Supplementary Information for "Microclimate Simulations Reveal the Potential of Multifunctional Green Infrastructure for Urban Heat Mitigation"

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1 Supplemtary note 1

Base scenario

Table S1 Base scenario: Roof materials properties

Material	Absorption	Emissivity	Specific Heat (J/kg·K)	Thermal Conductivity (W/m·K)	Density (kg/m³)
Concrete	0.8	0.8	200	0.2	620
Tin	0.5	0.1	500	203	2700
Tiles	0.9	0.7	300	0.84	1900

Green Infrastructure (GI) Scenarios

Table S2 Base scenario: Wall material properties

Material	Absorption	Emissivity	Specific Heat (J/kg·K)	Thermal Conductivity (W/m·K)	Density (kg/m^3)
Good Insulation	0.5	0.7	800	0.6	1274.64
Moderate Insulation	0.52	0.75	650	0.65	1686
No Insulation	0.52	0.65	570	0.6	1856

Table S3 Base scenario: Soil profile properties

Profile	Emissivity	Albedo	Roughness Length (m)	Heat Conductivity (W/m·K)
Barren	0.6	0.1	0.015	-
Other Surfaces	0.5	0.05	0.01	-
W/O Flexible Pavement	0.6	0.1	0.01	1.63
Loamy Soil	0.6	0.0	0.015	-
Asphalt Road	0.6	0.1	0.01	-
W/O Concrete Pavement	0.5	0.1	0.01	-
Urban Surfaces	0.6	0.2	0.01	1.63
Service Lane	0.5	0.2	-	1.63
Default Surface	0.9	0.2	0.015	-

Table S4 Base scenario: Vegetation properties

Type	Transmission	Emissivity	Albedo
Grass	0.2	0.8	0.2

Table S5 Green Roof (GR) Material Properties

Material	Transmission	Emissivity	Albedo	Plant Height (m)	LAI
Funkia Hosta	0.3	0.97	0.2	0.4	1.5
Substrate	-	0.95	0.3	-	-

Table S6 Permeable Pavement (PP) Material Properties

Material	Volumetric Heat Capacity (J/kg·K)	Heat Conductivity (W/m·K)	Saturation Water Content	Field Capacity	Wilting Point
Smashed Brick	2	0	0.395	0.135	0.068

Table S7 Bioretention Cell (BRC) Vegetation Properties

Type	Transmission	Emissivity	Albedo	Plant Height (m)
Hedge Light	0.3	0.97	0.2	0.8

2 Supplementary note 2

Methodology

We validated the ENVI-met model by comparing observed and simulated temperatures, achieving a high correlation ($R^2 = 0.87$), which indicates reliable model performance. We collected spatially distributed temperature data using mobile sensors mounted on a survey vehicle. Additionally, we documented land use and building typologies through field surveys and imagery to provide contextual information for the study.

