



Assessing the Synergistic Effects of Combined Nature-Based Solutions on Urban Heat Islands: A GIS-Based Multi-Scale Modeling Approach for Brussels

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ABSTRACT

Urban Heat Island (UHI) effects are intensifying as a result of rapid urbanization, posing serious risks to public health, increasing energy demand, and undermining climate resilience. This research explores the synergistic cooling potential of combining multiple Nature Based Solutions (NBS), including green roofs, urban forests, and water bodies across different spatial scales in Brussels. A GIS-based multi-scale modeling framework, integrated with ENVI-met simulations, is employed to assess the thermal impacts and feasibility of various NBS combinations. The findings aim to support evidence-based approaches for sustainable urban planning and climate adaptation.

KEYWORDS

Urban Heat Island (UHI), Nature-Based Solutions (NBS), Green infrastructure, GIS-based spatial analysis, ENVI-met, Synergistic effects, Climate resilience, Urban cooling strategies

PROBLEMS

While the effectiveness of individual Nature-Based Solutions (NBS) such as green roofs, urban trees, and water bodies in mitigating Urban Heat Island (UHI) effects has been widely documented, current research remains fragmented and scale-limited. (Table 1) provides a comparative overview of these NBS types in terms of temperature reduction and additional benefits. Most studies isolate single interventions and lack an integrated approach that considers the synergistic interactions among multiple NBS types across various urban spatial scales. This gap restricts the development of holistic, scalable strategies for climate-resilient urban planning.

Table 1. Comparative Analysis of Nature-Based Solutions (NBS) for Urban Heat Island (UHI) Mitigation: Temperature Reduction and Additional Benefits

NBS Type	Temperature Reduction(°C)	Study Reference	Study Scale	Synergistic Effects	Other Benefits
Green Roofs	2-3°C	Bianchini & Hewage (2012)	Building-level	Green Roofs + Urban Trees	Increases biodiversity
Urban Trees	Up to 5°C	Gill et al. (2007)	Neighborhood-level	None	Improves air quality
Water Bodies	3°C	Santamouris(2014)	City-level	None	Enhances urban cooling
Permeable Pavements	1-2°C	EPA(2021)	Neighborhood-level	None	Reduces runoff, improves water management
Urban Forests	4-6°C	Gill et al. (2007)	City-level	None	Increases biodiversity

OBJECTIVE/HYPOTHESIS

1. Assess the individual and combined cooling effects of various NBS (e.g., green roofs, urban forests, water bodies) on UHI in Brussels. 2. Develop and validate a GIS-based multi-scale model, using ENVI-met, to simulate NBS impacts at building, neighborhood, and city scales. 3. Evaluate the cost-effectiveness, scalability, and feasibility of different NBS strategies under Brussels' urban conditions. 4.Recommend effective, evidence-based NBS strategies for policymakers to enhance climate resilience. 5. Explore the long-term sustainability and co-benefits of NBS, including carbon reduction, biodiversity enhancement, and improved quality of life.

AUDIENCE

Urban planners, climate researchers, policymakers, environmental scientists, sustainable development professionals.

RESEARCH QUESTION

1. What are the individual and combined effects of different Nature-Based Solutions (NBS) on mitigating the Urban Heat Island (UHI) effect in Brussels? 2. How can a GIS-based multi-scale model be developed and validated to simulate the thermal impact of NBS on different urban scales in Brussels, ranging from individual buildings to entire neighborhoods? 3. Which NBS configurations provide the most cost-effective and feasible solutions for reducing UHI intensity in Brussels, and how can these configurations be optimized for large-scale implementation? 4. What are the long-term environmental and social benefits of implementing NBS in Brussels?

ORIGINALITY

This study addresses a key gap in Urban Heat Island (UHI) research by systematically evaluating the synergistic cooling effects of different combinations of Nature-Based Solutions (NBS), rather than studying each strategy in isolation as done in most previous studies. Furthermore, it offers a multi-scale perspective, comparing the performance of NBS combinations at the building, neighborhood, and broader urban scales. This research provides a comprehensive framework to optimize NBS deployment for urban climate resilience.



