EcoHealth Economic Valuation Framework
Quantifying the Health Return on Investments in Greenspace

Case Study: Increasing Tree Canopy, Brampton, Ontario

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Prepared for the Greenbelt Foundation and EcoHealth Ontario in partnership with Toronto Region Conservation Authority and Region of Peel Public Health

By Green Analytics Corp.

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1. Background

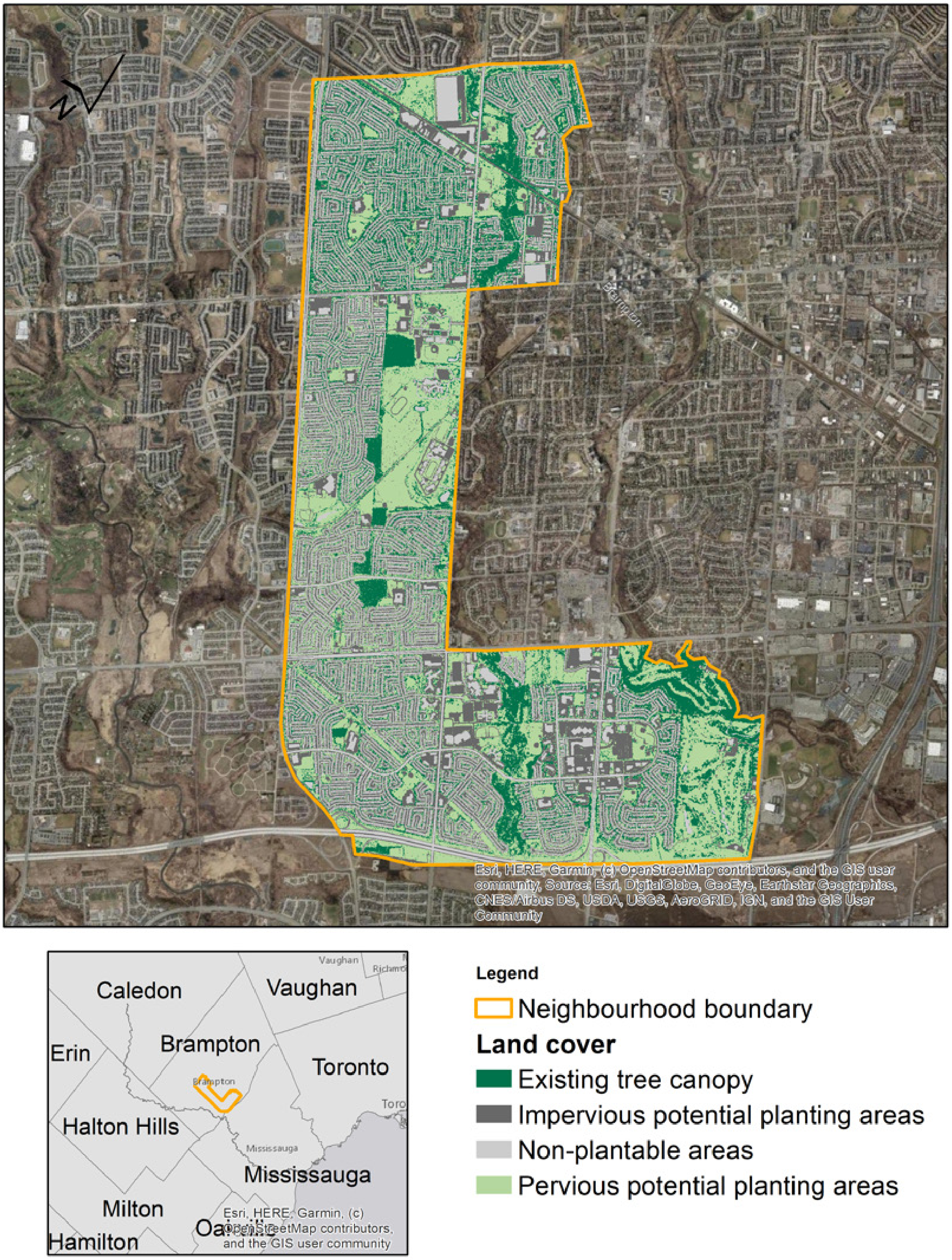
This case study estimates the monetary value of health benefits that would result from increasing tree canopy cover under two different tree planting scenarios in a Brampton, Ontario, neighbourhood. The project supports the Peel Climate Change Partnership Green Natural Infrastructure Strategy, which aims to increase tree canopy to mitigate very hot temperatures and associated negative health outcomes in high priority neighbourhoods in Peel Region. By 2080, annual mean temperatures in Peel Region are projected to rise as much as 5 degrees Celsius from current levels, and the frequency of very hot days[1] are projected to increase by as much as 5 times from current levels (12 to 62 days) (Region of Peel, 2018).

1.1. Case Study Community

The case study is a heat vulnerable community located in Brampton, Ontario[2]. The study area, outlined in Figure 1, is approximately 1,521 hectares and is primarily a residential area. According to Statistics Canada's 2016 Census, the estimated population of the Brampton study area is 73,652. A socio-demographic profile of the study area is provided in Appendix 1 including a demographic profile comparison between the study area and the entire Regional Municipality of Peel.

1 A very hot day is when the daily maximum temperature recorded is greater than 30 degrees Celsius (Climate Data, 2020).
2 Heat vulnerable neighbourhood is an area that is exposed to very hot temperatures.

FIGURE 1: Brampton study area



The case study community is one of three communities within Peel Region identified as a high heat vulnerable community based on an assessment of heat vulnerability carried out in 2019 (defined below). Of the three communities, the selected study area was chosen as a case study because its location within Peel engages several partners, thereby providing the best opportunity for knowledge transfer. The selected community spans the jurisdictional boundaries of both the Toronto Region Conservation Authority (TRCA) and the Credit Valley Conservation (CVC) Authority and includes the Fletcher Creek neighbourhood and County Court neighbourhood, two neighbourhoods participating in the Sustainable Neighbourhood Action Program (SNAP) run by TRCA and CVC.

1.2. Heat Vulnerability Index

Hot temperatures and air pollution increase probability of morbidity and mortality, and level of vulnerability is dependent on an individual's physiological, social, and economic conditions (Health Canada, 2011; Ho, Knudby, Chi, Aminipouri, & Lai, 2018).[3] Heat vulnerability was assessed according to the heat vulnerability index, which ranks vulnerability based on three criteria: exposure, sensitivity, and adaptive capacity (Figure 2).

- Exposure: where are surface temperatures highest?
- Sensitivity: where are more sensitive populations located, including the elderly and very young?
- Adaptive capacity: where are the places residents can cool down?

FIGURE 2: Heat vulnerable locations (shown bottom right) in Peel region using indicators of exposure (red, top left), sensitivity (blue, top right), and adaptive capacity (green, bottom left).

3 While the focus is often on temperatures classified as very hot, hot temperatures below 'very hot levels' are shown to increase risk of mortality as well (Chen, et al., 2016).

Table 1 reports heat vulnerability variables for the Brampton study area. The exposure variable is based on the number of very hot days as reported for the Toronto Pearson International Airport, the closest weather station to the case study location. A very hot day is when maximum temperature is recorded higher than 30 degrees Celsius (Environment and Climate Change Canada, 2019). From 2010-2019, 203 very hot days were recorded at the Toronto Pearson Airport weather station.

The sensitivity variable is calculated based on percent of the community that are elderly and children, percent of population living in low income, and percent of population speaking neither French nor English. In the Brampton study area, 31% percent of the population are children or seniors, 14% of the population are considered low-income and 6% of the population do not speak English or French (Statistics Canada, 2016; Region of Peel, 2020; Environics Analytics, 2020).

The adaptability variable indicates the level of access to transit and cooling facilities. A total of 182 bus stops and 1 nearest train station are found in the case study area. Also, four (4) recreation and community centers, four (4) libraries, and three (3) shopping centers and malls are present in the proximity of the target location (Google Maps, 2020).