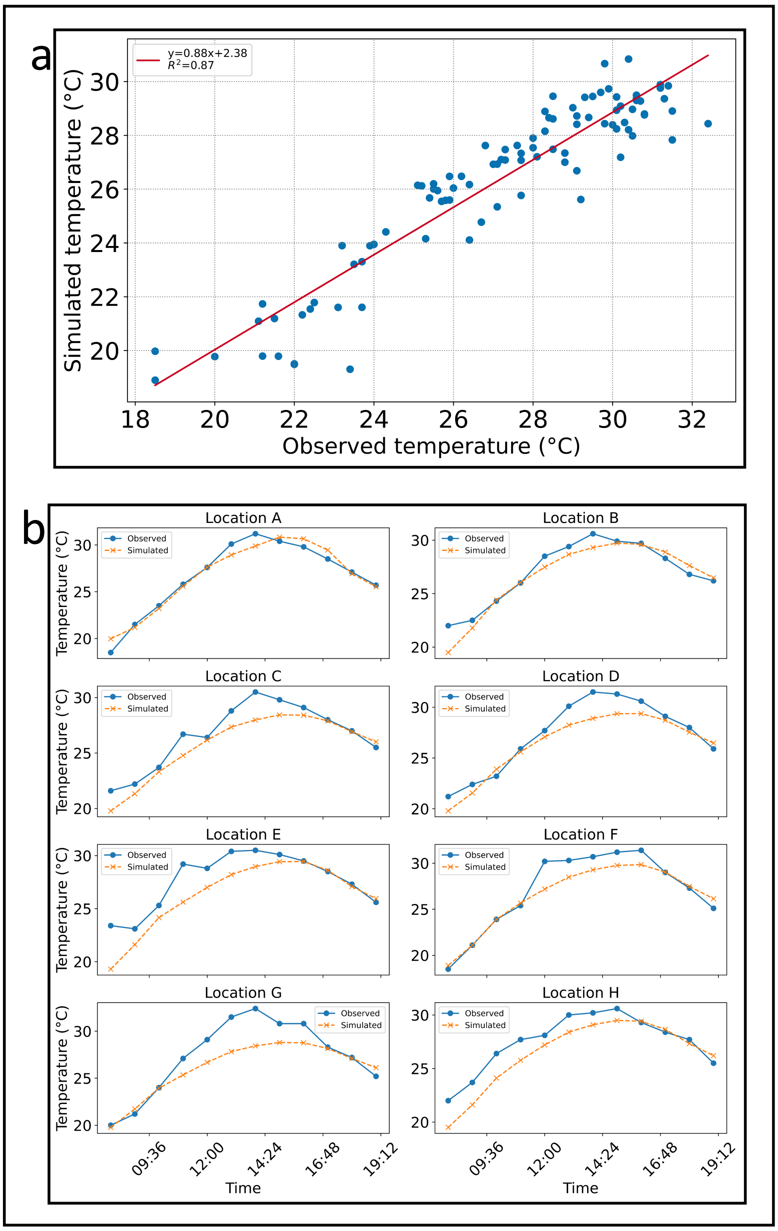

Fig. S1 Validation of the ENVI-met model. (a) Comparison of observed and simulated temperature for all surveyed locations between 8:00 AM and 7:00 PM on 10 February 2024 at a height of 2 m, yielding an R^2 of 0.87. (b) Time-series plot of observed and simulated temperatures, illustrating close temporal agreement.

Fig. S2 Photograph of the survey vehicle used for mobile temperature measurements, equipped with mounted temperature sensors.

Fig. S3 Snapshots from the surveyed study area depicting land use characteristics and building typologies. These images provide a general overview of the urban landscape, highlighting key features relevant to the study's environmental and climatic assessment.

