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SUPPLEMENTARY FILE

Detail Description of Estimated Values

Carbon Storage & Sequestration

The estimates of carbon storage and annual carbon sequestration for the Thompson Rivers University (TRU) campus trees are based on a synthesis of values reported in scientific studies and modeling using i-Tree software.

Carbon Storage

Research shows considerable variation in the amount of carbon a tree can store. Xia et al. (2018) reported a broad range of 11 to 852 kilograms per tree, while McPherson et al. (2005) observed urban tree storage between 50 and 103 kilograms per tree. Andrew et al. (2018) identified species such as the Norway Maple storing up to 181 kilograms per tree. Based on the mix of mature and young trees on the TRU campus, a conservative storage range of 200–300 kilograms per tree was adopted. The i-Tree model supported this assumption, estimating an average of approximately 260 kilograms per tree. Multiplying by the estimated number of trees (1,806) yielded a total carbon storage of 361,200 to 541,800 kilograms, or 361.2 to 541.8 metric tons.

Annual Carbon Sequestration

Annual carbon sequestration also varies significantly by species, maturity, and growing conditions. Xia et al. (2018) reported annual rates between 3.5 and 96 kilograms per tree, McPherson et al. (2005) between 2.7 and 60 kilograms, and Andrew et al. (2018) up to 181 kilograms with avoided emissions. The i-Tree model for TRU estimated an average sequestration rate of 3 kilograms per year per tree. Based on this, a conservative range of 3–30 kilograms of carbon sequestered per tree per year was selected. Scaling this up across campus results in a total annual sequestration between 5,418 and 54,180 kilograms, or 5.4 to 54.2 metric tons.

Monetary Valuation

Using a carbon price of CAD 170 per metric ton, the total monetary value of carbon storage on campus is estimated to be between CAD 61,404 and CAD 92,106. Similarly, the annual value of carbon sequestration ranges between CAD 918 and CAD 9,211. Taking the midpoints, the median values are approximately CAD 76,755 for total storage and CAD 5,065 per year for annual sequestration.

Given the diversity of tree species, ages, and environmental conditions on campus, carbon storage and sequestration rates naturally vary. Presenting a range rather than a single value provides a more accurate reflection of this variability and avoids overstating the precision of the estimates. These ranges are shown in table 3.

Storm Water Reduction

The TRU campus trees provide vital stormwater management services by intercepting rainfall through their canopies, thereby reducing surface runoff, mitigating flood risks, and relieving pressure on stormwater infrastructure. These services were quantified based on tree canopy area, local precipitation data, and interception efficiency, following methods outlined by Xiao et al. (2000) and McPherson et al. (1997).

The Canopy Projected Area (CPA)

CPA was calculated as a critical parameter for estimating rainfall interception. CPA represents the area covered by a tree's canopy as projected onto the ground. For the TRU dataset, the canopy diameter (spread) in meters was used to compute CPA for each tree using the formula for the area of a circle:

$$CPA = \pi \times \left(\frac{Spread}{2}\right)^2$$

(1)

The average Canopy Projected Area (CPA) per tree was calculated as 28.69 m², based on measured canopy spreads, with a standard error of 1.02 m². This gives a 95% CI [26.69,30.69].

Rainfall Interception Calculation

Using Kamloops' 2024 average annual precipitation of 295.9 mm converted to 0.2959 meters, assuming an interception efficiency of 20%, times the average CPA at 28.69 m² the rainfall intercepted per tree yields 1.70 m³ per year (Kamloops Weather Stats, 2024). For TRU's 1,806 trees, the total rainfall interception amounts to approximately 3,070 cubic meters annually. The intercepted rainfall volume was calculated using the formula:

$$R_{intercepted} = CPA \times P \times E$$

(2)

where P is the precipitation in meters and E is the interception efficiency (Xiao et al., 2000).