TABLE 1: Heat Vulnerability Index of Brampton Study Area

VARIABLES	INDICATORS	RESULTS
Exposure	Surface Temperature: Total Very Hot Days (2010-2019)	203 days
	% Tree canopy cover	18.4%

Source: Environment and Climate Change Canada (2019)

VARIABLES	INDICATORS	RESULTS
Sensitivity	Low Income Prevalence	14%
	Age – Senior (65+)	15%
	Age – Children (0-14)	16%
	Number of Sensitive Buildings: Major Repairs	34%
	High-rise buildings: Occupied Private Dwellings	More than 5 storeys: 12% Less than 5 storeys: 7%
	Education: No certificate, diploma, or degree	19%
	Language (neither English nor French)	6%
	Unemployment	8%
	Living Alone/ One-person household	14%

Source: Statistics Canada (2016); Region of Peel (2020); Environics Analytics (2020)

VARIABLES	INDICATORS	RESULTS
Adaptability	Access to transit	Bus stops: 182 Train stops: 1
	Access to cooling facilities/areas	Recreation and community centers: 4 Libraries: 4 Shopping centers and malls: 3 Movie theatres: 0 Parks: 3

Source: Google Maps (2020)

1.3. Increasing Canopy Cover

Planting trees and increasing canopy cover is one means to reduce exposure to hot temperatures. The Brampton study area has 49.5% of plantable space and a current tree canopy cover of 18.4% (TRCA, 2020).

Scenarios

To understand the health return on investment of increasing canopy cover, this case study estimates the monetary value of health and wellbeing benefits under two scenarios: increasing the existing canopy cover in the study area by 50% and by 80%. Increasing the current canopy cover by 50% and 80% would result in a canopy cover in the study area 27.6% and 33.1% respectively. These scenarios would require planting 33,784 and 54,054 new trees respectively. See Table 2 for a breakdown of the planting scenarios.

TABLE 2: Number of trees to be planted to reach 50% and 80% increase in existing canopy cover

	PRESENT (18.4% canopy cover)	NUMBER OF ADDITIONAL TREES TO ACHIEVE CANOPY COVER TARGET	
		50% INCREASE (27.6% canopy cover)	80% INCREASE (33.1% canopy cover)
Target Location	67,567	33,784	54,054

Source: Toronto and Region Conservation Authority (2020)

Increasing tree canopy cover can reduce the maximum air temperature, thus reducing the incidence of overall very hot days. According to a study conducted by Berardi, Jandaghian, & Graham (2020), increasing the canopy cover by 50% and 80% in the study area would result in a reduction in maximum air temperature of 0.39 and 1.51 degrees Celsius respectively in the Brampton neighbourhood. While the primary health benefits of interest are associated with reducing health impacts attributed to very hot temperatures and health and wellbeing benefits associated with reduced air pollution, the analysis also considers benefits associated with improved physical and mental health, and climate resilience.

2. Framework Overview

The economic framework applied in this case study links greenspace investments to improvements in health and wellbeing resulting in, for example, health system savings, prevented lost productivity associated with poor health and illness, and reduced mortality. Figure 3 depicts how investments in tree planting connects to health benefits and associated economic returns using the framework.

The framework provides analysts and decision-makers information on the ecohealth benefits of potential greenspace investments when evaluating policies, programs, and actions. It is meant to enhance the decision-making process by complementing other factors and information under consideration. The conceptual framework makes links between greenspace investments, health outcomes, and economic benefits to inform the decision-making process.

FIGURE 3: Pathway linking increasing canopy cover investment to economic benefits

GREENSPACE INVESTMENT	GREENSPACE FACTOR CHANGED	RESPONSE/ PATHWAY	PATHWAY AND HEALTH AND WELLBEING BENEFITS/ OUTCOMES	ECONOMIC BENEFITS
Plant and maintain trees to increase canopy cover by 50% and 80%	Quality	Exposure to air pollutants Exposure to very hot temperatures	Reduced exposure to air pollutants and effects from extreme heat • Lower rates of chronic health and mental illness and mortality Increased levels of physical activity • Lower rates of obesity/ overweight Reduced risk of mental health • Lower rates of depression, stress reduction, and improved cognitive function Increased resilience to climate change • Higher energy savings and carbon sequestration	Reduced incidences of adverse health effects/ diseases attributed to poor air quality and extreme heat (health system savings) Reduced rates of absenteeism and productivity loss Reduced lost leisure time Lower damage costs and insurance claims associated with extreme weather events

Note: From a public health perspective, the Climate Resiliency Pathway would also include health protective adaptation measures associated with improved air quality and relief from high temperatures.

Assigning a monetary value to greenspace investments is challenging, given the difficulties in identifying quantifiable health outcomes attributed to a policy, program, or planning decision. The evidence connecting greenspace investments to health outcomes is strongest in three areas:

1. Physical health improvements associated with higher levels of physical activity
2. Mental health improvements associated with spending time in nature
3. Health improvements and avoided health system costs and lost productivity associated with reduced exposure to air pollution (specifically reduced respiratory symptoms and incidences of cardiovascular disease) and reduced exposure to very hot temperatures.

The proposed approach in this case study relies on a number of assumptions supported by evidence from the literature. Assumptions draw on the most robust and well-regarded studies or integrate consistent trends shown across studies. The approach also structures the calculations in such a way that the model could be refined in the future as more locally relevant data becomes available or to reflect changes in assumptions or new knowledge.

3. Economic Valuation Approach

The analysis examines the health value of increasing canopy cover by 50% and 80% over the current baseline of 18.4% in the case study neighbourhood. The respective increases would result in a canopy cover of 27.6% (50% increase), and 33.1% (80% increase). The benefits and costs included in the study are outlined in Table 3. The net benefits of increasing canopy cover in both scenarios equals the estimated health benefits minus the costs of tree planting and maintenance to achieve the respective canopy cover targets.

TABLE 3: Net Benefits of Increasing Tree Canopy Cover by 50% and 80%

BENEFITS	COSTS
Health System Savings and Improved Productivity Attributed to a Reduction in Very Hot Temperatures	Tree Planting and Annual Maintenance Costs
Health System Savings Attributed to a Reduction in Air Pollutants	
Health System Savings Attributed to Higher Levels of Physical Activity	
Health System Savings Attributed to Improved Mental Health	
Carbon Sequestration	

3.1. Assumptions

It is important to note that the following assumptions are made when calculating the health savings due to unavailability of data related to the Brampton case study area:

1. Maximum temperatures of Toronto Pearson Airport are used as a proximate location for calculating reduction in very hot days.
2. Where cost data was unavailable for the Brampton case study area, it was either derived based on proximate locations or literature findings. Monetary values are converted into 2016-dollar value for consistency.
3. The incidences of health variables are calculated based on the proportion of population of proximate locations and/or literature findings. For instance, hospitalization and emergency visits are derived from the Region of Peel and then proportioned based on the population size of the Brampton case study area. Similarly, the number of physically active people in the City of Brampton is proportioned based on the population of the Brampton case study area. The daily incidence of ambulance calls related to very hot days is based on City of Toronto data then proportioned by the number of very hot days in the Brampton case study area. The increased incidence of very hot days is calculated using findings in the literature.
4. Odds ratios are converted into risk ratios to find out the probability of decreasing risk of physical inactivity and mental health.
5. Limited research has been done on mental health risk and greenspace area across age cohorts. Therefore, a study focusing on middle and old age individuals is used for this analysis.
6. It is assumed that all new trees will be planted during the same year.

3.2. Reduction in Very Hot Days

Public Health Canada and Environment and Climate Change Canada (ECCC) have developed parameters to predict extreme heat warnings. Based on weather forecast predictions, heat warnings are issued by ECCC to public health authorities 2-4 days prior to an extreme heat event or extended extreme heat event. ECCC continues to inform public health officials until these extreme heat event predictions are confirmed. Heat warnings are provided for three regions in Ontario: Southwest Ontario, Southern Ontario and Northern Ontario (Ministry of Health, 2020). For Southern Ontario, extreme heat event warnings are issued for regions when the forecasted temperatures increase to minimum 31 degrees Celsius for daytime and 20 degrees Celsius for overnight time or humidex values increase to minimum 40 for 2 days. Extended heat warnings are issued when the same conditions are continuous for 3 days or more (Environment and Climate Change Canada, 2020).

