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HEALTH-INFORMED HEAT MITIGATION APPROACH

Case Study of The Regional Municipality of York

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Extreme heat events are predicted to rise in the Greater Toronto Area due to climate change, leading to increased heat-related illnesses and mortalities. This study introduces a novel framework to understand how greenery cover can protect people from heat stress and build community resilience to climate change. Enriching the urban greenery cover is introduced as an important and *cost-effective* strategy to mitigate the urban heat island effect and provide cooling benefits.

The study applies a novel framework that combines statistical and simulation modelling using meteorological and health records data to estimate the economic benefits of reduced health impacts associated with increasing the urban greenery cover. The framework was applied to two residential neighbourhoods in York Region (Markham Village and East Woodbridge) representing typical urban neighbourhoods in Southern Ontario. The study examined the health impacts of heat exposure under two scenarios: (1) expected heat exposure in a typical summer and (2) expected heat exposure during an extreme heat event. Policymakers can utilize this approach for estimating community health responses and the economic benefits of municipal investments to mitigate the impacts of hot temperatures and extreme heat events.

Summary Findings:

- Even short-term rises in outdoor heat stress (humidex) result in higher mortality rates and health system use.
- Increasing neighbourhood greenery cover reduces maximum and minimum ambient temperatures and reduces humidex values during heat waves.
- Increasing greenery cover reduces overall temperatures during summer months lowering health-related risks due to hot temperatures.
- Increasing greenery cover reduces the daily average humidex during a heat wave event resulting in fewer heat-related mortalities and emergency department visits.
- Mitigating exposure to extreme heat results in direct economic benefits attributed to reduced use of health system services, lower energy use, and increased worker productivity.

Study Overview

The study applies a novel framework to support decision-makers in taking action to mitigate the urban heat island (UHI) effect within residential neighbourhoods in Southern Ontario. The framework assesses the impacts of enriching greenery cover on temperature, outdoor thermal comfort, and building energy consumption. It also assesses the co-benefits of reduced exposure to excessive heat on population health and worker productivity. The model is applied to two case study neighbourhoods in The Regional Municipality of York (i.e., York Region), Markham Village and East Woodbridge (as shown in Figure 1), to explore the heat mitigation potential of increasing canopy cover.

The developed framework predicts population health impacts based on the historical relationship between heat exposure and health records for 17 consecutive years (2003 to 2019). According to the relationship, the study builds prediction models to forecast the health impacts of heat exposure for two scenarios: expected heat exposure in a typical summer and expected heat exposure during an extreme heat event.

Based on the forecasted impacts, the model then explores the economic benefits of increasing greenery cover as a heat mitigation strategy. The estimated economic benefits include health system savings associated with fewer ambulatory calls and emergency department visits, avoided premature mortalities, building energy savings, and avoided productivity losses.

Figure 1: Case studies

Markham Village

East Woodbridge

The study investigates two scenarios for increasing the greenery cover: 1) the intense greenery cover (Intense GC) scenario, which defines the maximum allowable tree canopy and vegetation cover, and 2) the moderate greenery cover (Moderate GC) scenario, which provides around 50% of the allowable tree canopy and vegetation cover. The maximum allowable area refers to available spaces for planting trees; this includes municipal parks, roadsides, and urban interspaces between buildings. The following results for York Region are based on the analysis of both neighbourhoods. A detailed description of the methodology, approach, and specific results for each neighborhood are presented in the technical report.