Monetary Valuation

To estimate the economic value of this service, the intercepted rainfall volume was multiplied by an average stormwater management cost of CAD 2.60 per cubic meter. This cost is consistent with the study by Millward and Sabir (2011), which estimated the avoided cost of stormwater treatment at $1.93 USD per m³ for urban parks in Toronto.

$$V_{stormwater} = R_{intercepted} \times C_{management}$$

(3)

The management cost was derived based on averages reported in urban forestry literature. To account for scientific uncertainty in the variables, a plausible range of interception benefits was also developed and is shown in table 1 below.

Table A1: *Summary of Range of Scientific Uncertainty*

Variable	Current Assumption	Lower range	Upper range
CPA (m2)	28.69	26.69	30.69
Annual Precipitation (P in meters, m)	0.2959	0.260	0.330
Interception Efficiency (E in %)	20	15	25
Intercepted rainfall volume (m³/tree)	1.70	1.04	2.531
Management Cost (CAD$ per m³)	2.60	2.00	3.00
Value of stormwater (CAD$ per tree)	4.42	2.08	7.60
Toal valuation based on 1806 trees (CAD$)	**7,7980**	**3,756**	**13,718**

Table A1 shows the economic benefit to be CAD 7,980 per year and varies between CAD 3,756 CAD and 13,718 CAD per year.

Air Pollution Removal

Baltimore’s data was selected due to its relevance for university campus environments. Many campuses, including those in Baltimore, feature a mix of green spaces, moderate urbanization, and diverse land use. The presence of institutions like Johns Hopkins University, Morgan State University, and the University of Maryland reflects a landscape that balances urban density with substantial tree canopy coverage. This aligns well with the environmental setting of most university campuses, where tree benefits include pollution removal, aesthetic enhancements, and ecosystem services.

Monetary Valuation

The air pollution removal benefits of campus trees were estimated using pollution removal rates and economic valuation metrics derived from Nowak et al. (2006). The total Canopy Projected Area (CPA) for campus trees was calculated as discussed before. Pollution removal rates were adapted from Baltimore, where urban forests remove an average of 12.2 g/m²/year the equivalent to 0.0122 kg/m²/year with a range from 0.0045 to 0.0171 kg/m²/year.

The price for pollution removal was derived from Baltimore's data, where Nowak et al. (2006) reported that 499 metric tons of pollution removal were valued at USD2.7 million, equating to USD5.41 per kilogram of pollution removed. This value was converted to CAD using an exchange rate of 1 USD = 1.35 CAD, resulting in an adjusted rate of CAD7.30 per kilogram.

The total air pollution removed by campus trees was estimated to be 632.13 kg/year, based on a total canopy area of 51,814 m² and the standardized removal rate of 0.0122 kg/m²/year from Nowak et al. (2006). The corresponding economic value was calculated to be approximately CAD4,615 per year with a range from CAD1,583 to CAD6,919, reflecting societal benefits such as improved air quality, enhanced public health, and reduced environmental damage.

This methodology assumes that the standardized pollution removal rates and economic valuation from Baltimore are applicable to the campus trees. While localized factors such as species composition and meteorological conditions could refine the estimates, this approach provides a reliable baseline. Table A2 provides a summary

Table A2: *Air Pollution Removal Valuation Summary*

Variables	Details	Lower Bound	Upper Bound
Total Canopy Projected Area (CPA in m²)	51,814	48,202	55,426
Adopt Pollution Removal Rates (kg/m²/year)	0.0122	0.0045	0.0171
Calculate Total Pollution Removed (kg/year)	632.13	216	947.8
Adopt Valuation Rate at $1.35 CAD per USD	7.30	7.30	7.30
Calculate Economic Value (CAD$)	4,615	1,583	6,919

Energy Savings

To estimate the energy savings provided by trees on the TRU campus, this study adopted a proportionality approach based on findings from Millward and Sabir (2011), who quantified the energy savings produced by the dominant tree species in Allan Gardens, Toronto. The Allan Gardens study calculated the total energy benefits by assessing electricity and natural gas savings associated with reduced heating and cooling demand due to tree shading. Both

Allan Gardens and the TRU campus sit in temperate, mid-latitude urban environments where tree shading, and wind-break effects drive comparable heating and cooling savings. The methodology incorporated local energy costs and species-specific contributions to total park benefits. The key results from their study for seven species also found on TRU's campus are shown in Table A3 below.