Heat warnings are based on predicted conditions. For this analysis, "Very hot days" are used. Theses are defined as days with recorded daily maximum temperature greater than 30 degrees Celsius (Climate Data, 2020). The cooling effect of increasing the current canopy coverage (18.4%) to 27.6% and 33.1% is based on the results of Berardi, Jandaghian, & Graham (2020)'s study and applied to observed incidences of very hot days as measured at Toronto Pearson Airport weather monitoring station (see Appendix 2 for more information on the methodology). The analysis is a conservative estimate that focuses only on recorded maximum temperatures to measure the potential health impact of tree canopy cover and does not take into consideration the health impacts of humidity, lowered nighttime temperatures, and improved thermal comfort.

The most recent year for much of the data compiled in the analysis is from 2016; therefore, 2016 is taken as a reference point for the study. Table 4 (below) shows the estimated difference in very hot days if there had have been 27.6% canopy cover (50% increase scenario) and 33.1% canopy cover (80% increase scenario) in 2016 compared to the baseline amount of 18.4% canopy cover. Based on these scenarios, in 2016 there would have been 4 (50% greater scenario) and 17 (80% greater scenario) fewer very hot days. According to Region of Peel's 2041 Discussion Paper (2018), extreme heat days are expected to increase to 62 days by 2080. Based on this projection, if canopy cover is 50% and 80% higher in 2080 compared to the current baseline amount (18.4%), the number of very hot days would decrease from 62 to 55 (50% greater scenario) and from 62 to 34 (80% greater scenario).

TABLE 4: Cooling Effect of Increasing Existing Canopy Cover by 50% and 80% in Brampton Study Area

	2016		2080	
Total very hot days	38		62	
	27.6% canopy cover 50% greater scenario	33.1% canopy cover 80% greater scenario	27.6% canopy cover 50% greater scenario	33.1% canopy cover 80% greater scenario
Reduction in temperature (°C)	**0.39**	**1.51**	**0.39**	**1.51**
Reductions in heat days	4	17	7	28
Total very hot days after increasing canopy cover	34	21	55	34

Source: Environment and Climate Change Canada (2019)

3.3. Health System Savings Attributed to Reduction in Very Hot Temperatures

Heat-related illnesses increase the burden on the economy by directly increasing public healthcare costs and indirectly decreasing worker productivity. People with pre-existing illnesses, chronic health conditions, those taking certain medications increasing vulnerability and those working in heat-stress occupations are at greatest risk of heat-related illness. Reduction in very hot days will decrease the vulnerability of people that are already at risk of very hot temperatures. The estimated total health system savings and productivity loss avoided with the reduction in very hot days is calculated by adding the health system and productivity cost at current canopy cover (18.4%) and at canopy covers of 27.6% and 33.1% respectively.

Total health system and productivity cost per year ($) *= Health system costs + Productivity loss costs*

Health System Costs

Very hot temperatures increase the risk of hospitalization, emergency department visits, and mortality, especially among people already suffering from acute and chronic mental health conditions. As mentioned in Section 1.2, temperatures not meeting the criteria of very hot can still be harmful and have been shown to increase risk of mortality (Chen, et al., 2016). The case study focuses on health impacts attributed to very hot temperatures. Increasing canopy cover can mitigate very hot temperature conditions reducing utilization of health system services. Data on hospitalization admissions and emergency department use for Peel Region is presented in Appendix 3, Table 15.

Direct health cost per year ($) = Cost of hospitalizations + Cost of emergency department visits + Cost of ambulance calls

Cost of Hospitalizations

The cost of a standard hospital stay at William Osler Health System, Brampton was $5,134 in 2016 (Canadian Institute of Health Information, 2020). The number of hospitalizations related to chronic health diseases in Peel Region was 14,076 in 2016 (see Appendix 3, Table 15) (Region of Peel, 2019). Since the population of Brampton case study area is 4.8% of the total population of Peel region, hospitalizations for the Brampton study area are estimated to be 676 (on average, 1.9 hospitalization per day).

Very hot days are correlated with an increase in hospital admissions, including a 1.2% rise in coronary heart disease-related hospital admissions, a 1.8% rise in stroke related-hospital admissions (Bai, et al., 2018), a 30% rise in diabetes-related hospital admissions (Bai, et al., 2016) and a 2.9% rise in respiratory-related hospital admissions (Lin, et al., 2009). The daily average number of hospitalizations during very hot days increases from 1.9 to 2, resulting in 76 hospitalizations attributable to very hot temperatures (see Appendix 2 for more information on methodology).

The estimated total cost of hospitalizations for the Brampton study area in 2016 is

= *Cost of standard stay at a hospital * Number of daily hospital admissions for chronic health diseases during very hot days * Total very hot days*

= $5,134 * 2 * 38 = **$390,184**

Cost of Emergency Department Visits

The average cost of a non-admitted emergency department visit for Central West Health Network was $100 in 2006 (Dawson & Zinck, 2009) which is equivalent to $117.6 in 2016. The number of emergency department visits related to chronic health diseases and mental health in Peel region was 60,427 in 2016 (see Appendix 3, Table 15) (Region of Peel, 2019). Since the population of the Brampton case study is 4.8% of the total population of Peel region, the number of emergency department visit for the Brampton study area is estimated to be 2,901 per year (on average, 8 emergency department visits per day).

According to Bustinza, Lebel, Gosselin, Bélanger, & Chebana (2013), the number of emergency department visits increases by 4% on extreme heat days in Quebec. Assuming a similar rate of increase, the daily average number of emergency department visits in the study area is estimated to increase from 8 to 8.3, resulting in an annual increase of 315.4 emergency department visits due to hot temperatures (see Appendix 2 for more information on methodology).

Based on these statistics, the estimated total cost of emergency department visits for Brampton study area in 2016 is

= *Cost of emergency department visits * Daily heat-related emergency department visits * Total very hot days*

= $117.6 * 8.3 * 38 = **$37,091**

Cost of Ambulance Calls

The cost of an average ambulance call service per visit is $240 in Ontario (Health Quotes, 2019; Humber River Hospital, 2020). Based on a study by Bassil and colleagues (2010) for Toronto, there were 201 ambulance calls attributed to heat on very hot days in 2005 (28 hot days) resulting in a daily average of 7.2 heat related calls.

Applying the same ratio of population to ambulance calls on very hot days would result in 7.6 ambulance calls attributed to heat in the Brampton Study Area (see Appendix 2 for more information on methodology).

The estimated total cost of ambulance calls for Brampton study area in 2016 is

= *Cost of ambulance * Daily average ambulance calls made during very hot days * Total very hot days*
= $240 * 0.2 * 38 = **$1,824**

***Estimated direct health cost in 2016 ($)* = $390,184 + $37,091 + $1,824 = $429,099**

Note: Other costs associated with a decline in inpatient hospitalizations, emergency department visits such as capital and overhead costs (building, lighting, heating, and related costs) are not accounted for in this study.

Productivity Loss Costs

A small rise in temperature makes individuals more irritable and reduces the concentration and ability of workers to do their tasks properly, causing a decline in productivity (Canadian Centre for Occupational Health and Safety, 2016). During summers, outdoor workers in industrial occupations lose on average 22 hours of work time due to increased breaks attributed to heat exposure, equivalent to approximately 1% of total hours worked in a year. Based on a study by Vanos, Vecellio and Kjellstrong (2019), the time lost is equivalent to an economic loss of $1,100 ($2018) to the employer (equivalent to $1,055.64 in $2016). Based on this estimation, the average economic loss to an employer in 2016 was $27.78 on a very hot day.

