urban design.

Case Study (II): Copenhagen, Denmark

To potentially envision the future of green infrastructure in Pune, we can compare it to other cities in the world where green infrastructure is already flourishing. Firstly, we can look at Copenhagen, Denmark and analyze the various strategies they have used to mitigate UHIs.

Denmark has established several key policies and frameworks to support the development of green infrastructure within the country. The Nature Package (Naturpakken), implemented in May 2016, focuses on nature conservation and management, providing a comprehensive framework for activities aimed at enhancing green spaces and biodiversity.

After the Copenhagen City Council approved a cloudburst management plan in 2012, Denmark faced increased rainfall and frequent cloud risks, exacerbated by a severe incident in 2011 that cost more than $910 million in repairs. This highlighted the urgent need for preventive measures to combat flooding and improve the city's resilience to extreme weather events. The introduction of the Cloudburst Management Plan marked a significant shift towards sustainable urban planning and infrastructure development to meet the challenges of climate change.The implementation of 300 cloudburst projects over the next 20 years, as well as the creation of seven distributed clouds. . watersheds across the city, demonstrate Denmark's commitment to improving its blue and green infrastructure to reduce the risk of flooding and improve the resilience of cities.

By combining elements of green infrastructure, such as parks and natural areas that absorb rainwater and control runoff, and water-bearing boulevards to drain excess water, the city not only solves cloudbursts, but also urban heat island problems.From one economic perspective , investments in these cloud projects are expected to yield significant returns. The combination of green surface solutions and drainage-based infrastructure not only helps to store and remove water and protect the entire city from 100-year rainfall, but also provides a compelling business case. The estimated total benefit of $767 million underlines the financial viability of these initiatives, showing that they not only increase the resilience and resilience of the city, but also provide a positive economic return. In addition, the expected positive reaction of the real estate market to the climate-adapted city further emphasizes the economic value and attractiveness of these innovative green infrastructure solutions in Denmark.

Additionally, the Food and Agriculture Package (Fødevare og landbrugspakken), introduced in December 2016, addresses sustainable agricultural practices and their environmental impact, contributing to the overall development of green infrastructure. The Green Map of Denmark ("Grønt Danmarkskort"), outlined in the Danish Spatial Planning Act of 2015, plays a crucial role in ensuring the interconnectedness of valuable natural areas to support biodiversity and facilitate species propagation.

Furthermore, Copenhagen Municipality's adoption of the Copenhagen Tree Planting Policy underscores the city's commitment to urban tree management and increasing canopy coverage. Integrating green roofs into the City of Copenhagen's Climate Plan and Climate Adaptation Plan further demonstrates the city's dedication to climate resilience and biodiversity enhancement. The Danish Rural Development Programme has also supported initiatives such as hedgerow planting to mitigate soil erosion and promote biodiversity in agricultural landscapes. These policies collectively reflect Denmark's proactive approach towards promoting sustainable land use practices and fostering the growth of green infrastructure to enhance environmental quality and biodiversity conservation.

These laws play a crucial role in mitigating Urban Heat Island (UHI) effects by promoting green infrastructure, preserving natural habitats, and enhancing urban planning strategies.

The Nature Protection Act of 2016 safeguards Denmark's natural heritage, including species, habitats, and cultural values, while ensuring public access to outdoor spaces. It designates nearly 10% of terrestrial Denmark as protected areas and regulates habitat protection and landscape development. The Forestry Act, consolidated in 2017, focuses on forest conservation and aims to increase forested areas in the country. The Danish Spatial Planning Act, established in 1992, requires municipalities to designate and manage valuable natural areas, ecological corridors, and networks, including the Green Map of Denmark. The National Park Act of 2016 empowers the Minister for the Environment to establish and regulate national parks. Lastly, the Land Distribution Act of 2005 simplifies land distribution and public land trade to optimize land use and enhance natural and environmental values in the landscape.

Copenhagen's green infrastructure goals are in line with its vision of a sustainable and livable city, as outlined in Co-create Copenhagen and the climate plan CPH 2025. The city aims to improve its green spaces

and increase the number of trees to create a more vibrant and environmentally friendly urban environment. By implementing measures to expand green areas, pocket parks, green roofs and green walls, Copenhagen is actively working to improve air quality, increase biodiversity and mitigate the urban heat island effect.