3 Supplementary note 3

Results

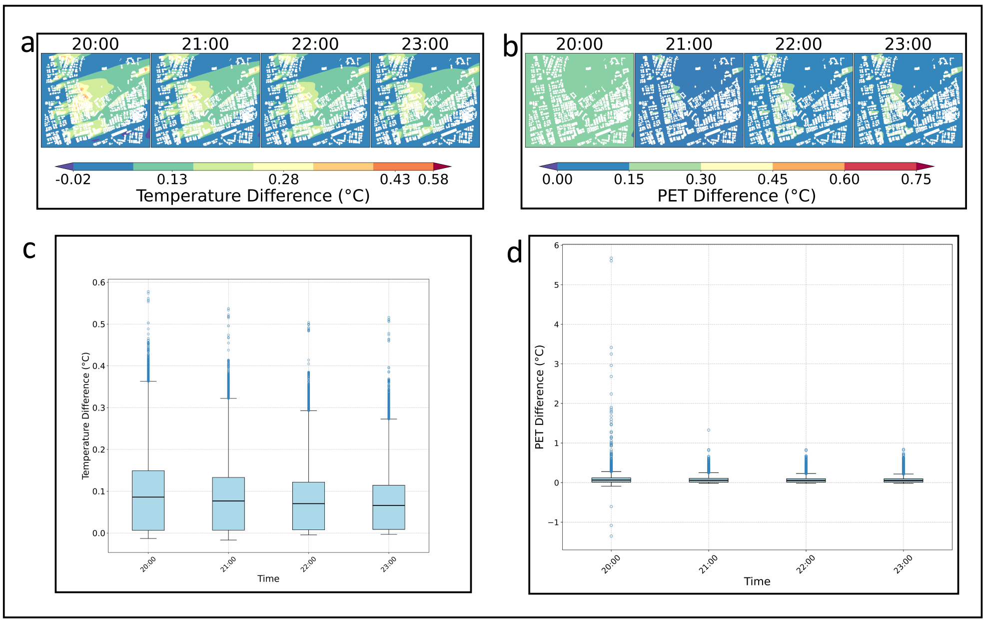

Fig. S4 Impact of Green Roofs (GR) on Temperature and Thermal Comfort During Nighttime (8 PM - 11 PM). a) and (b) illustrate the temperature differences between the Base scenario and the GR scenario. (a) shows the spatial distribution of these temperature differences across the study area, visually depicting the cooling effects of GR interventions. (b) presents the box plot representation, quantifying the variability and range of temperature differences across different urban locations.(c) and (d) focus on the impact of GR on Physiological Equivalent Temperature (PET). (c) maps the spatial distribution of PET differences, highlighting areas where GR implementation has led to improved nighttime thermal conditions. (d) provides a box plot analysis, capturing the distribution of PET reductions and emphasizing the extent to which GR enhances pedestrian-level comfort during nighttime hours.

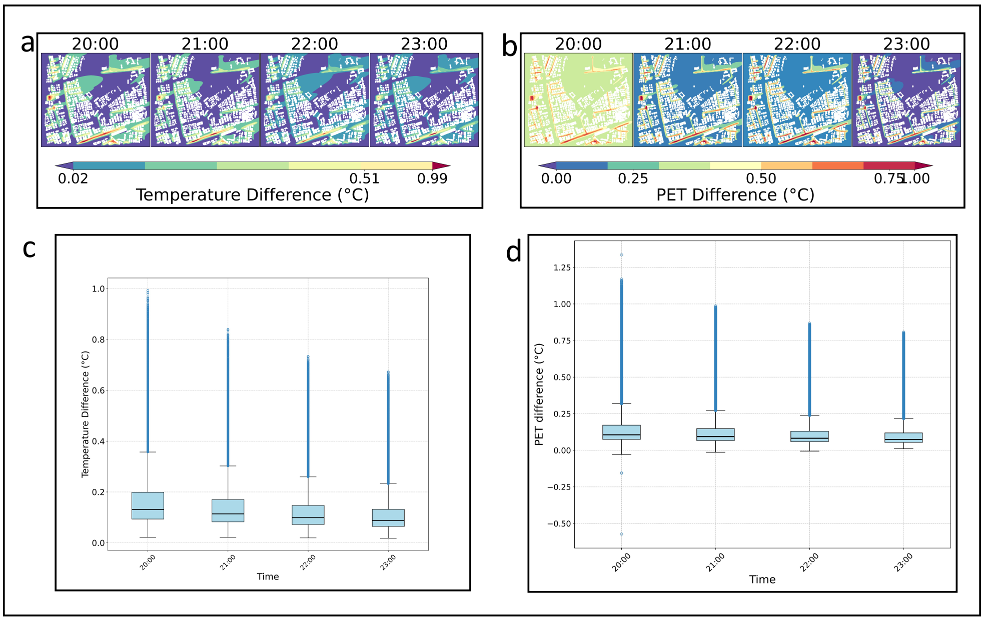

Fig. S5 Impact of Permeable Pavements (PP) on Temperature and Thermal Comfort During Nighttime (8 PM - 11 PM).(a) and (b) illustrate the temperature differences between the Base scenario and the Permeable Pavement (PP) scenario. (a) displays the spatial distribution of these temperature differences across the study area, highlighting the cooling effects of PP interventions. (b) presents the box plot representation, quantifying the variability and range of temperature differences observed across different urban locations. (c) and (d) examine the impact of PP on Physiological Equivalent Temperature (PET), a measure of thermal comfort. (c) shows the spatial distribution of PET differences, identifying areas where PP implementation has contributed to improved nighttime thermal conditions. (d) provides a box plot analysis, capturing the distribution of PET reductions and emphasizing the extent to which PP enhances pedestrian-level comfort during nighttime hours.

