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A Strategic Framework for Decision-Making: Enhancing Community Health and Climate Resilience During Extreme Heat Events

Waterloo Climate Institute Technical Brief

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ABSTRACT

This research advances urban sustainability and informs climate adaptation and community resilience strategies by evaluating how investments in natural infrastructure impact public health, environmental risk mitigation, and economic productivity. Focusing on extreme heat, the research introduces an evidence-based decision-making approach that employs advanced statistical and simulation models to predict the benefits of increased green cover—such as reduced temperatures, improved public health outcomes, and enhanced outdoor worker productivity. The model underpinning the research integrates community-level census and health data with localized weather measurements to project health outcomes, including mortality, hospitalizations, emergency calls, and ER visits. It also estimates the economic value of natural infrastructure through reduced mortality, decreased healthcare utilization, and improved labor productivity. This approach helps municipalities and decision makers make a strong case for evaluating nature-based mitigation and adaptation measures to effectively respond to climate changes.

Developed in partnership with local stakeholders, applications of the model have been carried out in 10 municipalities in Ontario and Nova Scotia. The analyses equip municipalities with defensible, data-driven results to prioritize investments in natural infrastructure as a cost-effective strategy to reduce climate vulnerability and promote sustainable, healthy communities.

Keywords: natural infrastructure, climate impacts, extreme weather, health benefits, urban sustainability, extreme heat.

JEFFREY WILSON

Associate Professor,
University of Waterloo

MOHAMED DARDIR

Adjunct Assistant Professor,
University of Waterloo

Assistant Professor of Architecture,
South Dakota State University

KEY MESSAGES

- **Urban Greenery Reduces Heat:** Advanced microclimate simulations demonstrate that increased urban green cover significantly lowers city temperatures, offering a scalable solution for heat mitigation.
- **Health Benefits:** Expanding green cover is linked to measurable reductions in heat-related health impacts, including premature deaths, emergency department visits, hospital admissions, and ambulance calls.
- **Economic Returns on Investment:** Natural infrastructure investments reduce energy demand, lower healthcare costs, and boost workforce productivity—delivering strong economic returns for municipalities.
- **Decision-making Framework:** A data-driven decision-making framework that combines environmental, health, and economic metrics equips policymakers with actionable insights to guide climate-resilient planning and investment.

INTRODUCTION
INVESTING IN NATURAL INFRASTRUCTURE

Climate change is intensifying urban heat, posing serious risks to public health, straining healthcare systems, and reducing quality of life. Extreme heat events increase mortality, hospitalizations, and emergency service use, particularly in vulnerable communities. Urban greenery—such as parks, tree canopies, green roofs, and ground cover—offers a proven, nature-based solution by reducing surface temperatures and cooling the urban environment. Increased green cover has been shown to reduce heatwave intensity and support healthier, more livable cities (US EPA, 2015; Henderson et al., 2022). Strategic investments in natural infrastructure can mitigate the impacts of climate change while delivering multiple co-benefits.

To encourage municipal investments in natural infrastructure requires a comprehensive and evidence-based approach that demonstrates the environmental, economic, and health benefits. The current perception is that expenditures to maintain or expand natural infrastructure are costs to municipalities. As a result, these investments are often overlooked due to limited budgets and competing priorities. By demonstrating the economic value of natural infrastructure—including reduced mortality, avoided healthcare costs, and productivity gains—this research reframes natural infrastructure as a strategic investment. The goal is to equip municipal, provincial and federal policy makes and community leaders with actionable data and a defensible framework to support climate-resilient investments and urban development.

BACKGROUND

EXTREME HEAT IN CANADA

Climate change hazards, such as extreme heat, pose significant risks to urban areas. These hazards result in catastrophic economic costs, loss of life, and negative health outcomes. The consequences include increased energy consumption for cooling, higher healthcare costs due to heat-related impacts on health, and reduced productivity. Climate projections for Canada suggest the rate of severe heat events will increase dramatically during this century (Environment and Climate Change Canada, 2023). Heatwaves are the climate hazards of most critical concern facing Canadian municipalities and will result in significant economic losses to governments, businesses, and households (Canadian Climate Institute, 2022). The International Panel on Climate Change (IPCC) continues to provide strong evidence of increasingly frequent and extreme weather events as consequences of climate change (Intergovernmental Panel on Climate Change, 2022). These climate change hazards result in catastrophic economic costs to Canadians, substantial loss of life and negative health outcomes (Canadian Climate Institute, 2022; DeClerq, 2022; Henderson et al., 2022). For example, the 2021 heatwave in BC resulted in 595 heat-related deaths making it the deadliest climate event in Canadian history (Henderson et al., 2022). In addition to causing premature mortality, extreme heat events strain the health care system leading to substantially higher rates of ambulance calls (29% higher), hospital admissions for coronary heart disease (1.2% higher), and stroke (1.8% higher) (Bassil et al., 2011; Bai et al., 2016, 2018). The elderly, homeless, and those living with chronic conditions are especially vulnerable (Yardley et al., 2011; Buchin et al., 2016). Projections by the Toronto and Region Conservation Authority (TRCA) suggest a six-fold increase in the number of extreme heat days by the year 2100 in Southern Ontario, causing death and straining emergency response and health system services (TRCA, 2021). Modelling by the Intact Centre on Climate Adaptation, projects by the year 2080 extreme heat will impact more than 17 million Canadians living in metropolitan areas (Eyquem and Feltmate, 2022).