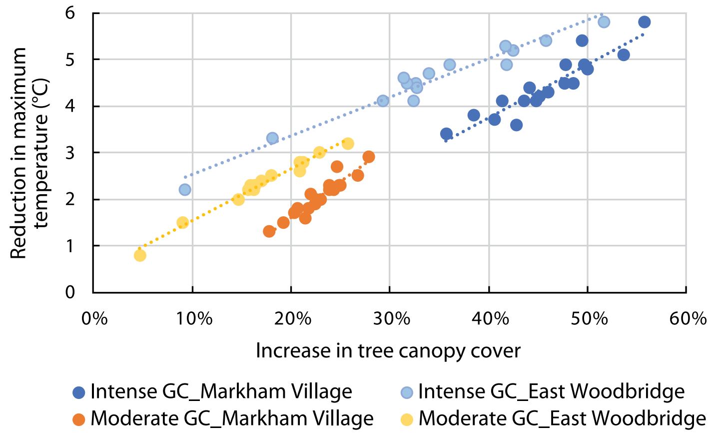
Tree canopy cover refers to the tree crowns that provide shading to the ground and buildings. **Greenery cover** includes tree canopy but also includes ground vegetation cover like grass cover, shrubs and bushes.

Environmental Impacts

Daily Maximum Temperatures

Increasing greenery cover has a significant impact on reducing the ambient air temperature and temperature-humidity index (humidex). Greater reductions in ambient temperature have been observed with greater percentages of greenery cover. Figure 2 shows the increased reductions in daily maximum temperatures associated with tree canopy cover at various locations within the case study neighbourhoods. For example, increasing tree canopy cover by 40% to 50% reduces the maximum temperature by up to 5°C.

Figure 2: Reductions in maximum temperature associated with increases in greenery cover



Number of Hot Days

Increasing greenery cover reduces the number of hot days in a typical summer season. Hot days are defined when the maximum temperature is recorded as 30°C or more. In a typical summer season, case study neighbourhoods would experience 14 hot days per year. By applying the Intense GC scenario, no hot days are recorded in both neighbourhoods during the summer season.

Humidex

Increasing greenery cover reduces the daily average humidex during a heat wave event lowering the risk of exposure to dangerous health conditions. The humidex is used to identify outdoor heat stress which defines the human body's response to heat. According to Environment Canada, humidex defines the degree of comfort as follows:

The degree of comfort (Humidex values)

- 20 to 29: Little to no discomfort
- 30 to 39: Some discomfort
- 40 to 45: Great discomfort; avoid exertion
- Above 45: Dangerous; heat stroke quite possible

Using a forecasted heat wave scenario based on modeling from Environment and Climate Change Canada, the daily average humidex was recorded as 34 with a daily maximum value of 54 during extreme heat conditions presenting dangerous health conditions. The relationship between the daily average humidex and existing tree canopy cover is shown in Figure 3 for both neighbourhoods. The modelling results of existing tree canopy indicate a reduction of 0.33 in average humidex with each 10% increase in tree canopy cover.

Figure 3: Daily average humidex in association with existing tree canopy cover for both neighbourhoods