In addition, Copenhagen aims to become the first carbon neutral city of Europe by 2025 highlights its commitment to sustainable development and climate action. Green infrastructure plays a critical role in achieving this goal by sequestering carbon, reducing energy consumption through natural cooling and insulation, and increasing the overall resilience of cities to the effects of climate change.

Copenhagen was awarded the title of European Green Capital in 2014 because it was a very successful model for the rest of Europe and beyond. Since 2014, the municipality of Copenhagen has implemented several strategies related to the creation and support of GI. Copenhagen's Nature Strategy ("Bynatur i København 2015-2025") aims to ensure that the city develops into a "green and climate-friendly" city. It has two main goals - to create more nature in Copenhagen and to improve the quality of Copenhagen's natural areas. The strategy includes 30 different measures to promote these goals. Among the measures is, for example, an action plan to plant an additional 100,000 trees in the city.

Learnings and Inference: Case (II)

Based on the commitment made in the Copenhagen City Nature Strategy 2015-2025, Copenhagen Municipality has also approved a new policy on Copenhagen's trees city - Copenhagen tree planting policy, "Københavns Kommunes træpolitik" 2016-2025. The policy

- which outlines five policy principles for urban tree management - aims to prioritize trees in the city without hindering urban development, and ultimately to achieve a 20% canopy in the city.Green roofs are part of the city. Copenhagen Climate Plan and Climate Adaptation Plan and Urban Biodiversity Strategy. The requirement for a green roof is also included in the municipal planning in 2015, where green roofs are required for all new buildings in recently planned areas for which the buildings are suitable and made with a flat roof (at an angle of up to 30 degrees).

Denmark's green infrastructure projects are financed from various sources. The government has allocated DKK 48 million to two new LIFE projects co-financed by the EU. The afforestation program supported by the Danish Nature Protection Act is co-financed from the funds of water companies and municipalities. In addition, the Danish government, in collaboration with VILLUM FONDEN and the Aage V. Jensen Naturfond, established a nature fund with a total funding of 875 million Danish kroner. The aim of this fund is to improve thequality of Denmark's terrestrial and marine environment.

Green infrastructure projects such as afforestation, carbon wetlands and wetlands are financed through EAFRD initiatives, with a financial share of 75-100%. Other projects, such as roofing, are fully funded by the state.

However, Denmark faces challenges in implementing green infrastructure due to the dense population of cities and suburbs, resulting in limited space availability and intense competition for land use. The importance of agriculture in the country is a challenge for the development of green infrastructure, because the greening of agricultural land and management practices can be difficult. Trade-offs have been found between cultural and regulatory ecosystem services and service delivery that complicate the development of green infrastructure. infrastructure activity in the country.

Comparative Analysis: Copenhagen and Pune

Pune and Copenhagen make compelling comparative cases for urban heat islands, despite their geographic and climatic differences. Both cities have experienced rapid urbanization, resulting in an increased heat island effect characterized by rising temperatures, reduced green space and increased energy consumption. Pune experiences high temperatures mainly due to its tropical climate, while Copenhagen is located in a temperate climate. , face similar challenges, exacerbated by heat waves caused by climate change. Despite their distinct climates, both cities share a common focus on heat stress and effective mitigation strategies. Pune and Copenhagen have implemented strong policy initiatives to address urban heat islands and improve resilience to climate change. By integrating green infrastructure into urban planning and development regulations, both cities demonstrate their commitment to combating the negative effects of urbanization on temperature regulation and promoting a sustainable and livable urban environment.

Table 4: Comparative analysis of Copenhagen and Pune through strategies and objectives.