A study by Peters et al. (2015) using the Canadian Carcinogen Exposure database estimates that 6.9% of the Ontario labour force work in professions that expose them to solar radiation. Based on labour force data, the working population in the case study community is 32,212 people (Environics Analytics, 2020). Assuming a similar rate to the Ontario average, 2,223 workers in the study are in professions that expose them to solar radiation (see Appendix 3, Table 16, and Appendix 2 for more information on methodology).

The estimated cost of productivity loss for the Brampton study area in 2016 is

= *Average productivity loss per heat day * Employees exposed to solar radiation * Total very hot days*

= $27.78 * 2,223 * 38 = **$2,346,289**

Note: The impact of very hot temperatures on indoor workers (office and home) is not a part of the study.

The total estimated health and productivity cost for Brampton study area in 2016 is

Health system costs + Productivity loss costs

= $429,099 + $2,346,289 = **$2,775,388**

Health Cost and Productivity Loss Avoided by Increasing the Canopy Cover

Increasing the existing canopy cover of 18.4% to 27.6% and 33.1% would mitigate exposure to very hot days in the study area from 38 days to 34 and 21 days, respectively. The health costs and productivity losses due to very hot temperatures under the three canopy cover scenarios are highlighted in Table 5. Canopy cover levels 50% and 80% greater than baseline levels would have resulted in avoided health care costs and productivity loses totalling $292,146 and $1,241,621.

TABLE 5: Health Cost Avoided by increasing canopy cover by 50% and 80%

2016	18.4% CANOPY COVER (baseline)	27.6% CANOPY COVER (50% greater)	33.1% CANOPY COVER (80% greater)
Number of very hot days	38	34	21
Cost of hospitalization ($, per person)	5,134	5,134	5,134
Number of hospitalizations (per day)	2	2	2
Total hospitalizations	76	68	42
Total Cost of Hospitalizations ($)	**390,184**	**349,112**	**215,628**
Cost of emergency department ($, per visit)	117.6	117.6	117.6
Emergency department visits (per day)	8.3	8.3	8.3
Total emergency department visits	315.4	282.2	174.3
Total Cost of Emergency Department Visits ($)	**37,091**	**33,187**	**20,498**
Cost of ambulance ($, per visit)	240	240	240
Ambulance calls (per day)	0.2	0.2	0.2
Total ambulance calls	7.6	6.8	4.2
Total Cost of Ambulances ($)	**1,824**	**1,632**	**1,008**
Total Health Costs ($)	**429,099**	**383,931**	**237,134**
Productivity loss per heat day ($, per person)	27.78	27.78	27.78
Total Productivity Loss Cost ($)	**2,346,289**	**2,099,311**	**1,296,633**
Total Health and Productivity Loss Cost ($)	**2,775,388**	**2,483,242**	**1,533,767**
Health Cost Avoided ($)		**292,146**	**1,241,621**
% Change in Health Cost (Reduction)	**-**	**11%**	**45%**

3.4. Health System Savings Attributed to Reduction in Air Pollutants

According to the TRCA's Urban Forest Study Technical Report (2011), 0.08 kg of pollution is removed per tree resulting in $0.89 in air quality benefits (equivalent to $0.95 in 2016) Using the same framework, air pollution removed and equivalent monetary value are calculated for the Brampton study area. Table 6 provides the estimated pollutants removed and associated value based on a canopy cover of 18.4%.

TABLE 6: Estimated Pollutant Removed and Associated Values for Brampton study area

FIXED CHARACTERISTICS	VALUES
Area (ha)	1,521.13
Population	73,652
Number of trees	67,567
Absolute Tree Cover (ha)	279.67
Percentage Tree Cover (%)	18.4
Average pollutants removed per tree (kg)	0.08
Total removed pollutants at existing number of trees (kg)	5,405
Saving per tree ($)	0.95
Total savings at existing number of trees ($)	64,189
Savings per pollutant removed ($/kg)	11.88

Source: Toronto and Region Conservation Authority (2011); Environics Analytics (2020); Toronto and Region Conservation Authority (2020)

For the Brampton study area, at 18.4% canopy cover, 5,405 kgs of pollutants are removed, which is equivalent to $64,189 in savings (see Appendix 2 for more information on this methodology). The same estimations are applied at 27.6% canopy cover and 33.1% canopy cover. The results are presented in Table 7. The estimated additional pollutants removed are 2,703 kgs at 27.6% canopy cover and 4,324 at 33.1% canopy cover equivalent to health savings attributed to improved air quality of $32,095 and $51,351 in respectively.

TABLE 7: Estimated additional pollution removed and associated savings attributed to improved air quality

	27.6% CANOPY COVER (50% greater)	33.1% CANOPY COVER (80% greater)
Additional number of trees	33,784	54,054
Additional removed pollutants (kg)	2,702.72	4,324.32
Additional savings attributed to improved air quality ($)	32,094.80	51,351.30

3.5. Health System Savings Attributed to Higher Levels of Physical Activity

Increasing tree canopy cover increases greenspace and influences the level of physical activity of the residents living in the neighbourhood. The total annual health cost of physical inactivity is estimated to be $289.65 per adult in 2012, which is equivalent to $307.29 in 2016 (Krueger, Turner, Krueger, & Ready, 2014). Considering forty two percent (42%) of the individuals were physically active in the City of Brampton in 2013-14 (Brampton Geohub, 2020), the total number of physically active people in the Brampton case study area are estimated to be 30,934 (73,652 * 42%) while the total number of physically inactive people is 42,718 (73,652 - 30,934) (assuming the same level of physical activity for Brampton case study area) (see Appendix 2 for more information on methodology).

According to a study conducted by McMorris, Villeneuve, Su, & Jerrett (2015), urban green areas have a positive relationship with physical activity for adults in Canada, especially young adult females. The association remains consistent at all income levels; however, it becomes weaker with increases in age. It is also found that the odds ratio of taking part in leisure-time physical activity (LTPA) during leisure time was 1.20 for people living in the second least green areas (24%-35%) compared to those living in the least green (below 24%). The odds ratio is converted to a scale of 1.15 using the conversion function suggested by Osborne (2006) (see Appendix 3, Table 17 for more information on this methodology). The scaler suggests that when increasing the greenness in an individual's living environment from below 24% to 24%-35%, the individual is 15% more likely to participate in leisure-time physical activities (LTPA).

As mentioned in Section 1, the current tree canopy cover in Brampton is 18.4%, which falls within the range of the lowest greenness quantile (below 24%) as outlined in the study of McMorris and colleagues (2015). An increase in existing canopy cover by 50% and 80% will increase the total canopy cover in Brampton to 27.6% and 33.1%, respectively, both of which fall within the second lowest quantile of greenness (24%-35%). Therefore, it is assumed that by increasing Brampton's existing tree canopy cover by 50% or 80%, 15% of the physically inactive population would meet the recommended moderate-to-vigorous physical activity (MVPA) goals. It is acknowledged that the scaler (1.15) was originally derived from the study in greenness and LTPA not MVPA. However, in order to perform the estimation, it is assumed that the findings from the LTPA-related study also apply to our study of MVPA.

The estimated physical inactivity health cost avoided when increasing the tree canopy cover in the Brampton study area by 50% or 80% is:

*= Economic burden of physical inactivity per person ($307.29) * Physical inactive population at existing tree canopy cover (42,718) * (Scaler – 1) (Percentage of physically inactive people that meet MVPA goals when exposing to increased canopy cover) (1.15 - 1 = 15%)*

= $307.29 * 42,718 * 15% = **$1,969,022**

3.6. Health System Savings Attributed to Improved Mental Health

Growth in tree cover reduces human stress levels and contributes positively to overall mental health of people living near greenspaces. The economic burden of mental illness in Canada amounted to $50,847 million in 2003 and it includes direct medical cost, health utilities loss and productivity loss (Lim, Jacobs, Ohinmaa, Schopflocher, & Dewa, 2008). In 2016-dollars, this amounts to $63,880.9 million. As a result, the economic burden of mental illness per individual is equivalent to $1,817.29.

