



# Policy Brief

## MITIGATING AIR POLLUTION AND URBAN HEAT THROUGH CLIMATE-SENSITIVE HEALTH INTERVENTION

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### INTRODUCTION

Rapid urbanization and economic growth have intensified environmental and ecological challenges, particularly air pollution and urban heat, posing serious risks to public health and environmental sustainability in developing countries such as Pakistan. Cities act as engines of economic growth but are increasingly characterized by dense built-up environments, vehicular emissions, industrial activity, declining green spaces, and rising public health risks. These pressures have led to the emergence of two interlinked urban climate phenomena: Urban Heat Island (UHI) and Urban Pollution Island (UPI). The UHI refers to higher Land Surface Temperatures (LST) in urban areas compared to surrounding rural areas, often resulting in residents perceiving temperatures higher than measurements suggest. In contrast, the UPI describes higher concentrations of air pollutants in urban atmospheres, largely driven by transportation infrastructure, industry, energy consumption, and fossil fuel combustion. These phenomena reinforce each other through complex interconnected mechanisms, where higher temperatures accelerate pollutant formation and stagnation, and air pollution further modifies local climatic conditions.

Among these two interconnected phenomena, air pollution is recognized as one of the leading environmental risk factors for premature mortality, contributing significantly to cardiovascular and respiratory diseases, physiological stress and deteriorating human mental wellbeing. Pollutants such as NO<sub>2</sub>, SO<sub>2</sub>, CO, and O<sub>3</sub> are major contributors to smog formation in cities of Pakistan. According to global air quality assessments, Pakistan consistently ranks among the most polluted countries, with annual PM<sub>2.5</sub> concentrations far exceeding WHO guidelines. Lahore and Faisalabad, two major metropolitan and industrial hubs, exemplify these challenges, experiencing persistent smog episodes, heatwaves, and increasing health risks. The UHI effect intensifies heat waves, increases energy demand, and raises heat-related morbidity, mortality and physiological stress, particularly among vulnerable populations.

Despite growing recognition of these challenges, limited integrated evidence exists on the combined impacts of UHI and UPI on public health in Pakistan. This study addresses this gap by systematically assessing urban heat and air pollution dynamics in Lahore and Faisalabad by employing a geospatial approach of spatial analysis and the innovative Thermal Haze Adversity Index (THAI) behavioral and governance tool. By linking climate stressors with health-sensitive urban planning incorporating green interventions, the research provides evidence-based guidance



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for several proposed interventions. Vegetation loss and escalation in UPI and UHI requires the increase in green cover to ensure sustainable cities. The study directly supports SDGs 3 (Good Health and Well-Being), 11 (Sustainable Cities and Communities), and 13 (Climate Action) by addressing air-pollution-related illness, improving urban environmental quality, and enhancing climate resilience planning in rapidly urbanizing cities.

## RESEARCH METHODOLOGY

This study adopted a multi-tier, geospatially driven methodology to assess urban heat, air pollution, and their implications for climate-sensitive health interventions in Lahore and Faisalabad. The methodological framework integrated remote sensing, spatial analysis, and environmental indicators to capture both spatial and temporal variations in urban climate stressors, taking three temporal periods: annual, heatwave, and smog periods over a decade (2015-2024). First, the Urban Heat Island (UHI) was assessed employing cloud computing using satellite-derived LST obtained from multi-temporal Landsat 8 imagery. To understand land-use drivers of thermal variability, key spectral indices (NDVI, NDBI, NDWI, and NDBaI) were calculated. The Ecological Evaluation Index (EEI) was computed through the Urban Thermal Field Variance Index (UTFVI) to evaluate thermal comfort and ecological stress levels across an urban neighbourhood. The computed results were validated by meteorological data from met station. Second, the UPI was analyzed through a spatio-temporal assessment of major atmospheric pollutants ( $\text{NO}_2$ ,  $\text{SO}_2$ ,  $\text{CO}$ , and  $\text{O}_3$ ), using Sentinel 5P atmospheric datasets. Pollution hotspots were identified and overlaid with land-use patterns to assess emission sources and exposure risks. Seasonal variations were examined to capture pollution dynamics during smog-prone periods.