UHI Mitigation Strategies	Copenhagen	Pune	Potential Strategies for Pune
Green	Copenhagen features diverse green spaces like King's Garden, Fælledparken, Ørstedsparken,	Pune has some greenspaces, but there ispotential for increasing	Pune can increase the number of parks and green spaces, especially in urban heat island hotspots, to enhance

Space sand Parks	of feringrecreational areas, lushlandscapes, and tranquil retreats for residents and visitors.	green cover to mitigate UHI effects.	coolingeffects and improve urban microclimate.
Green Roofs andWalls	Green roofs are prevalent inCopenhagen, with the City's Climate Plan, Climate AdaptationPlan, and Biodiversity Strategy mandating their integration in new buildings with flat roofs.	Pune has limited implementation of greenroofs and walls, but thereis potential forincorporating these features in new construction projects.	Pune can incentivize the adoption of green roofs and walls in building regulationsand provide subsidies or tax incentives to encourage property owners to retrofit existing buildings with green features.
Policy Setting	The policy setting for green infrastructure in Copenhagen isrobust, as evidenced by initiativeslike the Climate Plan, Climate Adaptation Plan,	The challenges posed byrapid urbanization inPune, such as traffic congestion inadequate housi ng,have diverted attentionand resources away fromprioritizing green infrastructure development.	Pune can strengthen its policiesfor advocating greeninfrastructure by integratingsustainability goals into urban planning framewor ks,engaging stakeholders in collaborative decision-making processes, conductin gthorough assessments of green infrastructure benefits, andaligning policies with nationaland international sustainabilitytargets
Urban Greening Programs	The Nature Package introduced in2016 in Denmark includes initiatives to further activities on Green Infrastructure, halt biodiversity loss by 2020, and ensure valuable nature areas are interconnected for species to thrive. This framework alignswith EU objectives and aims to enhance nature conservation	Pune has limited urbangreening initiatives compared Copenhagen but can benefit from similar programs to enhancegreen cover and mitigateUHI effects.	Pune can establish urbangreening incentives and partnerships with private developers to incorporate greenery into building designsand public infrastructure projects. Additionall y, community engagem entprograms can be implemented to involve residents in tree planting and maintenanceactivities.
Heat Resilient Urban Planning	Copenhagen implements heat- resilient urban planning by integrating green infrastructure,such as green roofs and parks, to combat rising temperatures and heat island effects.	Pune's urban planningpractices may not prioritize heat resilience to the same extent as Copenhagen, but there isan opportunity tointegrate heat-resilient design principles into future developmentprojects.	Pune can integrate heat- resilient urban planning guidelines into city master plans and zoning regulations toensure that new developments prioritize shade provision, natural ventilation, and heat mitigation strategies.

Primary Data Analysis

In this data analysis, we aim to examine the responses collected from 168 participants regarding their awareness, concerns, and experiences related to Urban Heat Islands in Pune through a questionnaire. Through analyzing the responses, we seek to identify prevalent perceptions, concerns, and potential avenues for addressing the issue.

Table 5: Percentage Data of the Responses Collected

Sr. No.	Question	Yes	No	Maybe
1	Have you heard of the term "Urban Heat Island"before?	22.6%	76.8%	0.6%
2	Are you aware of any effects Urban Heat Islandscan have on the environment and public health?	19.6%	38.1%	42.3%
3	Are you familiar with any strategies or solutionsto mitigate the effects of Urban Heat Islands?	20.8%	26.8%	52.4%
4	How concerned are you about the impact of Urban Heat Islands on your city or community?	79.8% (Concerned)	2.4% (Very Concerned)	17.9% (Not Concerned atall)
5	Would you be willing to support initiatives aimed at reducing Urban Heat Islands, such asincreasing green spaces or implementing coolroofing technologies?	11.9%	60.1%	28.0%
6	Have you ever received information or educationabout Urban Heat Islands from local authorities or community organizations?	7.1%	85.1%	7.7%
	How important do you think it is for local governments to address the issue of Urban HeatIslands?	65.5% (very important)	5.4% (important)	29.2% (not important)

7				
8	Have you personally experienced any discomfortor health issues related to heat in urban areas?	25.0%	20.2%	54.8%
9	Do you think Pune is experiencing hotter temperatures compared to previous years?	59.5%	17.9%	22.6%
10	Have you noticed any changes in the intensity ofheatwaves in Pune?	80.4% (more intense)	0% (lessintense)	19.6% (no difference)
11	Do you feel that Pune is experiencing more extreme weather events, such as heavy rainfall orprolonged heatwaves, in recent years?	79.2%	17.9%	3.0%
12	Have you observed any changes in vegetation orgreenery in Pune, particularly in urban areas?	56.5%	9.5%	33.9%
Source: Primary data (Questionnaire)				