There is limited literature on the relationship between mental health and tree canopy cover. Kardan and colleagues (2015) in a study of Toronto, for example, concluded that presence of trees, while important for physical health, have an insignificant effect on mental health. An Australian study by Astell-Burt, Feng, & Kolt (2013), however, found that canopy cover had a positive association with improvements in mental health for middle and old age individuals in Australia. The study also found that the odds ratio of reducing mental health risk was 0.94 for people living in neighbourhoods with 21% to 40% greenness in comparison to those living in neighbourhoods with less than 20% greenness. When converting the odds ratio to a scaler following the function suggested by Osborne (2006), the scale is 0.96, which means that the increase in tree canopy cover will reduce the mental health risk of an individual by 4% (see Appendix 3, Table 17 for more information on methodology). For this analysis we have adopted the findings from Astell-Burt, Feng, & Kolt (2013). While there is substantial evidence indicating greenspaces can positively contribute to mental health of individuals, the specific role of canopy cover is less clear (Engemann, et al., 2019). Further, as reported in a review article by Tilman and colleagues (2018), the positive relationship between greenspace and mental health is less conclusive among younger populations[4].

According to the Region of Peel (2019), the number of people self-reporting poor mental health was 28.3% in 2014. Using the same rate, the total number of people reporting poor mental health in the study area is estimated to be 18,863. Among those, the percentage of middle and old age individuals (38.5%) reporting poor mental health based on the population profile of the region is estimated to be 7,262 (see Appendix 2 for more information on methodology).

As mentioned in Section 3, an increase in existing canopy cover by 50% and 80% will increase the total canopy cover to 27.6% and 33.1% respectively. Since 27.6% and 33.1% fall within the 21%-40% greenness range of the study, it is assumed that the increase in tree canopy cover by 50% or 80% will result in a 4% improvement for middle and old age individuals who have poor mental health.

The estimated avoided mental health cost when increasing the tree canopy cover by 50% and 80% is:

*= Economic burden of mental illness per person ($1,817.29) * (1 - Scaler[5]) (Improvement in mental health condition) (1-0.96 = 4%) * Number of middle and old-aged people with poor mental health (7,262)*

= $1,817.29 * 4% * 7,262 = **$527,886**

4 Tillman and colleagues (2018) found, in a review of 35 studies on the relationship between nature and mental health, that 50% of studies reported no statistical significance between nature and mental health among younger populations.

5 See Glossary. Scalers are used for increase in canopy cover scenarios only.

3.7. Tree Planting Costs to Reach Canopy Cover Targets

The estimated tree planting and tree establishment costs to increase the current canopy cover by 50% and 80% in the Brampton study area are $383,786 and $614,053 (Table 8). Tree planting and tree establishment costs are from the City of Brampton planning and development tree assessment guidelines. The average life span of a suburban tree is based on the value used by Regional Municipality of York in their Green Infrastructure Asset Management Plan (Barkovitz., 2019). The estimated cost to meet the target of a 50% and 80% increase in the existing cover is $383,786 and $618,053, respectively (see Appendix 2 for more information on methodology).

TABLE 8: Estimated tree planting trees in Brampton study area

COST OF PLANTING NEW TREES	VALUE
Average cost per tree (planting and tree establishment)	$500
Life span of suburban tree	44 years
Cost per tree (Straight-line depreciation method)	$11.36 per year
50 % increase in existing canopy cover (33,784 trees)	$383,786
80 % increase in existing canopy cover (54,054 trees)	$614,053

3.8. Summary

This case study examined the monetary value of health benefits associated with higher levels of canopy cover in a Brampton neighbourhood. Two scenarios were examined: a 50% increase in canopy cover and an 80% increase in canopy cover over the baseline amount of 18.4%. The respective increases result in a canopy covers of 27.6% (50% increase), and 33.1% (80% increase).

The health benefits of more canopy cover over current levels equals $2,437,363 in the 50% increase scenario and $3,175,826 in the 80% increase scenario. Table 9 presents a summary of the findings.

TABLE 9: Health Return on Investment at 50% and 80% Increases in Canopy Cover

NET BENEFITS OF INCREASING CANOPY COVER (annual)	27.6% CANOPY COVER (50% greater)	33.1% CANOPY COVER (80% greater)
Health System Savings and Improved Productivity attributed to a Reduction in Very Hot Days	$292,146	$1,241,621
Health System Savings Attributed to a Reduction in Air Pollutants	$32,095	$51,351
Health System Savings Attributed to Higher Levels of Physical Activity[6]	$1,969,022	$1,969,022
Health System Savings Attributed to Improved Mental Health[7]	$527,886	$527,886
Total Benefits	$2,821,149	$3,789,880
Costs: New Tree Planting and Annual Maintenance Costs	($383,786)	($614,053)
Net Benefit	**$2,437,363**	**$3,175,826**

6 In both scenarios, tree canopy cover falls within the 24%-35% greenness range of the selected study; therefore, the levels of health cost will remain the same.

7 In both scenarios, tree canopy cover falls within the 21%-40% greenness range of the selected study; therefore, the levels of health cost will remain the same.

4. Other Canopy Cover Benefits

In addition to providing better air quality, reducing exposure to very hot temperatures, and improving mental and physical health, increasing canopy cover provides other benefits such as carbon sequestration, energy savings, habitat and biodiversity, improved water quality and reduced stormwater runoff (Kardan, et al., 2015). See Appendix 4 for consideration of carbon sequestration and energy savings as part of the climate resiliency pathway. Carbon sequestration, for example, would provide benefits of \$1,748 at 27.6% canopy cover and \$2,797 at 33.1% canopy cover when compared to the baseline amount of 18.4% canopy cover. Other benefits not included in the study include improved sleep quality and reduced heat annoyance due to higher thermal comfort (van Loenhout, et al. 2016; McLeod & Hopfe, 2103, Altman et al., 2012). Increasing canopy cover in a neighbourhood also contributes to increasing values of amenities and properties (AECOM 2017; NSW Government, 2018).

5. Limitations

The following study limitations are noted and recommended as areas to address in future studies:

1. Tree canopy size depends on multiple factors, such as tree types and crown size. However, for this study, these factors have been kept constant when calculating the number of additional trees needed to meet 50% and 80% increase in existing tree canopy cover.

2. The focus of the current study was on maximum recorded air temperature. The impact of humidity was not included as humidity index and wet-bulb globe temperature data for the Brampton study area was unavailable. Very hot environments (temperature above 30 degrees Celsius) was used as a benchmark to calculate very hot temperature days. However, it should be noted that temperature below 30 degrees Celsius can also have an impact on heat related morbidity and mortality rates and can be a potential area of further research.

3. Literature and statistics of closest locations were taken as a reference and converted to 2016-dollar values wherever data was unavailable for the Brampton study area. If local data becomes available, calculations can be updated.

4. The impact of very hot temperatures on indoor workers (workplace and home) and other indirect health expenses are not explored in this study.

5. The health savings from mental health centered around middle and old age individuals and did not focus on young populations.

6. Appendices

6.1. Appendix 1: Community Profile

The study area is approximately 1,521.13 hectares and is primarily a residential area. The estimated total population is 73,652. According to the Statistics Canada 2016 Census, 44% of the housing stock is single detached houses, 21% is duplex or houses converted into flats, 19% is apartments, 13% is row house, and 3% is semi-detached houses. Seventy one percent (71%) of the dwellings are owned by households and 29% are rented. Most of the dwellings were built more than 20 years ago: 82% of the dwellings were built before 2001, 9% were built between 2001 and 2010, and 9% were built after 2011 (Environics Analytics, 2020). Thirteen percent (13%) of dwellings were deemed as not suitable for living on account of insufficient number of bedrooms to accommodate the number of household members living in the dwelling, and 4% of the dwellings require major repairs (Region of Peel, 2020). A summary of the housing characteristics for the case study area are provided in Table 10.