METHODOLOGY

- Remote sensing data (e.g., Landsat 8, Sentinel-2) will be used to map urban vegetation and land cover.
- ENVI-met microclimate simulations will test the thermal performance of individual and combined NBS strategies.
- GIS-based spatial analysis will model NBS impacts at building, neighborhood, and city levels.
- Performance metrics include surface temperature reduction, spatial coverage, and feasibility.
- (Figure 1) illustrates the overall research methodology and workflow combining these approaches across different spatial scales. (Figure 2) was made by Akogo(2022) shows the spatial distribution of land surface temperature during a 2018 heat wave in Brussels, emphasizing the importance of accurate spatial data in UHI assessment.

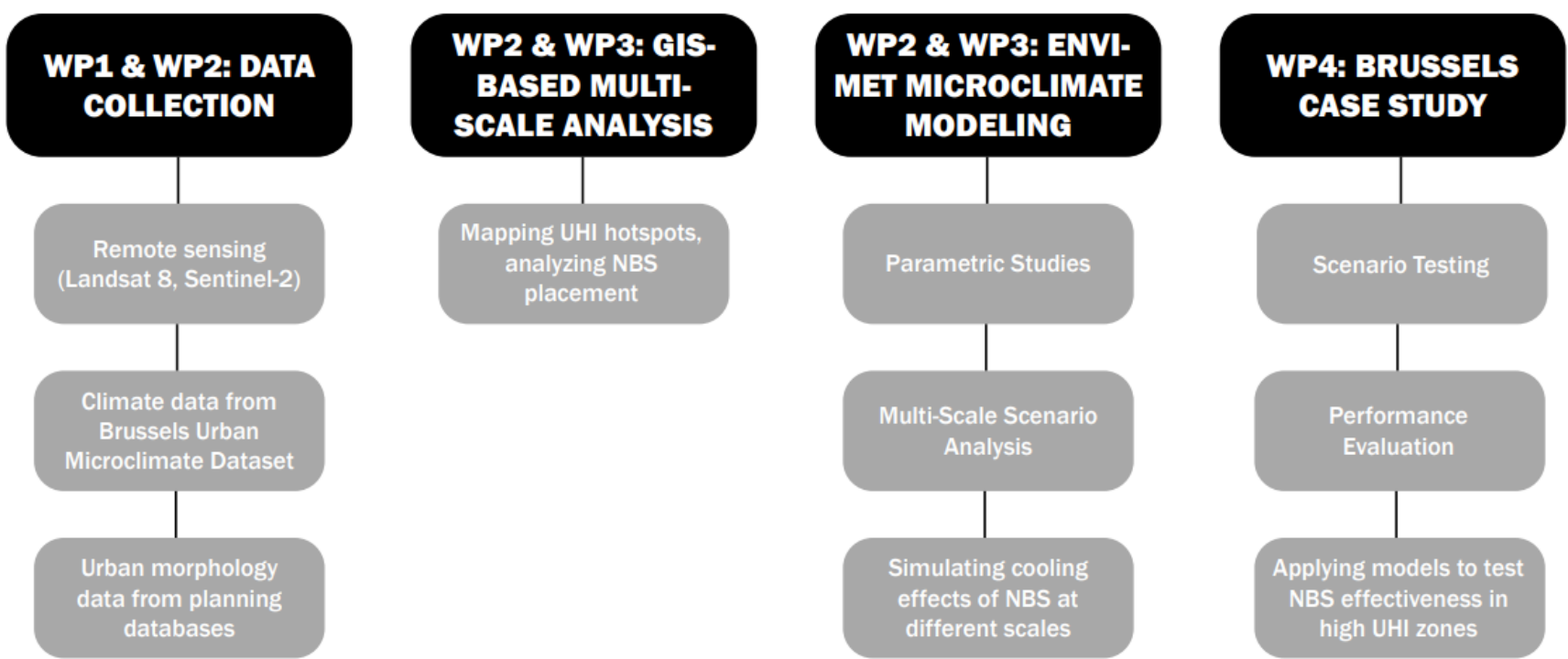


Figure 1. Research methodology framework and workflow

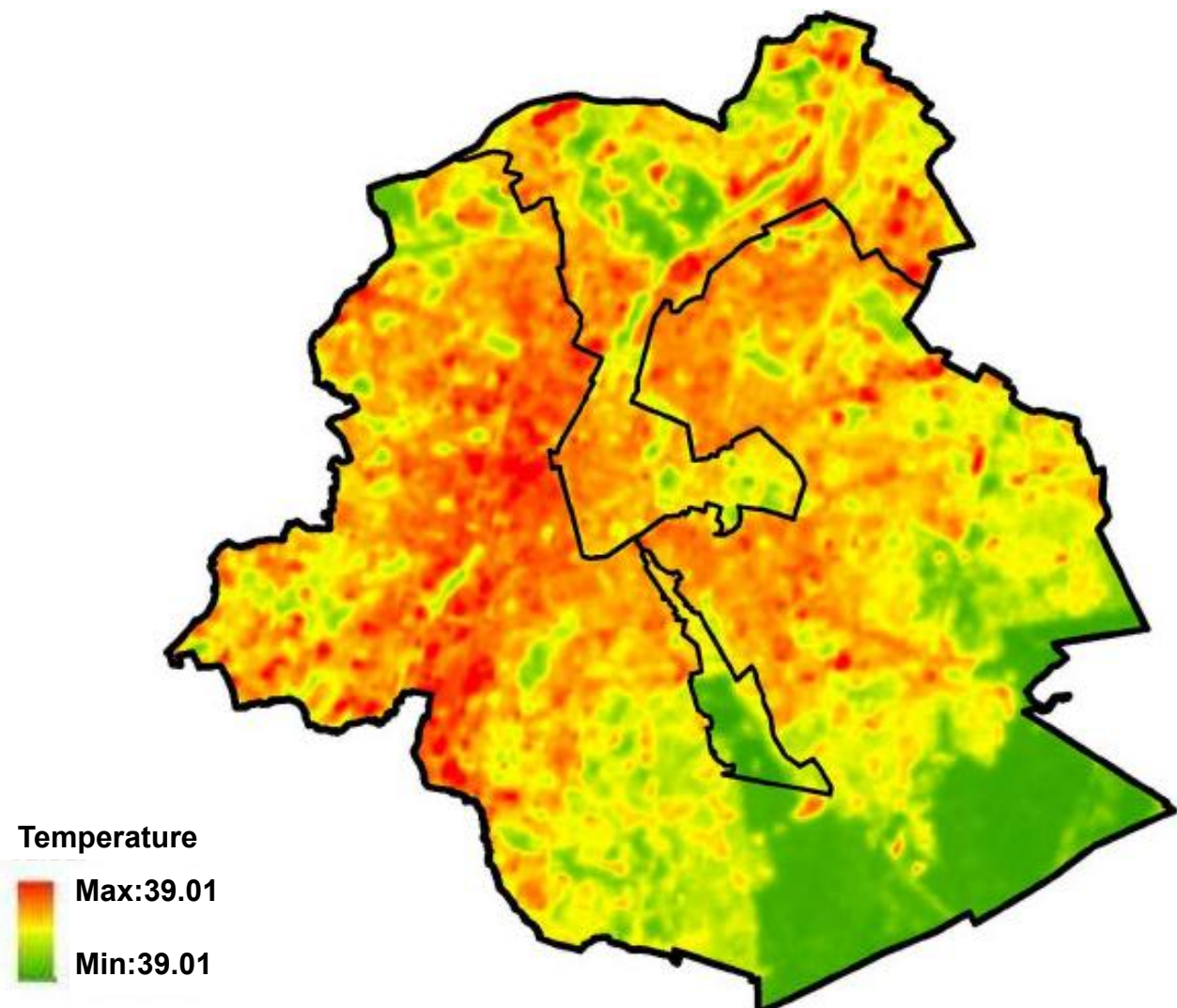


Figure 2. Land Surface Temperature Map of the heat wave from 08/02/2018 in Brussels

RESULTS

The expected outcomes of this research on Nature-Based Solutions (NBS) in Brussels will provide valuable insights for urban planners, policymakers, and researchers. The findings will highlight the cooling benefits of combined NBS interventions, such as green roofs, urban trees, and water bodies, and demonstrate their cost-effectiveness and scalability. This study will serve as a guide for the strategic implementation of NBS to mitigate the Urban Heat Island (UHI) effect in Brussels. Furthermore, I hope the results will offer a framework for future research and policy development on climate resilience in urban environments, providing a foundation for similar studies in other cities.

CONCLUSION

Integrated NBS interventions can significantly enhance urban cooling and climate adaptation. This research will deliver practical insights for implementing multi-scale NBS strategies in Brussels and beyond.

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