The questionnaire is split into two parts, namely:
Awareness and Understanding of Urban Heat Islands:

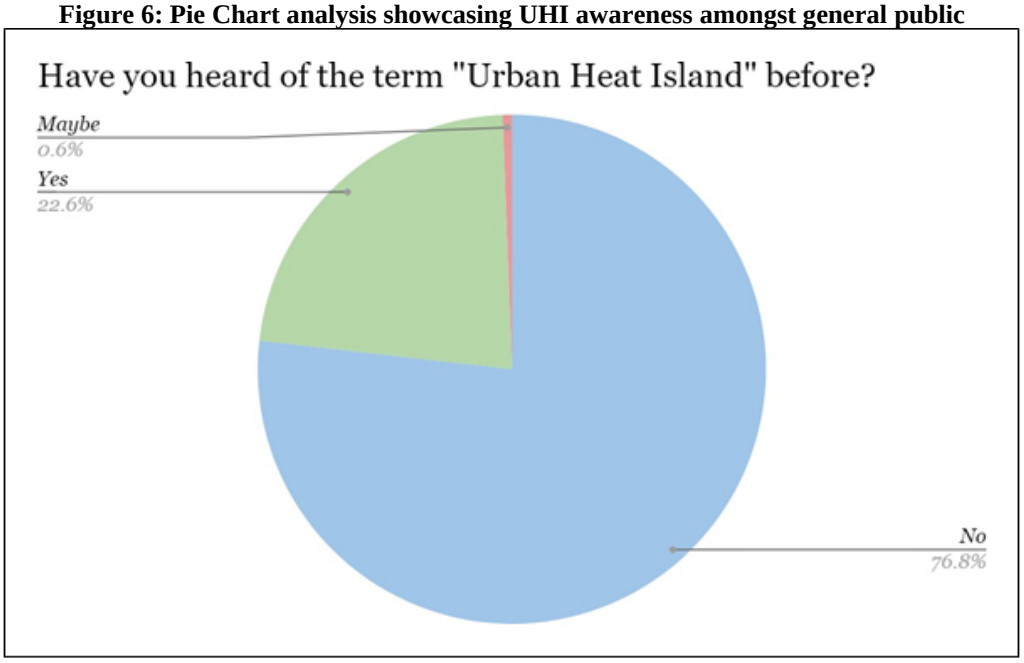
Here, we will assess the level of awareness among participants regarding the concept of UHIs and their understanding of its causes and impacts. This will involve analyzing responses to questions related to familiarity with the term "Urban Heat Island" and knowledge of its effects.

Perceived Impacts on Health and Environment:

In this part, we will examine participants' perceptions of the effects of UHIs on public health, environmental quality, and overall livability in Pune. This analysis will involve assessing responses concerning health issues, discomfort, and changes in vegetation and greenery attributed to perceived climate change in Pune.

Graphical Analysis on Awareness and Understanding of Urban Heat Islands:

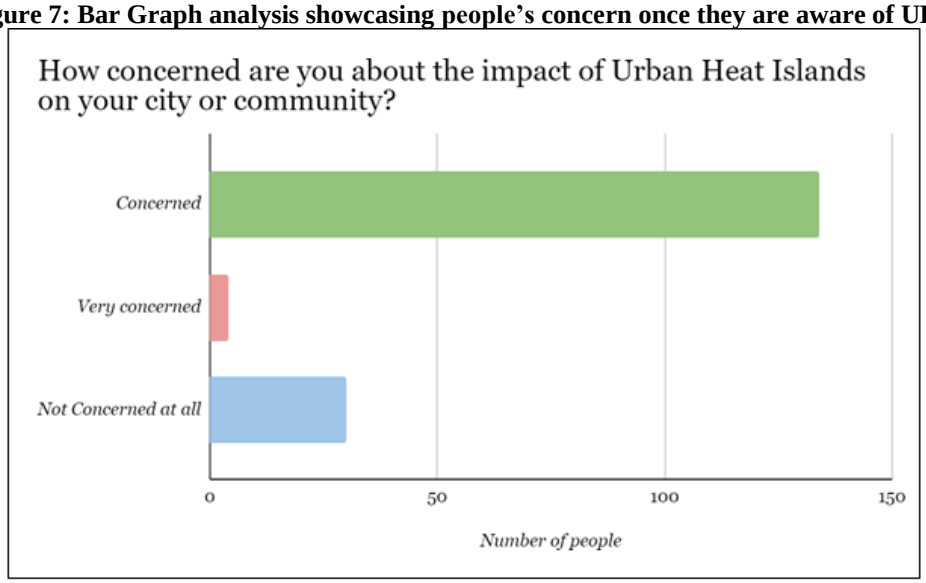
Figure 6: Pie Chart analysis showcasing UHI awareness amongst general public