TABLE 10: Weighted Average Housing Characteristic, Distribution Brampton Study Area

BRAMPTON STUDY AREA		WEIGHTED AVERAGE DISTRIBUTION
Dwellings by Structure Type	Single-Detached House	44%
	Apartment with more than 5 storeys	12%
	Apartment with less than 5 storeys	7%
	Apartment or Flat in a Duplex	21%
	Row House	13%
	Semi-Detached House	3%
Dwellings by Tenure	Owner	71%
	Renter	29%
Dwellings by Period of Construction	1960 or before	5%
	1961 to 1980	13%
	1981 to 1990	34%
	1991 to 2000	30%
	2001 to 2005	6%
	2006 to 2010	3%
	2011 to 2016	2%
	After 2016	7%
Dwellings by Housing Suitability	Suitable	87%
	Not Suitable	13%
Dwellings by Housing Condition	Only Regular Maintenance or Minor Repairs Needed	96%
	Major Repairs Needed	4%

Source: Statistics Canada (2016); Region of Peel (2020); Environics Analytics (2020)

Population Demographics

In the study area, 16% of the population is under the age of 14, 16% are within 15-24, 53% are within 25-64, and 15% are over 65 years of age. In contrast to Peel region, variations were observed within the following age cohorts. The population in Brampton study area was 4% higher in the 25-34 age category, and 2% higher in both 20-24 and 65 above age cohorts. The population of Peel region was 4%, 2% and 1% higher in 45-54, 0-14, and 35-44 age cohorts, respectively (Environics Analytics, 2020). A summary of the age distribution for the case study area compared to Peel Region are provided in Table 11.

TABLE 11: Weighted Average Age Distribution of Brampton Study Area and Peel Region in 2016

	BRAMPTON STUDY AREA	PEEL REGION	
Age group	**Weighted Average Distribution**	**Weighted Average Distribution**	**Difference in Distribution**
0 to 14 years	16%	18%	-2%
15 to 19 years	7%	7%	0%
20 to 24 years	9%	7%	2%
25 to 34 years	17%	13%	4%
35 to 44 years	13%	14%	-1%
45 to 54 years	11%	15%	-4%
55 to 64 years	12%	12%	0%
65 years and over	15%	13%	2%

Source: Statistics Canada (2016); Region of Peel (2020); Environics Analytics (2020)

Fifty-eight percent (58%) of the study area population has an after-tax income of less than $30,000. Comparatively, 52% of the population in Peel Region has an after-tax income below $30,000. A summary of the income distribution for the case study area compared to Peel Region are provided in Table 12.

TABLE 12: Weighted Average After-Tax Income Distribution of Brampton Study Area and Peel Region in 2016

	BRAMPTON STUDY AREA	PEEL REGION	
Income group	**Weighted Average Distribution**	**Weighted Average Distribution**	**Difference in Distribution**
Under $10,000 (including loss)	20%	18%	2%
$10,000 to $19,999	21%	19%	2%
$20,000 to $29,999	17%	15%	2%
$30,000 to $39,999	14%	13%	1%
$40,000 to $49,999	11%	11%	0%
$50,000 to $59,999	7%	8%	-1%
$60,000 to $69,999	4%	5%	-1%
$70,000 to $79,999	2%	4%	-2%
$80,000 to $89,999	1%	2%	-1%
$90,000 to $99,999	1%	1%	0%
$100,000 and over	1%	3%	-2%

Source: Statistics Canada (2016); Region of Peel (2020)

Fifty percent (50%) of the population in the study area have post secondary education of some kind. Thirty one percent (31%) have a high school diploma or equivalent and the remaining 19% do not have a high school certificate or diploma. Comparatively, in Peel region, 55% of the population have post secondary education, 28% have secondary school and 17% do not have a high school certificate or diploma (Environics Analytics, 2020). A summary of the education distribution for the case study area compared to Peel Region are provided in Table 13.

TABLE 13: Weighted Average Education Attainment Distribution of Brampton Study Area and Peel Region in 2016

	BRAMPTON STUDY AREA	PEEL REGION	
Education Attainment	**Weighted Average Distribution**	**Weighted Average Distribution**	**Difference in Distribution**
No certificate, diploma, or degree	19%	17%	2%
Secondary school diploma or equivalent	31%	28%	3%
Apprenticeship or trades certificate or diploma	4%	5%	-1%
College, CEGEP or other non-university certificate or diploma	19%	18%	1%
University certificate or diploma below bachelor level	2%	3%	-1%
University certificate, diploma, or degree at bachelor level or above	25%	29%	-4%

Source: Statistics Canada (2016); Environics Analytics (2020)

The participation, employment, and unemployment rates of the study area were 66%, 60%, and 9% respectively. A summary of the labour force distribution for the case study area compared to Peel Region are provided in Table 14.

TABLE 14: Weighted Average Labour Force Distribution of Brampton Study Area and Peel Region in 2016

	BRAMPTON STUDY AREA	PEEL REGION	
Labour Force	**Weighted Average Distribution**	**Weighted Average Distribution**	**Difference in Distribution**
Participation Rate	66%	62%	4%
Employment Rate	60%	67%	-7%
Unemployment Rate	9%	8%	1%

Source: Statistics Canada (2016); Region of Peel (2020)

6.2. Appendix 2: Detailed Methodology

i. Reduction in Very Hot Days

With reference to the study by Berardi, Jandaghian, & Graham (2020), the estimated cooling effects of increasing canopy cover is determined by calculating the reduction in daily maximum air temperature with the increase in canopy cover by 50% and 80%, respectively. The weather data for Toronto Pearson Airport is extracted from Environment and Climate Change Canada website (Environment and Climate Change Canada, 2019).

1. Reduction in daily maximum air temperature attributed to increases in existing canopy cover by 50% and 80% is calculated using the formula below. The total number of very hot days with increased canopy cover at both scenarios are then calculated.

> ***Reduction in daily maximum air temperature at 50% / 80% increase in canopy cover per year (°C):***
> *Current daily maximum air temperature - Cooling effect at 50% / 80% increase in canopy cover*

2. To calculate reduction in very hot days in a year, the current number of very hot days are subtracted by the total number of very hot days at the greater amounts of canopy cover.

ii. Health System Savings and Improved Productivity Attributed to Reduction in Very Hot Temperatures

The estimated total health system savings and productivity loss avoided with the reduction in very hot days is calculated by adding the health system and productivity cost at current, and 50% and 80% increases in canopy cover, respectively.

> ***Total health system and productivity cost per year ($)*** *= Health system costs + Productivity loss costs*

Avoided health system costs of 50% and 80% increases in canopy cover are determined by subtracting current health care costs by health care costs of respective scenarios.

The detailed calculations for health system costs and productivity loss are presented below. The same formulas are used to calculate total health costs for all scenarios.

a. HEALTH SYSTEM COSTS

The costs of hospitalizations, emergency department visits, and ambulance calls attributed to very hot temperatures are added to determine the total cost related to the health system per year.

> ***Direct health cost per year ($)*** *= Cost of hospitalizations + Cost of emergency department visits + Cost of ambulance calls*

The detailed calculations for cost of hospitalizations, emergency department visits and ambulance calls are shared below.

1. Cost of Hospitalizations

   The cost of a hospital stay at William Osler Health System for 2016 is from the Canadian Institute of Health Information website (Canadian Institute of Health Information, 2020). The number of hospitalizations for chronic health diseases for 2016 is total hospital admissions related to coronary heart diseases, cardiovascular diseases, diabetes, and respiratory diseases from Region of Peel Health Report (Region of Peel, 2019).

   To estimate hospital admissions for the Brampton study area, the total number of hospitalizations in Peel region are proportioned based on the population size (Brampton case study population is 4.8% of total population of Peel Region) and then divided by the total number of days in the year to calculate the daily hospital admission in 2016. Literature findings are incorporated using the formula below to account for the incremental admissions during very hot days. The admissions of each chronic health disease are then added to determine the total number of hospital admissions attributed to very hot days. Heat exposure increases coronary heart disease-related hospital admissions by 1.2%, stroke related-hospital admissions by 1.8% (Bai, et al., 2018), diabetes-related hospital admissions by 30% (Bai, et al., 2016) and respiratory-related hospitalization by 2.9% (Lin, et al., 2009).