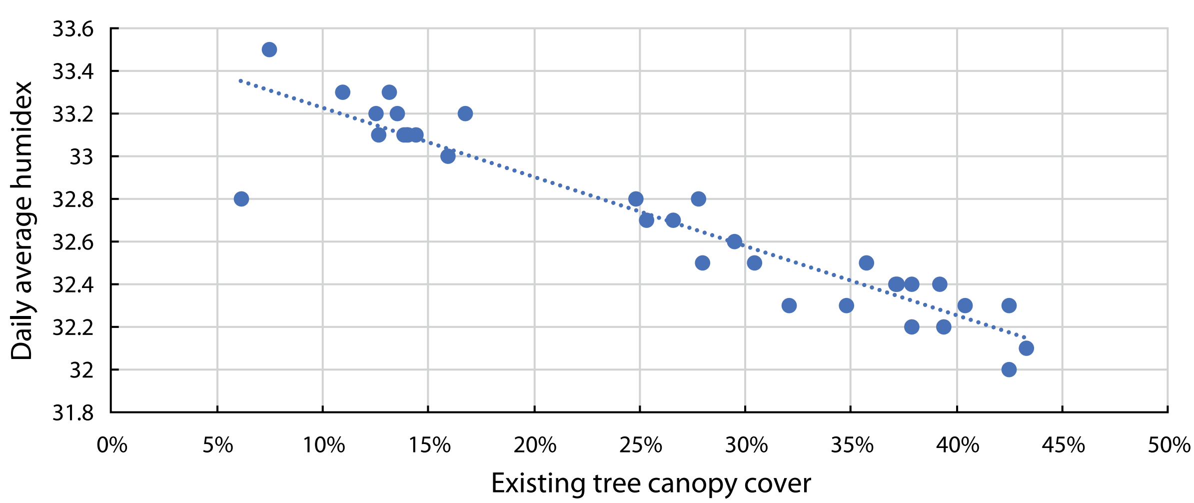
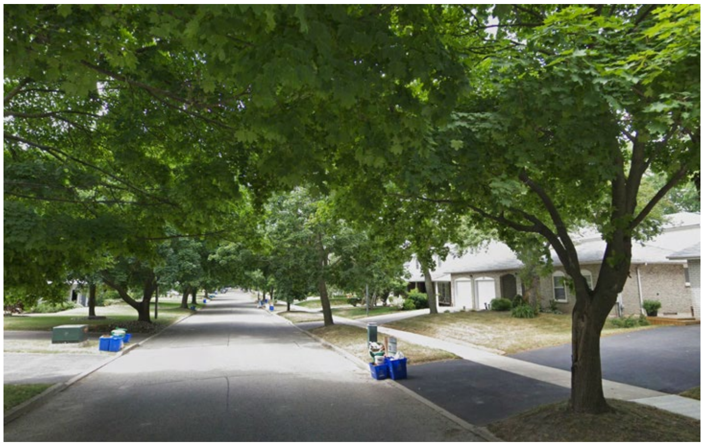


Figure 4: Examples of intense greenery covers in the Greater Toronto Area



Source: Google Maps

Implementing the intense greenery cover scenarios for both neighbourhoods results in a 12.8% reduction in the daily average humidex and a reduction of 16.8% in the daily maximum humidex reducing neighbourhood exposure to dangerous health conditions during heat waves. Figure 4 shows some examples around the Greater Toronto Area of intense greenery covers.

DAILY AVERAGE HUMIDEX ↘ **12.8%**

DAILY MAXIMUM HUMIDEX ↘ **16.8%**

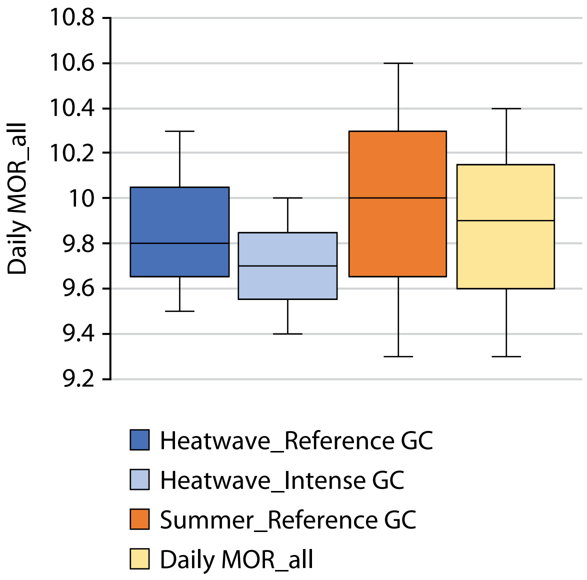
Health Impacts

On Emergency Department Visits and Mortality Rates

Emergency department visits and mortality rates are correlated with higher humidex values during extreme heat events (humidex ~ 40). Based on data analyses, the impact of humidex on health records was higher in warm months (transitional seasons) than in summer seasons. This illustrates the potential impacts that climate change can have on health when heat events occur unexpectedly during these periods.

The analysis confirmed the direct impact of increased humidex on emergency department visits (within the same day of heat event occurrence); and a short-term impact (within 4 days) of increased humidex on mortality rates. The health predictions were based on York Region rates assuming similar GC scenarios to be applied across the Region. The modelling shows that by applying the Intense GC, approximately 2 lives can be saved every 10 days during a heat wave. During the whole summer season, the Intense GC scenario resulted in an average of 15 avoided deaths, 255 avoided visits to emergency departments and 62 fewer ambulatory calls. For details on methods and approach refer to technical report. This reduction is greater during the extreme weather scenario (heatwave), as shown in Figure 5. This refers to the efficiency of denser greenery covers in reducing mortalities during the hot season.