Source: Primary Data

The data highlights a significant disparity in awareness and concern regarding Urban Heat Islands (UHIs) among respondents in Pune. Alarmingly, a substantial majority (76.8%) of participants admitted to never having heard of the term "Urban Heat Island" before. This glaring lack of awareness underscores a crucial gap in public knowledge regarding environmental phenomena that directly impact urban areas. It suggests a pressing need for educational initiatives aimed at raising awareness about UHIs and their implications for cities like Pune.

Figure 7: Bar Graph analysis showcasing people's concern once they are aware of UHIs



Source: Primary Data

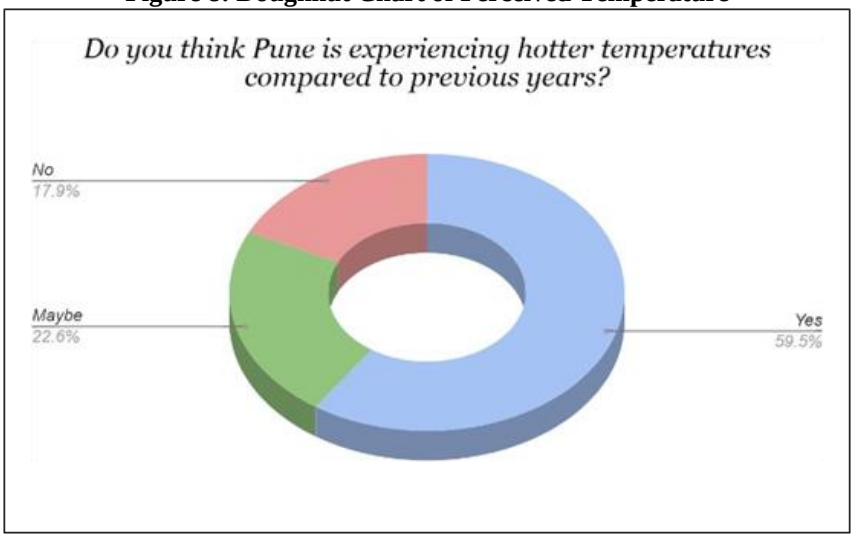
However, despite the prevailing lack of awareness, the responses to the second question reveal a noteworthy shift in sentiment once participants were informed about UHIs. Overwhelmingly, 79.8% expressed concern about the impact of UHIs on their city or community, with an additional 2.4% indicating very high levels of concern. This stark contrast underscores the importance of education and information dissemination in fostering public understanding and engagement with environmental issues.

The data underscores the critical role of education in addressing environmental challenges such as UHIs. It highlights the potential for informed awareness-raising efforts to catalyze public concern and support for mitigation strategies. Moving forward, initiatives aimed at educating residents about UHIs and their consequences could play a pivotal role in fostering sustainable urban development and enhancing community resilience to climate change impacts in Pune.

Graphs on Perception of Health and Environmental Impact:

Climate perception is intricately woven into the fabric of cognitive processes and social dynamics within specific cultural milieus. Through channels like mass communication, interpersonal dialogue, and formal education, individuals come to recognize climate change. Research has shown that people's direct connections to climate change are based on recurring themes such as weather changes and potential climate impacts, the causal role of human activityand natural cycles, and the relationship of climate change to a consumer society.