   Number of daily hospital admissions of each chronic health disease during very hot days
   *= Daily hospital admissions of each chronic disease * (1 + Percentage increase for each chronic health disease admission on a very hot day)*

   The total cost of hospitalization for all scenarios is calculated using this formula:

   Cost of hospitalizations per year ($) *= Cost of standard stay at a hospital * Number of daily hospital admissions for chronic health diseases during very hot days * Total very hot days*

2. Cost of Emergency Department Visits

   The average cost of non-admitted emergency visits for Central West Health Network in 2006 is derived from Dawson and Zinck (2009) and then converted to 2016 dollar value. The number of emergency department visits for chronic and mental health diseases for 2016 is calculated by adding emergency department visits related to coronary heart diseases, cardiovascular diseases, diabetes, respiratory diseases, and mental health disorders from the Region of Peel Health Report (Region of Peel, 2019).

   Emergency department visits estimated for the Brampton study area are based on the total number of emergency visits in Peel region proportioned by the study area population then divided by the total number of days in a year to calculate the daily emergency visits in 2016. The incremental emergency department visits during very hot days are estimated according to Bustinza, Lebel, Gosselin, Bélanger, & Chebana (2013), finding that the number of emergency department visits increases by 4% on very hot days.

   Total heat-related emergency department visits during very hot days *= Daily heat-related emergency department visits * (1 + Percentage increase in heat-related emergency department visits on a very hot day)*

   The total cost of emergency department visits for all scenarios is calculated using this formula:

   Cost of emergency department visits per year ($) *= Cost of emergency department visits * Daily heat-related emergency department visits * Total very hot days*

3. Cost of Ambulance Calls

The cost of an ambulance call is based on data from Health Quotes (2019) and Humber River Hospital (2020). We adopt the formulae by Basil, et al. (2010) in a study that estimated the total number of heat-related ambulance calls in Toronto for the year 2005. To calculate the daily average heat related cases, the total number of ambulance calls is divided by total number of very hot days in Toronto in 2005 (Environment and Climate Change Canada, 2019). To estimate the ambulance calls for the Brampton study area, the total number of daily ambulances calls in Toronto is proportioned based on the population differential (Brampton case study population is 2.5% of total population of Toronto).

Cost of ambulance calls per year ($) *= Cost of ambulance * Daily average ambulance calls made during very hot days * Total very hot days*

b. PRODUCTIVITY LOSS

For productivity loss avoided, the average economic loss to employers on a very hot day in 2018 is derived from Vanos, Vecellio, & Kjellstrom (2019) and converted to 2016 dollars. Based on this estimation, the average productivity per worker on a very hot day is determined by dividing the average economic loss with total heat days in 2016. The estimated number of workers impacted is from a study by Peters et al. (2015) using the Canadian Carcinogen Exposure database which estimates that 6.9% of the Ontario labour force work in professions that expose them to solar radiation. Based on labour force data, the working population in the case study community is 32,212 people (Environics Analytics, 2020). Assuming a similar rate to the Ontario average, 2,223 workers in the study are in professions that expose them to solar radiation.

The estimated cost of productivity loss for the Brampton study area in 2016 is

*= Average productivity loss per heat day * Employees exposed to solar radiation * Total very hot days*

iii. Health System Savings Attributed to a Reduction in Air Pollutants

Savings from reduction in air pollutants is calculated at existing, 50% and 80% increase in canopy cover using the average pollutants and savings data calculated by Toronto and Region Conservation Authority (2011). Area and population of the Brampton study location is derived from Environics Analytics (Environics Analytics, 2020) and tree related data are derived from Toronto and Region Conservation Authority (2020).

The following formulas are used to calculate the total pollutants removed, savings, and savings per pollutant at all scenarios.

1. ***Total pollutants removed at existing number of trees per year (kg)*** *= Average pollutants removed * total number of trees*
2. ***Total savings at existing number of trees per year ($)*** *= Savings per hectare tree coverage * total number of trees.*
3. ***Total savings per pollutant removed at existing number of trees per year ($)*** *= Total savings / Total pollutants removed.*

iv. Health System Savings Attributed to Higher Levels of Physical Activity

1. The direct and indirect costs of physical inactivity in 2009 are derived from Krueger, Turner, Krueger, & Ready (2014) and then converted to 2016 dollars. The percentage of people physically active in Brampton in 2013-14 is derived from Brampton Geohub (2020) and then proportioned based on the population size of the Brampton study area.

2. To calculate the increased number of physically active people with 50% and 80% increase in canopy cover, odd ratios of participating in physical activity are derived from McMorris and colleagues (McMorris, Villeneuve, Su, & Jerrett, 2015) and then adjusted using a scaler (see Appendix 3, table 17).

3. ***Avoided health cost from physical inactivity per year ($)*** = *Economic burden of physical inactivity per person * (Scaler - 1)[8] (Percentage of physically inactive people that meet MVPA goals when exposing to increased canopy cover) * Number of physically inactive people*

v. Health System Savings Attributed to Improved Mental Health

1. The economic burden of mental illness for 2003 in Canada is derived from Lim, Jacobs, Ohinmaa, Schopflocher, & Dewa (2008) and then converted to $2016 per individual. The percentage of people self-reporting poor mental health in 2014 in the Peel Region is derived from Region of Peel report (2019) and then proportioned based on the population size of the Brampton study area. The proportion of middle and old age individuals is then calculated (38.5% of the people report poor mental health in study area).

2. To calculate the reduced mental health risk at 50% and 80% increase in canopy cover, odds ratio are derived from the literature[9] (Astell-Burt, Feng, & Kolt, 2013) and then adjusted using a scaler (see Appendix 3, table 17).

3. Avoided health costs of 50% and 80% increases in canopy cover are determined by subtracting current health costs by health costs of respective scenarios.

   Avoided health cost from mental illness per year ($) = *Economic burden of mental illness per person * (1-Scaler[10])(Percentage improvement in mental health condition when exposing to increased tree canopy cover) * Number of middle and old-aged people with poor mental health*

8 See Glossary. Scalers are used for increase in canopy cover scenarios only.
9 A closely related study is taken as a reference due to limited literature on mental health and tree canopy cover.
10 See Glossary. Scalers are used for increase in canopy cover scenarios only.

6.3. Appendix 3: Supplementary Information

TABLE 15: Chronic Diseases Health Data

PEEL REGION	2016	
	ED VISITS	HOSPITALIZATIONS
Coronary Heart Diseases	2,002	4,376
Cardiovascular Disease	2,111	1,639
Diabetes	2,220	1,176
Respiratory Diseases	35,366	6,885
Mental Health Disorders	18,728	-
Total	**60,427**	**14,076**

Source: Region of Peel (2019)

TABLE 16: Total of Industrial Workers

OCCUPATION	NUMBER OF EMPLOYEES
Trades and Transport	8,135
Manufacturing and Utilities	3,975
Total	**12,110**

Source: Statistics Canada (2016); Environics Analytics (2020)

TABLE 17: Scaler Calculations for Physical and Mental Health

RR = OR / [(1-P0) + (P0 x OR)]

	ODDS RATIO	PO[11]	RR
Physical Health	1.20	Proportion of active users = 0.21	1.15
Mental Health	0.94	Proportion of poor mental health individuals = 0.29	0.96

Source: McMorris, Villeneuve, Su, & Jerrett (2015); Astell-Burt, Feng, & Kolt (2013); Osborne (2006)

11 Proportion of non-exposed individuals that experience the outcome.

6.4. Appendix 4: Climate Change Resiliency Path (for consideration, not currently included)

Carbon Sequestration Savings

According to iTree output results, at present level of canopy cover, the net carbon sequestration per area for residential land in City of Brampton is 307.2 kg/year/hectare (Toronto and Region Conservation Authority , 2020). The carbon sequestration at 18.4% of canopy cover would be 85,914.62 kg. The social cost of carbon was $0.0407 per kg ($40.70 per tonne) for 2016 (Wherry, 2016). The additional carbon sequestration savings at 50% and 80% canopy cover is $1,748.43 and $2,797.43, respectively.