Figure 5: Predictions of all-cause mortality when applying the intense GC scenario



Economic Benefits

Extending the assumptions to York Region, mitigating the impact of extreme heat under the intense greenery cover scenario provides direct economic benefits totalling 165.5 million dollars seasonally[1] ($CAD 2022) as a result of avoided premature mortality, health system savings, lower energy use, and increased worker productivity (Table 1). The health system savings include reduced emergency department visits and reduced ambulatory calls. Lower energy use is attributed to a reduced need for air conditioning and other cooling-related energy use. Increased worker productivity refers to avoided loss of time due to fewer breaks attributed to hot temperatures and heat exposure. For a detailed description of the calculation, it is recommended to refer to the technical report.

Table 1: Economic benefits of mitigating the impact of extreme heat under intense green cover scenario

Avoided premature mortality	$133,500,000[2]
Reduced emergency department visits	$83,280
Reduced ambulatory calls	$297,600[3]
Energy savings	$5,270,000[4]
Increased worker productivity	$26,370,000

Conclusion

The applied framework is based on a historical dataset from 2003 to 2019 for York Region. The conclusions illustrate the environmental, health, and economic benefits of increasing greenery cover as a heat mitigation strategy. Hot days are expected to increase in the GTA from 20 days per year to 66 days by 2050 based on severe climate change scenarios. The proposed method presented in this report can be used by other municipalities as a decision-making tool to assess the benefits of nature-based solutions in urban development plans. The modelling predictions offer insights to other municipalities with similar economic and demographic conditions for the expected potential benefits associated with intensifying the urban greenery cover as a heat mitigation technique.

Future studies could include environmental, social, and demographic variables in the health records predictions. Further modelling could also identify vulnerable neighbourhoods that would benefit most by increasing greenery cover or implementing other heat mitigation measures. A more detailed cost estimation model is recommended to consider the life cycle costs, operational costs, and productivity benefits. Also, practical information about trees should be considered, such as the time required for tree growth, selected tree species, and the life expectancy of trees.

The method and findings of this report are related to a recently published paper by the authors entitled "Health-informed predictive regression for statistical-simulation decision-making in urban heat mitigation" in the *Journal of Sustainable Cities and Society*. Link to paper: https://doi.org/10.1016/j.scs.2023.104853

1. All attributes are related to the hot season. 2. Based on a recommended estimate for policy analysis in Canada examining the willingness to pay Canadians to reduce the risk of premature death, the economic cost of an avoided premature death was adopted at CAD $8.9 million (15 fewer deaths were predicted each season based on greenery cover scenario); see the technical report for more details. 3. Based on historical data, we assume that within the summer season there are 20 hot days (temperature over 30°C). Since the reduction in ambulatory calls were based on hot days, we multiplied the daily reductions (found in the technical report) by 20.
4. Similar to ambulatory calls, the energy savings was based on 20 hot days. Thus, we multiplied the daily energy savings (found in the technical report) by 20.

Funding for the project was provided by the Greenbelt Foundation which supports research that identifies ways to leverage Greenbelt systems to increase benefits to residents and communities and advance a sustainable and resilient region.

In 2020, the Greenbelt Foundation and EcoHealth Ontario released two case studies on the economic, public health and community well-being benefits of urban green space. Previous studies in Ontario have examined the health benefits of green space, but these were the first to calculate the health savings from those benefits using a cost optimization tool for assessing different natural infrastructure scenarios. The results of this work showed the importance of strategically planning, protecting, and enhancing green space in and around the Greenbelt, as a means for improving human health benefits and reducing community vulnerability to the impacts of climate change. This report builds on that initial work to provide decision-makers with a more comprehensive resource to understand the contribution of green space enhancements to the health of local communities.

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