Figure 8: Doughnut Chart of Perceived Temperature

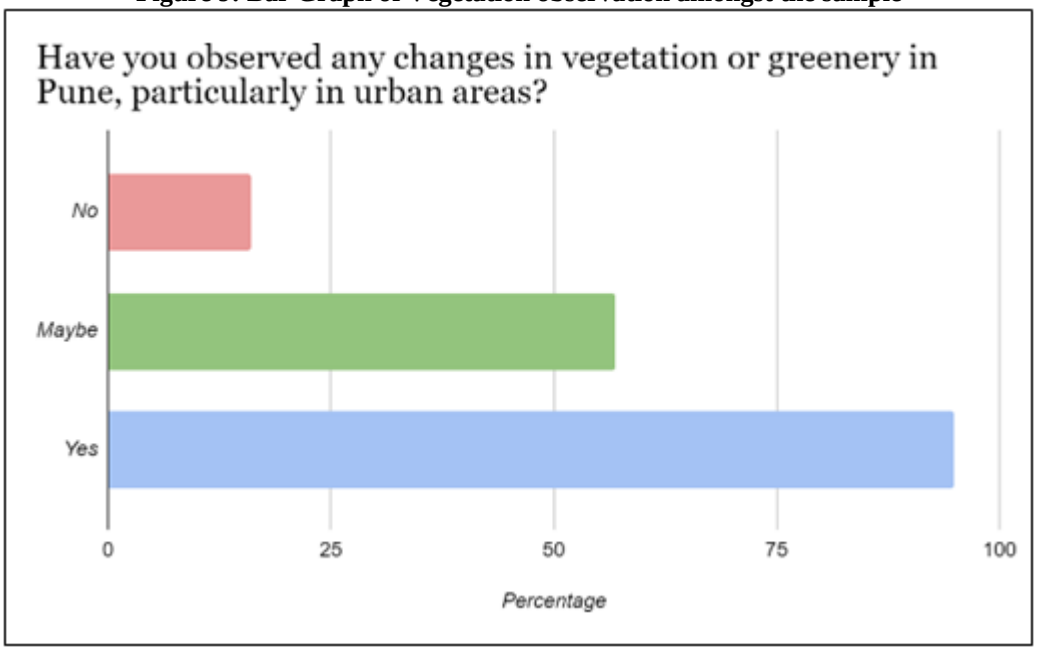


Source: Primary Data

Of the 168 respondents, a significant 25% reported directly experiencing problems due to the heat. This suggests that a significant proportion of the population directly struggles with the harmful effects of heat in urban environments. In addition, a significant proportion of respondents, 54.8%, expressed uncertainty by choosing the 'Maybe' option. This ambivalence highlights the nuanced perception of heat discomfort, which can be influenced by different sensitivities, frequency of exposure or awareness of health consequences.

The high percentage of respondents also affirming that Pune is experiencing hotter temperatures compared to previous years (60%) and noticing an increase in the intensity of heatwaves (80%) suggests a strong consensus regarding the escalating heat trends in the region.

Figure 9: Bar Graph of Vegetation observation amongst the sample



Source: Primary Data

When we look at the results for the questions regarding the changes in biodiversity around the city as well as frequency of extreme weather, the high percentage of respondents reporting that Pune has experienced more extreme weather events such as heavy rains or prolonged heat waves in recent years (80%) indicates a widespread perception of increased climate change and occurrence of disruptive weather events. This perception is in line with global trends of climate change affecting weather patterns leading to more frequent and intense extreme events. Similarly, most respondents (56%) who have observed changes in vegetation or greenery in Pune, especially urban areas, emphasize. observable effects of environmental changes on the urban landscape. These changes affect the city's biodiversity, microclimate regulation, and the overall aesthetic and recreational value of the city's green spaces.

IV. Policy Recommendations

Based on existing research, here are few policy recommendations for the government to addressthe issue in Pune:

1. **Tailored Policies for Pune:** Despite being recognized as a vulnerable area of energy and infrastructure, Pune lacks specific policies focused on mitigating UHIs. The Maharashtra government should allocate dedicated resources and develop targeted policies to address UHI issues in Pune, acknowledging its unique urban dynamics and climate vulnerabilities.
2. **Adoption of Innovative Technologies:** Pune can learn from global best practices, such as Singapore's use of cool pavement technology and heat-resilient urban planning. The government should incentivize the adoption of such innovative technologies and urban design strategies to mitigate heat island effects. This may include promoting the use of heat-reflective materials for pavements, rooftops, and buildings to reduce surface temperatures and improve urban microclimates.
3. **Public Education and Awareness:** There is a pressing need to educate local residents about climate change, UHIs, and their potential impacts on health and well-being. The government should launch comprehensive awareness campaigns, workshops, and community outreach programs to inform residents about UHI phenomena and encourage sustainable behaviors. Additionally, integrating climate change education into school curricula can help foster a culture of environmental stewardship among younger generations.