Third, a buffer-based analyses were applied to examine the cooling effects of green spaces up to 300m. Fourth, suitable site selection by integration of population density, minimal greenery, UHI and UPI layers enabled the identification of climate-sensitive health risk zones, highlighting areas where combined heat and pollution exposure is most severe. This integrated approach provides a robust evidence base to inform targeted, location-specific policy interventions for urban resilience and public health improvement. Finally, THAI was developed, which measures public health risks associated with air pollution and urban heat and reflects the effect of government environmental policies and public awareness on perception, behaviour, and adaptive capacity.

## FINDINGS AND CONCLUSIONS

The findings revealed a strong spatial and functional linkage between urban heat and air pollution in both Lahore and Faisalabad, with distinct patterns shaped by land use, urban morphology, and anthropogenic activity. High LST and air pollution consistently coincide with dense built-up areas, industrial zones, major transport corridors, and commercial centers, confirming the dominance of impervious surfaces and emissions in creating the UHI and UPI effect and threatening citizen health and the sustainability of the cities.

Spatio-temporal analysis revealed a precise increase in heat intensity over the decade, remarkably during summer, with heatwave and smog seasons increasing UHI effects. The finding revealed an overall increase of  $4^\circ\text{C}$  and  $5^\circ\text{C}$  in the mean LST of Lahore and Faisalabad from 2015-2024. The



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compactly built-up environment documented 1-2°C higher temperatures than nearby rural areas during the smog period, intensifying the UHI intensity. Thermal stress derived from UTFVI of Lahore showed worst situation is intensifying during heatwave seasons. While Faisalabad showed growing thermal stress, indicated by poor environmental, social, and economic health of urban areas, particularly during heatwave and smog periods.

Furthermore, air pollution assessment showed strong seasonal and spatial variability. Overall, both Lahore and Faisalabad exhibited a decline and stabilization in NO<sub>2</sub> and SO<sub>2</sub> in recent years, which indicated the impact of effective emission control strategies and policy interventions. While O<sub>3</sub> showed a consistent upward trend, mainly linked to heatwave conditions and plays a minor role in smog formation. In contrast, CO demonstrated a gradual and persistent increase in both cities, especially in urban cores, highlighting continued pressure from traffic, combustion, and meteorological trapping effects. UPI patterns over Lahore revealed a stable yet expanding pollution footprint from the central core to the outer skirts. Unlike Lahore, the central and northern urban-industrial zones of Faisalabad persist as dominant air pollution hotspots. In addition, Faisalabad has expanding low-to-medium risk zones, which are identified through pollution risk mapping.

The findings of the present research also provide challenging empirical support for the urban green spaces' mitigation potential in both cities. The study concluded that the large parks and continuous green spaces depicted a cooling of 1-4°C within a radius of 100 m, gradually reduced at 200-300 m, while small, fragmented street parks gave a negligible cooling effect. Dense green space and tree canopy maintained LST below 30°C constantly in areas with Normalized Difference Vegetation Index (NDVI) values above 0.6-0.7. The study findings concluded that the green spaces and tree cover reduced surface temperature by 1.5 to 2°C and, accordingly, lowered pollutant concentration and improved the air quality. Based on the study findings, vegetation density, canopy cover, spatial continuity, and the selection of proper tree species are important to improve urban cooling and air purification functions.

The spatial analysis highlighted that unplanned urban expansion, loss of vegetation, and inadequate environmental governance are common drivers across both cities. Despite differences in urban form, the interaction between heat and air pollution follows similar pathways, reinforcing the need for integrated site-specific policy responses rather than sector-specific interventions. The findings of the site suitability analysis identified priority areas for green space (green roofs, vertical garden, green walls and green belts) development, offering actionable guidance for climate-resilient and health-oriented urban planning.