To minimize the associated impacts and damage costs of climate change and extreme weather events, the IPCC's latest report, Meeting Report on Climate Change and Cities July 2024, supports investments in natural

infrastructure as a cornerstone of climate adaptation strategies and ecosystem protection (IPCC, 2024). Natural infrastructure often used interchangeably with the terms green infrastructure and nature-based solutions refers to existing or restored natural systems (i.e., forests, floodplains, and wetlands) to increase resilience to climate impacts resulting in environmental, economic, and social co-benefits (Luedke, 2019). Expanding vegetation cover in urban areas, for example, offers multiple benefits to the urban microclimate, including reducing heatwave intensity (US EPA, 2015; Henderson et al., 2022). Many cities, however, struggle to implement and maintain sufficient natural infrastructure due to financial constraints, lack of political will, and competing land-use priorities.

This research provides a comprehensive framework to inform local decision-making by integrating environmental, health, and economic considerations. Unlike previous models that isolate specific impacts or focus on individual-level responses, this holistic approach captures the interconnected nature of community outcomes (Chapman et al., 2018; Qi, Ding & Lim, 2022; Salata et al., 2017; Santamouris et al., 2020; Venter et al., 2020; Sadeghi et al., 2022).

DECISION-MAKING FRAMEWORK: BENEFITS, AND LIMITATIONS

This research establishes a decision-making framework designed to guide urban development projects related to natural infrastructure, specifically considering community health and climate resilience. The framework integrates statistical and simulation methods to estimate the environmental, health, and economic co-benefits of increasing urban greenery, such as tree canopies and ground vegetation, as a strategy for mitigating extreme heat.

METHODOLOGY

The integrated framework combines two complementary approaches:

Statistical Modelling: Employs regression analysis on fine-resolution daily public health datasets to predict mortality rates and emergency department visits based on variations in outdoor environmental conditions.

Microclimate Simulation: Utilizes an environmental assessment tool to model how changes in greenery cover impact ambient temperatures, outdoor heat stress, and buildings' energy consumption.

The key co-benefits assessed by the framework include:

- **Environmental:** Improvements in local microclimate, including temperature moderation and heat stress reduction.

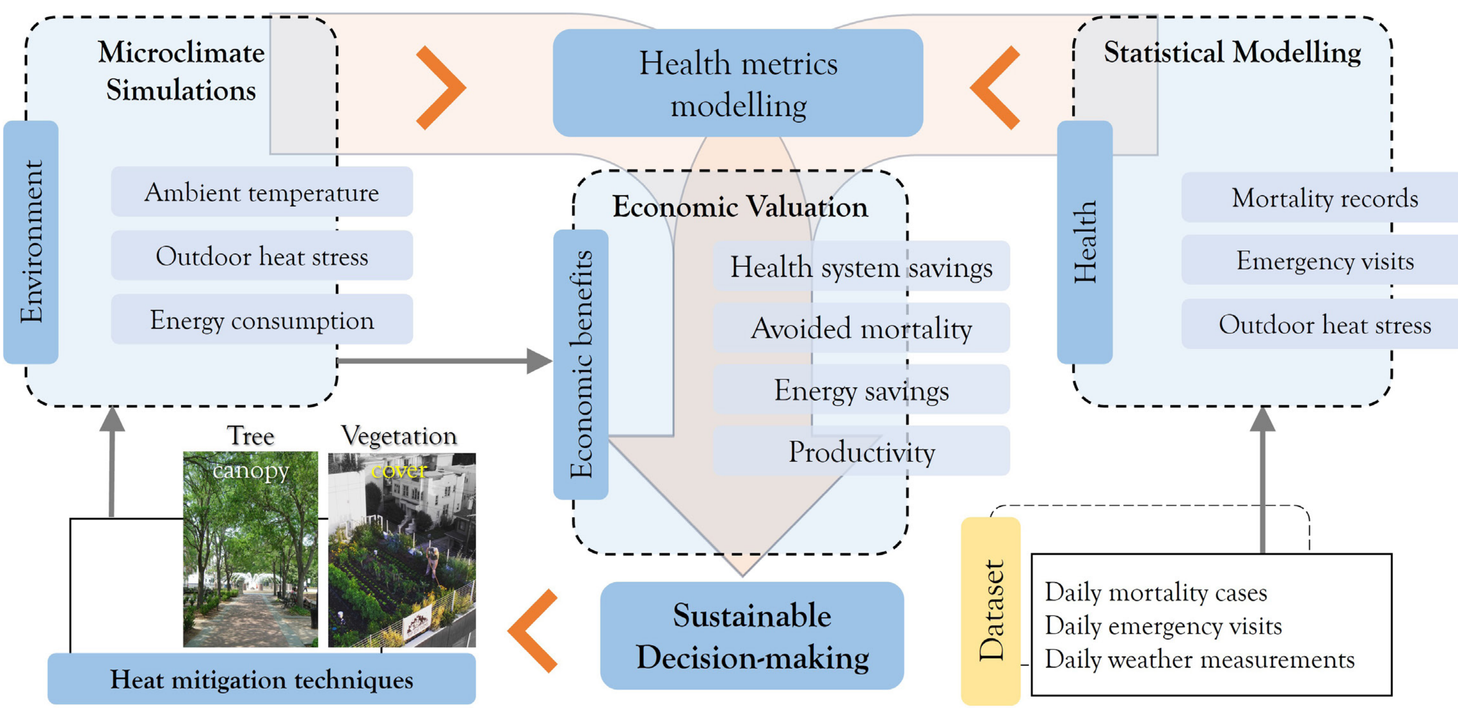
- **Health:** Reduced heat-related mortality and morbidity, improving overall public health outcomes.
- **Economic:** Quantified direct and indirect benefits such as healthcare cost savings, lower energy expenditures, and decreased productivity losses.

