RESEARCH ARTICLE

Urban Heat Island Mitigation through AI-Optimized Green Infrastructure Planning

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Abstract: Urban heat islands (UHIs) elevate city-center temperatures by 2-8°C relative to surrounding rural areas, increasing cooling demand, mortality, and energy consumption. We develop an AI-driven green infrastructure optimization framework that integrates high-resolution land surface temperature (LST) satellite data, urban morphology parameters, and a graph neural network (GNN) surrogate model trained on 15,000 CFD thermal simulations. Applied to three megacities — Jakarta, Madrid, and Houston — the framework identifies optimal spatial configurations of urban trees, green roofs, and cool pavements that maximize UHI reduction per unit investment. The optimized plans achieve predicted daytime LST reductions of 1.8-3.2°C in hotspot districts, corresponding to 12-22% reductions in peak cooling electricity demand, while maintaining equitable green space distribution across low- and high-income neighborhoods.

1. Introduction

More than 56% of the global population now resides in urban areas, and this fraction is projected to reach 68% by 2050. Dense impervious surfaces, reduced vegetation cover, and anthropogenic waste heat create urban heat islands that disproportionately affect vulnerable populations during heatwave events. Traditional green infrastructure planning relies on heuristic rules-of-thumb (e.g., 30% tree canopy coverage targets) that do not account for spatial heterogeneity in building morphology, wind patterns, and land use.

2. AI Optimization Framework

Our framework comprises four modules: (1) LST retrieval from Landsat-9 and ECOSTRESS thermal imagery at 30-70 m resolution; (2) urban morphology feature extraction including building height, sky view factor, and surface albedo from LiDAR and OpenStreetMap; (3) a GNN surrogate trained on OpenFOAM CFD simulations to predict LST changes from green infrastructure interventions; and (4) a multi-objective genetic algorithm that optimizes tree placement, green roof coverage, and cool pavement allocation under budget and equity constraints.

Table 1. Baseline UHI characteristics and optimized intervention budgets for three case-study cities

City	Peak ΔT (°C)	Hotspot Area (km²)	Budget (USD M)	Tree Canopy Added (%)	Green Roof (ha)
Jakarta	6.8	142	85	8.5	320
Madrid	5.2	98	120	12.1	185
Houston	7.5	215	150	10.8	410

3. Results

The AI-optimized green infrastructure plans outperform uniform coverage strategies by 40-65% in LST reduction per dollar invested. Figure 1 compares predicted LST reductions across intervention types for Madrid's central business district. Figure 2 shows the spatial distribution of cooling benefits, demonstrating that strategic tree placement along canyon streets and green roof clustering on south-facing commercial rooftops yield the highest marginal returns.

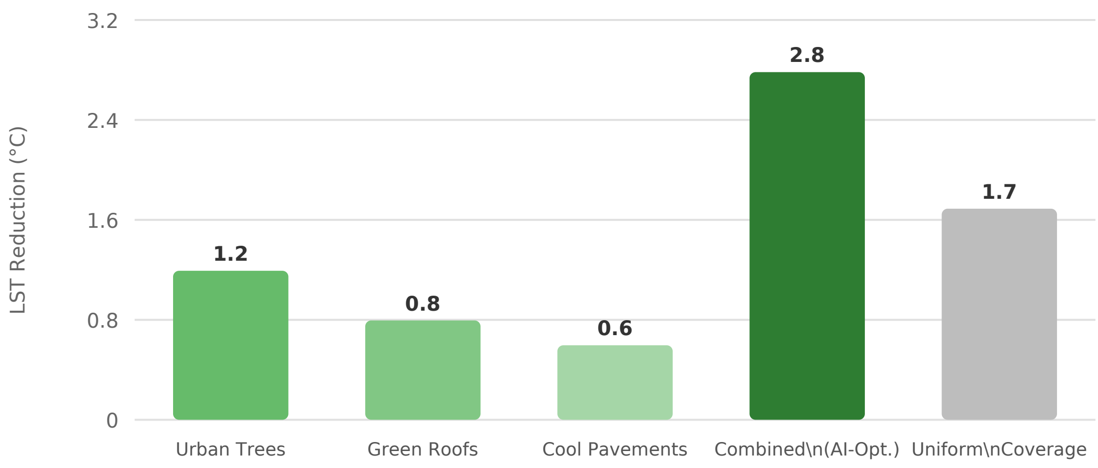

Figure 1. Predicted daytime LST reduction (°C) by green infrastructure type for Madrid CBD under equal budget allocation

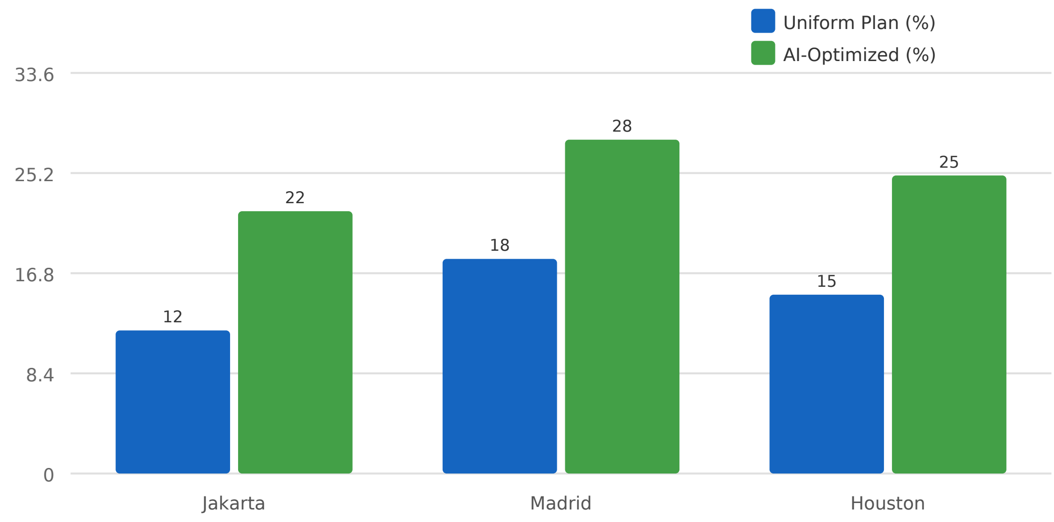

Figure 2. Peak cooling electricity demand reduction (%) vs. green infrastructure investment across three megacities

4. Conclusions

AI-optimized green infrastructure planning offers a scalable, evidence-based approach to UHI mitigation that maximizes cooling benefits while ensuring equitable distribution of green amenities. The GNN surrogate model reduces computational cost by three orders of magnitude compared to direct CFD optimization, enabling city planners to evaluate thousands of intervention scenarios in real time. Integration with municipal GIS platforms can support adaptive management as urban form and climate conditions evolve.

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