Besides, citizens' capacity and adaptability to cope with both phenomena are important aspects during the current emerging climate crisis. Thus, unlike conventional quantitative measuring methods, the study also measured both phenomena qualitatively, and an innovative tool developed under the current project, named THAI, highlights that increased public awareness and government environmental policies significantly influence perception, behavioral adaptation, and resilience of citizens to mitigate the effects of heat and air pollution at the individual level. This tool (THAI) highlights the role of environmental mitigation with community awareness and adaptive capacity.



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In conclusion, this study demonstrates a clear causal pathway in large Pakistani cities: UHI and UPI effects driven by pollutants such as NO<sub>2</sub> and SO<sub>2</sub> intensify heat exposure and air pollution, leading to adverse health and well-being outcomes. Questionnaire findings and the THAI framework confirm that residents in these areas experience heat stress more severely than measurements alone suggest and support adaptive and policy-led interventions. Guided by these integrated spatial and human-perception insights, the study proposes targeted urban green space interventions as an effective response. Strategically expanding and distributing green infrastructure, through parks, micro-forests, green roofs, and green corridors, can reduce heat and pollution exposure, improve public health, and strengthen climate resilience despite the persistent UHI and UPI crisis.

## POLICY RECOMMENDATIONS

### Short-term

Recommended Policy	Urgency	Priority	Impact
<b>1. Plant Test Areas (Demonstration Beds)</b>	<b>High</b>	<b>Medium</b>	<b>Medium</b>
<p><b>Policy Action:</b></p> <p>Develop plant test areas (demonstration beds) employing evidence-based air cooling &amp; cleaning native tree species along roadsides, flyover bridges, schoolyards, and other high-exposure municipal localities. These pilot projects will deliver instant localized &amp; cooling air quality benefits, while testing native species functioning under heat-pollution stress environments.</p> <p>Furthermore, a partnership with local plant nurseries for supply &amp; maintenance is also proposed. Later, pilot-based outcomes, the provincial Govt should begin inexpensive urban native plant outlets.</p> <p><b>Lead Institutions:</b> PHA &amp; Forest Department, EPA</p>	<p><i>This intervention is cost-effective and highly visible for rapid cooling and air quality improvement, while building public trust and empirical evidence for city-wide scaling.</i></p> <p><b>Planning Instruments:</b> Climate Action Plans and Heat Action Plans, Public-private partnership (PPP) frameworks with local nurseries.</p> <p><b>Monitoring Indicators:</b> Survival rate and growth performance (%) of planted species, Reduction of schoolyard temperatures &amp; particulate matter near test areas.</p>		
<b>2. Green Roofs and Green Walls through Incentives</b>	<b>Low</b>	<b>High</b>	<b>High</b>
<p><b>Policy Action:</b></p> <p>Large industrial units and commercial buildings should promote the installation of solar panels for clean energy, and green roofs, for insulation and air cleaning, i.e. Daroghawala &amp; Misri Shah in Lahore and Industrial site near Ghulam Muhammad Abad &amp; Saifabad in Faisalabad.</p> <p>Adoption should be encouraged through financial incentives such as grants or tax rebates, as well as mandatory regulatory provisions for new and retrofitted buildings.</p> <p><b>Lead Institutions:</b> Solar Power Companies &amp; PHA</p>	<p><i>This measure targets big polluters, reducing emissions at the source and businesses' energy costs.</i></p> <p><b>Planning Instruments:</b> Building bylaws, green building codes, grant programs, and incentive-based schemes</p> <p><b>Monitoring Indicators:</b> Reduction in rooftop temperature and indoor cooling demand, building energy consumption, and improvement in air quality indicators</p>		