TABLE 19: Total Carbon Sequestration and Associated Savings of Existing, 50% and 80% increase in Canopy Cover of Brampton Study Area

	BASELINE (18.4% canopy cover)	27.6% CANOPY COVER (50% greater)	33.1% CANOPY COVER (80% greater)
Absolute tree cover (ha)	279.67	139.84	223.74
Carbon sequestration per area (kg/ha)	307.2	307.2	307.2
Total carbon sequestration (kg)	85,914.62	42,958.85	68,732.93
Social cost of carbon per kg ($/kg)	0.0407	0.0407	0.0407
Total carbon sequestration savings ($/kg)	3,496.73	1,748.43	2,797.43

Source: Toronto and Region Conservation Authority (2020)

Calculation details and assumptions:

1. The carbon sequestration per area for residential lands in City of Brampton is derived from iTree output files. The social cost of carbon for 2016 is derived from Wherry (2016).

> ***Total carbon sequestration savings per year ($)*** *= Social cost of carbon * Carbon sequestration per area * absolute tree cover*

Energy Savings

A study conducted by Smargiassi (2008) found that a degree increase in outdoor temperature results in a 0.36-degree increase in indoor temperature. Keeping other factors constant such as location, building type and height, and number of occupants, etc., reduction in outdoor temperature will also indirectly impact the indoor temperature, leading to less usage of air conditioners and energy consumption and hence contributing positively to climate change (World Health Organization, 2018).

On average, 36.9 Petajoules (PJ) were utilized by Canadian households on space cooling in 2016 (Natural Resource Canada, 2020). Out of which, 28.4 PJ were consumed by households in Ontario (Natural Resource Canada, 2020). The total number of households in Ontario were 5,169,170 in 2016 (Statistics Canada, 2016). Therefore, the average household energy consumption on space cooling in Ontario equals to 5.49 Gigajoules (GJ) in 2016 (equivalent to 1,525 kilowatt hours). In 2016, there were 18,481 households in the Brampton Study area. Eighty five percent (85%)[12] of the households had air conditioners. The residential electricity cost (without taxes) was $0.13 per kWH in 2013, equivalent to $0.14 in 2016 dollars (Green, Jackson, Herzog, & Palacios, 2016).

The estimated cost of energy consumption for Brampton study area in 2016 is

= *Residential electricity costs per kWH * Average household energy consumption on space cooling * Number of households with air conditioners*

= $0.14 * 1,525 * 15,709 = **$3,353,871.50**

A study conducted by Akbari and Taha (1992) reported that a 30% increase in vegetation and tree cover reduces the cooling energy consumption by 40% and 30% per household in urban and rural regions in Toronto and the annual savings in cooling costs can range in between $30 to $180 in urban areas and $60 to $400 in rural regions depending on the house size and location.

The estimated energy savings of a 30% increase in canopy cover for Brampton study area

= *estimated cost of energy consumption * proportion of reduction in cooling energy consumption*

= $3,353,871.50 * 40% = **$1,341,548.60**

Calculation details and assumptions:

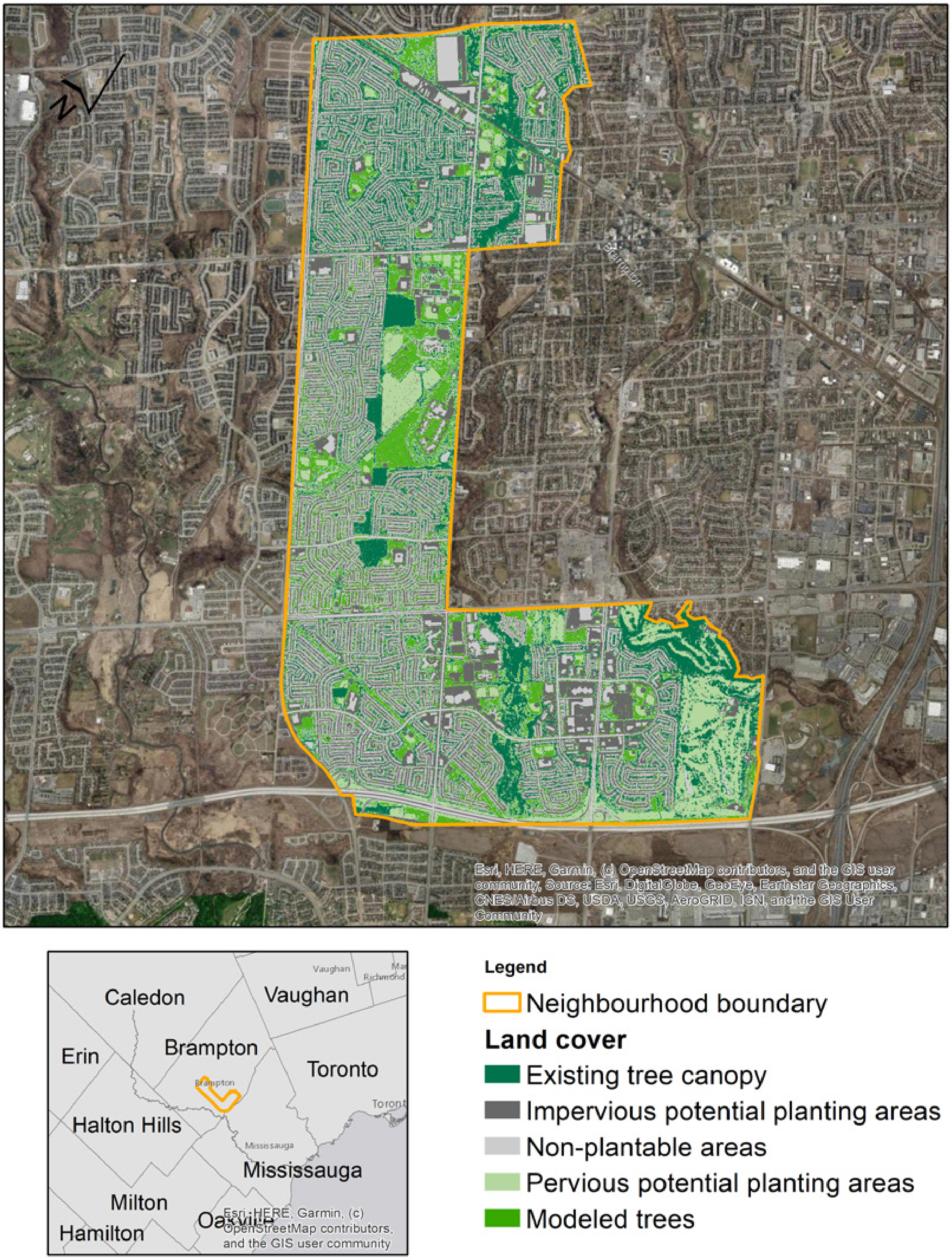
1. Data related to energy consumption on space cooling in 2016 for Ontario is derived from Natural Resource Canada (2020) and then divided by total number of households in Ontario to determine the average household consumption in GJ and kWH. Based on the assumption that 85% of the population have air conditioners (Gower, Mee, & Campbell, 2011). The residential electricity cost for Toronto in 2013 is derived from Green, Jackson, Herzog, & Palacious (2016) and then converted into $2016.

   Energy cost per year ($) = *Residential electricity costs per kWH * Average household energy consumption on space cooling * Number of households with air conditioners*

2. Minimum percentage of savings in cooling costs per household is derived from the literature and then multiplied by total energy cost to determine the energy savings at a 30% increase in canopy cover. The minimum annual savings in cooling costs per dwelling in 1992 is derived from Akbari and Taha (1992) and converted to $2016.

12 Based on the assumption that 85% of the population have air conditioners in Toronto (Gower, Mee, & Campbell, 2011).

FIGURE 4: Brampton study area



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8. Glossary

Heat vulnerable community:
An area that is exposed to very hot temperatures.

Very hot days:
Number of days with daily maximum temperature recorded greater than 30 degrees Celsius (Climate Data, 2020).

Scaler:
Value used to convert odds ratio to risk ratio.

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Possibility grows here.