Table A3: *Energy Saving Benefits Results from Millward and Sabir (2011)*

Species	Electricity (GJ)	Natural Gas GJ	Park%
Norway Maple	14.6	161	13
Sugar Maple	10.3	131	18
Siberian Elm	5.7	66	7
Silver Maple	9.3	93	5
Green Ash	2.4	31	6
Austrian Pine	1.9	21	3
Other Species	29.5	303	31
Total	**73.7**	**806**	**83**

In Table A3, the total percentage of the park sums up to 83%. This is because three non-TRU species (Crimean Linden, Littleleaf Linden, Columnare Maple) have been omitted. The prior mentioned species were rescaled, so that their park shares sum to 100%. The proportion of each species in TRU was also calculated. From these two proportions, a proportionality factor (TRU % ÷ rescaled park %) was computed for each species.

Table A4: *Calculation for Proportionality Factor*

Species	Rescaled Park%	TRU Count	TRU %	Proportionality Factor
Norway Maple	15.66	55	3.05	0.1950
Sugar Maple	21.69	9	0.50	0.0231
Siberian Elm	8.43	20	1.11	0.1316
Silver Maple	6.02	25	1.38	0.2292
Green Ash	7.23	151	8.36	1.1565
Austrian Pine	3.61	133	7.36	2.0393
Other Species	37.35	1413	78.24	2.0958
Total	**100**	**1806**	**100**	

Using the proportionality factor, the electricity and natural gas in table A3 was converted to TRU specific values. In our referenced study, electricity savings were calculated using a price of $0.10 USD/kWh (13.90 USD/GJ), which was discounted by 50% to account for the trees' location within an urban park. Natural gas savings were valued at 10.60 USD/GJ. These prices were inflated by 34% and converted to CAD (1.35 CAD/USD) in order to derive the present-day value of the benefits. Table A5 summarises the yielding rates of the benefits and Table A6 shows the energy saving benefit of each species.

Table A5: *Adjusted Electricity and Natural Gas Rates*

Commodity	2008 USD/GJ	CPI	Exchange Rate	2025 CAD/GJ
Electricity	13.90	1.34	1.35	25.15
Natural gas	10.60	1.34	1.35	19.17

Table A6: *Energy Saving Benefit by Species*

Species	Electricity (GJ)	Electricity (CAD$)	NG GJ	NG (CAD$)
Norway Maple	2.85	71.64	31.40	602.19
Sugar Maple	0.24	6.04	3.03	58.10
Siberian Elm	0.75	18.87	8.68	166.40
Silver Maple	2.13	53.57	21.30	408.68
Green Ash	15.70	394.71	190.20	3,648.69
Austrian Pine	3.87	97.35	42.83	821.15
Other Species	61.75	1,553.16	635.30	12,185
Total	**87.29**	**2,195.34**	**932.74**	**18,890**

Monetary Valuation

The total annual energy-savings benefit from TRU’s 1 806 campus trees was calculated at 21,085 CAD by adding the electricity and natural gas savings. The total value in energy savings per species and energy saving per tree is provided in table. To quantify the variability around the estimate, a 95% Confidence interval was constructed using the weighted sample standard deviation of per-tree savings from the seven species groups, which yielded 4.93 CAD per tree. Treating each tree’s savings as an independent draw, the standard error of the total sum across 1,806 trees was calculated as 209 CAD. Thus, the annual energy-savings benefit varies between 20,674 CAD and 21,496 CAD. Table A5 presents the calculation of total energy savings value based on species-specific per-tree savings and population counts at TRU.