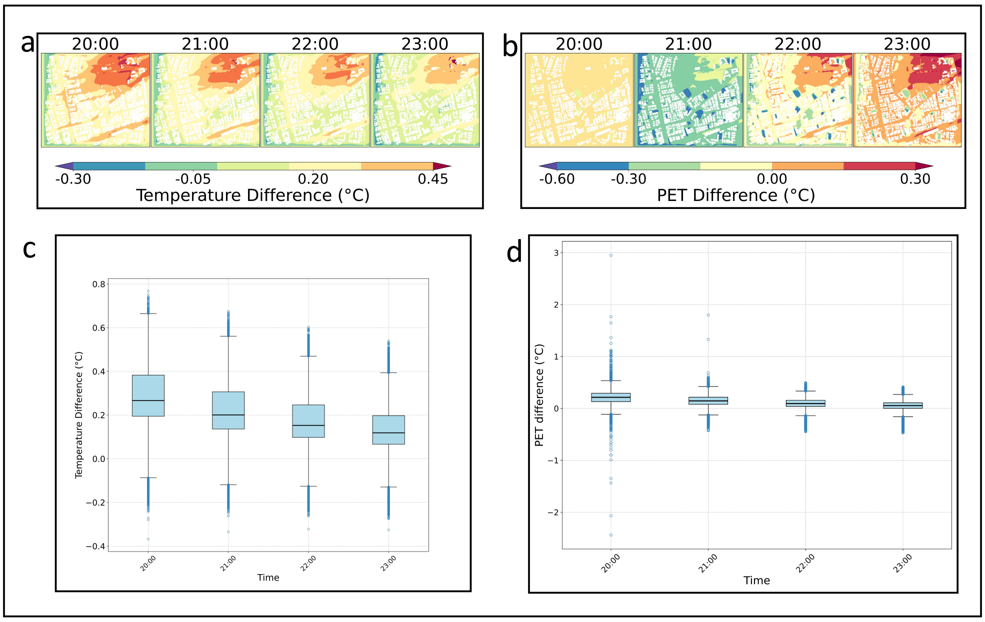

Fig. S6 Impact of Bioretention Cells (BRC) on Temperature and Thermal Comfort During Nighttime (8 PM - 11 PM).(a) and (b) illustrate the temperature differences between the Base scenario and the Bioretention Cell (BRC) scenario. (a) presents the spatial distribution of temperature differences across the study area, showcasing the cooling effects of BRC implementation. (b) provides a box plot representation, capturing the variability and range of temperature differences across different urban locations. (c) and (d) highlight the influence of BRC on Physiological Equivalent Temperature (PET), an indicator of thermal comfort. (c) visualizes the spatial distribution of PET differences, identifying regions where BRC interventions have led to improved nighttime thermal conditions. (d) displays a box plot analysis, illustrating the distribution of PET reductions and emphasizing the extent to which BRCs contribute to enhancing pedestrian-level comfort during nighttime hours.

Table S8 Comparative Summary of Urban Flood and Urban Heat Study

Aspect	Urban Flood Study [1]	Current Work (This study)
Study Area	Ahmedabad, India (16 sq. km)	Ahmedabad, India (1 sq. km)
Primary Focus	Flood mitigation using Green Infrastructure (GI)	Heat mitigation using GI
Methodologies Applied	1D-2D Hydrodynamic Modeling (DHI-MIKE+)	High-resolution urban climate modeling
Hydrological Component	Modeled flood extent, peak flood depth, runoff reduction	No direct hydrological modeling, but linked through soil moisture and evapotranspiration
Thermal Component	Not explicitly considered	Surface and air temperature reduction analysis
Data Sources	Sentinel-1 & Sentinel-2, field surveys, stormwater drainage (SWD) network data	High-resolution local meteorological & satellite data
GI Interventions Analyzed	Bioretention cells, permeable pavements, green roofs, vegetative swales	Bioretention cells, permeable pavements, green roofs
Temporal Scale	Simulated flood events for 2020-2022	Heat simulations focusing on diurnal variations
% GI Application	6%-24% per sub-catchment	3%-6% of total study area
Main Performance Metrics	Runoff reduction coefficient, flood extent, peak flood depth	Air temperature reduction, PET (Physiological Equivalent Temperature)
Main Findings	Green roofs Provided only modest runoff volume reduction (3.8%); Permeable pavements reduced flood volume by 20%, flooded area by 26.7%; Bioretention cells reduced flood volume by 24%, flooded area by 32% ;	Green roofs contributed localized cooling of up to 0.6°C, but had limited overall thermal impact; Permeable pavements provided moderate cooling benefits, reducing peak air temperature by about 0.8°C in the late afternoon; bioretention cells had the highest cooling impact, reduced temperature by upto 2°C;
Scale Comparison	GI effects were studied across an entire urban drainage network	GI effects were analyzed at a fine-scale neighborhood level

References

[1] Borah, A., Bardhan, R., Bhatia, U.: Protecting heritage: Insights into effective flood management using green infrastructure in a highly urbanized environment. International Journal of Disaster Risk Reduction **98**, 104075 (2023)