4. **Increase Green Cover:** Pune can focus on increasing the number of parks, green spaces, and urban forests to enhance cooling effects and improve the urban microclimate, similar to Copenhagen's extensive green spaces like King's Garden and Fælledparken .
5. **Promote Green Roofs and Walls:** Pune can incentivize the adoption of green roofs and walls in building regulations, providing subsidies or tax incentives to encourage property owners to retrofit existing buildings with green features.
6. **Promotion of Mundane Innovations:** In addition to large-scale technological solutions, there is also potential for "mundane innovations" – simple, low-cost, and locally appropriate interventions – to contribute to UHI mitigation efforts in Pune. The government should actively promote and support grassroots initiatives that harness local knowledge and resources to address heat island effects.

By implementing these policy recommendations, the government can effectively mitigate the impacts of Urban Heat Islands in Pune, enhance urban resilience to climate change, and create a more livable and sustainable city for current and future generations.

V. Conclusion

This research paper explored the critical aspects of urban heat islands (UHI) and air quality in Pune, with special emphasis on the role of green infrastructure and urban forestry in addressing these challenges. The study included a comparative analysis of Pune's green infrastructure initiatives with those of cities known for sustainable urban planning, such as Singapore and Copenhagen.

The study identified key issues facing Pune, including rapid urbanization that is causing the heat island effect on expand and expand. temperature, reduction of green areas and increase ofenergy consumption.

The main research question of this study was to determine how Pune can improve its green infrastructure strategies to reduce UHI and improve the livability of the city. Using a multifaceted methodology that included primary data collection, mapping of the city, comparative analysis and policy recommendations, the study revealed several important findings. It was evident that Pune has untapped potential for growth and development, giving it an opportunity to benchmark itself against the global standards of cities like Singapore and Copenhagen.

The study identified increasing green cover, promoting green roofs and walls, strengthening policy frameworks, and establishing urban greening programs as key strategies to upgrade and improve green infrastructure initiatives in Pune. Finally, this study underlines its importance in integrating green infrastructure into urban planning to combat the negative effects of urbanization on temperature regulation and create a sustainable and climate-resilient urban environment in Pune.

Scope for Future Research

Although this study provided valuable insights into the potential of green infrastructure and urban forestry to mitigate urban heat islands and improve air quality in Pune, there are several avenues for future research to explore and expand:

Evaluation of long-term impacts: Future studies could focus on making of longitudinal studies to assess the long-term effectiveness of green infrastructure interventions in Pune. This would require monitoring changes in urban temperature, air quality and resident well-being over long periods of time to assess the ongoing benefits of green initiatives.

Technological Innovations: Research focusing on the integration of technological innovations such as smart sensors, green. infrastructure monitoring systems and data analysis, optimizing the effectiveness of green initiatives Pune city may be a promising area of research. The use of technology can improve the efficiency and impact of green infrastructure projects.

Policy analysis and governance: Future research could delve into the policies and administrative structures involved in the implementation of green infrastructure in Pune.

Limitations of the Study

Limited Awareness of Urban Heat Islands (UHIs): One of the major limitations of the study is the prevailing lack of awareness of urban heat islands among the public in Pune. The study revealed a significant gap in knowledge about UHIs, as most participants admitted that they had never even heard of the phenomenon.

Data Availability and Reliability: The study's reliance on historical temperature data from meteorological stations in Pune to estimate the Urban Heat Island (UHI) may limit data availability and reliability. Differences in data collection methods, monitoring locations, and temporal coverage can affect the accuracy and reliability of UHI analysis.

Generalizability of findings: Due to Pune and its unique urban context, the generalizability of the research findings to other cities or regions may be limited.