Table A7: *TRU Tree Energy Savings – Calculation Table*

Species	Tree Count	Value per Tree (CAD$)	Total Value (CAD$)
Norway Maple	55	12.25	673.83
Sugar Maple	9	7.13	64.14
Siberian Elm	20	9.26	185.27
Silver Maple	25	18.49	462.25
Green Ash	151	26.79	4,043.40
Austrian Pine	133	6.9	918.5
Other	1,413	9.72	13,738.16
TOTAL	**1,806**		**21,085.55**

Table A8 is derived from Table A7.

Table A8: *Confidence Interval Calculation*

Metric	Value CAD$
Weighted average benefit per tree	11.12
Weighted variance (per tree)	24.3
Standard deviation (SD)	4.93
Standard error of total estimate	209.48
95% Confidence Interval (CAD)	20,674; 21,496

Table A9 summarises the process of proportionality and the calculation of savings.

Table A9: *Energy Savings Valuation Inference – TRU Campus Trees*

Step	Explanation
Per-Tree Energy Savings Estimate	Total CAD21,085 divided by 1,806 trees yields ≈ CAD11.12 per tree. This is a weighted average based on species-specific savings.
Species-Specific Energy Data Source	Millward and Sabir (2011) reported electricity and gas savings for individual species. These were used as the base values.
Energy Prices Used	Electricity: $0.10 USD/kWh (converted to $13.90 USD/GJ, then discounted by 50% for park setting). Natural Gas: $10.60 USD/GJ.
Species Mapping to TRU	TRU tree species were matched to similar species categories from Allan Gardens to assign per-tree energy savings values.
Exchange Rate & Inflation Adjustment	Conversion from USD to CAD assumed (e.g., 1.35) and adjusted to reflect current values (34% inflation).
Standard Deviation & Standard Error	Weighted SD across species reported as CAD4.93. Standard error of mean across 1,806 trees = 4.93 / √1806 ≈ 0.12. SE of total sum = CAD209.
Confidence Interval (95%)	Total estimate ± 1.96 × SE = $21,085 ± $209 → [20,674 , 21,496] CAD.

Aesthetic Value

The aesthetic value of TRU campus trees was estimated using findings from prior studies that quantified the contribution of trees to property values and urban amenity benefits. This analysis adopted methodologies from Millward and Sabir (2011), McPherson et al. (2005), and Xiao et al. (2018), which applied the hedonic pricing method to assess the economic value of urban trees. These studies measured the influence of tree presence and canopy cover on property values as a proxy for aesthetic and amenity benefits.

Millward and Sabir (2011) evaluated aesthetic benefits in Allan Gardens, Toronto, based on a total of 309 trees, estimating the annual aesthetic value at $9,661 USD. This corresponded to a per-tree value of approximately $31.27 USD annually. McPherson et al. (2005) reported annual aesthetic benefits ranging from $15 to $67 USD per tree across five U.S. cities, while Xiao et al. (2018) synthesized findings from multiple studies, reporting a broader range of $7 to $165 USD annually per tree.

Monetary Valuation

For the TRU campus, the aesthetic value was calculated by adopting a per-tree value of $31.27 USD annually and a range of $15 to $67 USD per tree, reflecting the findings from McPherson et al. (2005) and, Millward and Sabir (2011). This value was a converted to CAD using an exchange rate of 1 USD = 1.35 CAD. The resulting per-tree aesthetic benefit was $42.22 CAD with a range from $20.25 to 90.45 annually. The total aesthetic value for the TRU campus trees was then derived by multiplying the per-tree value by the total number of trees on campus. The total aesthetic value was estimated to be $76,249 and in the range $36,571 and $163,352. Table A6 shows a summary of the calculations:

Table A10: *TRU Campus Trees – Aesthetic Value Calculation*

Source Study	Per-Tree Value (USD$)	Per-Tree Value (CAD$)	Total Value (CAD$) for TRU (1,806 trees)
Millward and Sabir (2011)	31.27	42.22	76,249
McPherson et al. (2005) – Lower Bound	15.00	20.25	36,571
McPherson et al. (2005) – Upper Bound	67.00	90.45	163,352

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