INNOVATION AND LIMITATIONS

The novel aspect of this approach lies in its use of high-resolution data for precise statistical modelling. Nonetheless, the research faces several limitations:

- **Limited Health Data:** Availability of detailed health data to comprehensively analyze health outcomes related to green space exposure was restricted.
- **Census Data Constraints:** Annual census profiles restricted the integration of granular community-level data into statistical analyses, limiting the measurement of heat exposure impacts on specific populations, such as low-income groups.
- **Scope of Health Outcomes:** The study primarily focused on specific cause-based health records. Consequently, other important health outcomes, such as heat exhaustion among outdoor workers or school children, may not have been captured.

These limitations underscore the need for future research to expand upon current findings, exploring additional health outcomes and impacts to offer a more holistic understanding of how green spaces influence community health and well-being.



Decision-making framework to predict environmental, health, and economic co-benefit

ARGUMENTS: MODELLING THE PUBLIC HEALTH IMPACTS OF EXTREME HEAT EVENTS

This research uses a comprehensive modelling approach that integrates community-level census and health data with localized weather measurements to project the public health impacts of extreme heat. Key outcomes include projected mortality, hospital admissions, emergency department visits, and ambulance calls. Applications to date have focused on increasing urban vegetation cover, however, it can be extended to other natural capital investment scenarios.

KEY MODEL COMPONENTS:

Environmental Impact Assessment: The model applies an enhanced version of the Urban Weather Generator (UWG) to simulate the impact of increased green cover on local microclimates. It evaluates changes in air temperature, humidity, wind speed, and outdoor heat stress. Results show that even modest increases in vegetation can significantly reduce urban temperatures and improve overall environmental conditions.

Health Outcome Predictions: Using advanced statistical techniques, including non-linear multiple regression and clustering controls (Dardir et al., 2023), the model predicts the impact of heat on health outcomes. The analysis is based on 15 years of daily health and weather data during warm seasons. Findings indicate that increasing urban greenery can meaningfully reduce heat-related health risks, particularly in vulnerable populations.

Economic Benefit Analysis: The model estimates cost savings from reduced healthcare use, lower energy demand, and improved worker productivity due to a cooler urban environment. These quantified benefits provide a rationale for investing in natural infrastructure as a cost-effective climate adaptation strategy.

Integrated Modelling Approach: The integrated modelling approach offers an evidence-based analysis to help municipalities and community leaders evaluate specific urban development strategies. It is designed for flexible application, enabling decision-makers to assess the potential impacts of various natural infrastructure investments.

KEY FINDINGS

The following key findings highlight the co-benefits of expanding natural infrastructure in urban areas:

1. ENVIRONMENTAL BENEFITS

- Increasing urban greenery—including tree canopies, green roofs, and ground cover vegetation—reduces both maximum and minimum ambient temperatures. This mitigates outdoor heat stress and decreases the risk of extreme heat exposure during heat waves.
- Preserving and expanding urban natural infrastructure enhances biodiversity, strengthens ecosystem resilience, improves air quality, and serves as an effective carbon sink.

2. HEALTH BENEFITS

- Greater greenery coverage reduces overall summer temperatures, thereby lowering heat-related health risks.
- Natural infrastructure helps decrease daily average humidex levels and short-term humidex spikes during heat waves, resulting in fewer heat-related deaths and reduced emergency department visits.

3. ECONOMIC BENEFITS

- Mitigating exposure to high temperatures and extreme heat delivers direct economic advantages through reduced premature mortality, decreased reliance on healthcare services, lower energy consumption, and increased worker productivity.

CONCLUSION

The methodologies and findings outlined in this technical brief provide a robust framework for municipal authorities and policymakers to make community-oriented decisions that support healthier, more sustainable urban environments and enhance climate resilience. Currently, modelling applications primarily address urban greenery investments aimed at mitigating extreme heat impacts. However, this model is adaptable for other extreme weather scenarios, including flooding and high wind events, and can incorporate various types of natural infrastructure projects.

FUTURE WORK

Future research will broaden the scope to address additional climate-related hazards and environmental risks impacting Canadian communities, such as flooding, high wind events, and poor air quality.

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