### Medium-term

<b>3. Expand and protect large, contiguous urban green spaces</b>	<b>Medium</b>	<b>High</b>	<b>High</b>
<p><b>Policy Action:</b></p> <p>Protect and expand major parks and peri-urban green areas to maximize cooling and ecological benefits.</p> <p><b>Lead Institutions:</b> LDA, PHA &amp; Forest Department</p>	<p><b>Planning Instruments:</b> Master plans, land-use zoning, and green space protection bylaws.</p> <p><b>Monitoring Indicators:</b> LST (°C) reduction, NDVI increase, per-capita green</p>		



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	space (9m <sup>2</sup> /person).		
<b>4. Develop a green corridor in identified high-risk zones.</b>	<b>Low</b>	<b>Medium</b>	<b>High</b>
<p><b>Policy Action:</b> Create continuous green corridors along major roads, canals, ravines, watercourses, and open spaces to enhance wind-driven cooling and pollution dispersion. The Punjab government should prioritize planning that connects scattered parks and green areas into one continuous network of paths for walking and biking with nature. <b>Lead Institutions:</b> PHA, Municipal Corporation, EPA</p>	<p><i>Despite extensive design and funding needs, this measure provides a long-term strategy for increasing green space accessibility.</i> <b>Planning Instruments:</b> Street design standards, environmental regulations, and urban greening guidelines. <b>Monitoring Indicators:</b> Tree canopy cover (%), corridor continuity, PM<sub>2.5</sub> and NO<sub>2</sub> concentrations.</p>		
<b>Long-term</b>			
<b>5. Integration of UHI-UPI layers into statutory master planning.</b>	<b>Low</b>	<b>Medium</b>	<b>High</b>
<p><b>Policy Action:</b> UHI-UPI composite risk maps should be part of development proposals, zoning decisions, and strategic environmental considerations.  <b>Lead Institutions:</b> LDA, Planning &amp; Development Department, Urban Unit</p>	<p><i>This step ensures that heat-pollution risks are logically considered in development (master plans, environmental planning and zoning decisions). It can assist policymakers and urban planners to identify high-risk areas, guide land-use intensity, prioritize mitigation measures, and prevent the concentration of vulnerable populations in heat- and pollution-exposed zones.</i> <b>Planning Instruments:</b> Master plans, development control regulations, and Strategic Environmental Assessment frameworks. <b>Monitoring Indicators:</b> Share of projects screened using UHI-UPI layers, spatial reduction of high-risk zones.</p>		
<b>6. Use THAI for Targeted Adaptation</b>	<b>Medium</b>	<b>Medium</b>	<b>High</b>
<p><b>Policy Action:</b> Apply the Thermal Haze Adversity Index (THAI) tool to recognize communities in need of heat awareness, early warning systems, air pollution action plan &amp; adaptive support.  <b>Lead Institutions:</b> Punjab Health Department, PDMA, NDMA, Local Governments</p>	<p><i>This strategy enables systematic identification of communities that are most exposed to heat-related risks, supporting the design of heat awareness initiatives, deploying early-warning systems, and delivering adaptive support to populations with heightened vulnerability.</i> <b>Planning Instruments:</b> Heat Action Plans, public health communication strategies. <b>Monitoring Indicators:</b> Heat-risk awareness levels, early-warning system coverage.</p>		
<b>7. Protected Low-Emission Zones (LEZs)</b>	<b>Low</b>	<b>Medium</b>	<b>High</b>



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**Policy Action:**

Over the long term, the government should legislate the establishment of protected zones where high-emission vehicles, industries, or polluting activities are restricted, enforced with fines or technology such as video surveillance.

**Lead Institutions:**

Punjab Safe City Authority, Punjab Traffic Police

*Legislating protected low-emission zones would provide a legally enforceable mechanism to maintain the benefits of expanded greening. These zones would directly lower local pollutant concentrations, mitigate urban heat accumulation, and protect public health.*

**Planning Instruments:**

Low-Emission Zone (LEZ) notification frameworks, smart city surveillance and digital enforcement policies.

**Monitoring Indicators:**

Reduction in traffic-related air pollutants (PM<sub>2.5</sub>, NO<sub>2</sub>) within LEZs.