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RESEARCH ARTICLE

Multidimensional Valuation of Trees at Thompson Rivers University: An Ecological, Cultural, and Socio-Economic Exploration

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ABSTRACT

This study evaluates the ecosystem services provided by 1,806 trees on the Thompson Rivers University (TRU) campus, quantifying their economic, environmental, and social contributions through benchmarked valuation techniques. The total appraisal value of these trees is estimated at approximately 34.3 million Canadian dollars (CAD), with an annual ecosystem service yield of CAD343,000. Key annual service values include CAD76,755 for carbon storage, CAD5,065 for carbon sequestration, CAD4,615 for air-pollution removal, CAD7,980 for stormwater management, CAD21,000 in energy savings, and CAD76,250 in aesthetic benefits. Beyond these measurable services, the urban forest enhances biodiversity, supports cultural and educational experiences, and promotes mental well-being through the provision of tranquil green spaces. The methodology presented provides a replicable framework for valuing urban forests in academic settings and highlights the importance of proactive policies to safeguard and enhance green infrastructure as a core element of campus planning and sustainability efforts.

Keywords: air pollution removal, biodiversity, campus sustainability, carbon sequestration, carbon storage, ecosystem services, green infrastructure, stormwater management, sustainability planning, tree valuation, urban forest

Introduction

Urban green spaces are increasingly recognized as pivotal to enhancing environmental quality, human well-being, and the sustainability of urban landscapes. Trees, as key elements of these green spaces, contribute services that support air purification, carbon sequestration, temperature regulation, and mental and physical health benefits, which are indispensable to sustainable urban development (Costanza et al., 1997; Costanza et al., 2014) . Recognizing and quantifying these services is essential for informed landscape planning, resource allocation, and the ongoing preservation of green assets within academic institutions.

This study, undertaken at Thompson Rivers University (TRU) in Kamloops, British Columbia, focuses on assessing the ecological and economic contributions of over 1,800 trees located across the university's campus. These trees collectively enhance the campus ecosystem, promoting ecological resilience and livability.

The study quantifies the ecological and economic value of these campus trees by translating tree-based services into both ecological metrics and dollar-equivalent figures. Established ecosystem-service valuation methods were adapted to TRU's total canopy cover, species composition, and local climate to estimate annual carbon sequestration, air-pollutant removal, stormwater interception, energy-cost savings, and aesthetic benefits. The resulting data equip TRU to prioritize planting, maintenance, and budget allocations and provide transferable metrics for campus planning and policy decisions at other institutions. By identifying and quantifying these benefits, the study highlights the importance of preserving and managing urban natural assets as key components of sustainable, resilient, and human-centred campus environments.

Researchers have progressively built upon our understanding of urban tree benefits. A significant portion of this body of work focuses on identifying key environmental advantages. For instance, researchers like Atreya et al. (2021) examined the pollution absorption capabilities of urban trees. They and others quantified how urban trees remove pollutants like ozone, nitrogen dioxide, and particulate matter, directly improving air quality in urban areas. Livesley et al. (2016) and Helletsgruber et al. (2020) emphasized the critical role of trees in supporting biodiversity and ecological functions. They highlighted how urban trees provide habitats for various species, enhance ecological connectivity, and contribute to overall urban ecosystem health, which is crucial for sustainable urban development. Dunn-Johnston et al. (2016) also contributed to this area by focusing on the importance of selecting tree species with low emissions to improve air quality, pointing out that some tree species emit volatile organic compounds (VOCs) that can contribute to ozone formation. Asanok et al. (2021) further investigated how urban trees mitigate the harsh impacts of urbanization, emphasizing their role in providing shade, cooling cities, absorbing pollutants, and reducing the urban heat island effect.

Other research has focused on the economic value of urban trees and the benefits they provide. Peacock et al. (2018) assessed the monetary value of trees on the Harewood House estate in the United Kingdom and found that they provided significant ecosystem services worth around £29 million, covering an area of 200 hectares. This value amounts to approximately CAD49.3 million. This type of research quantifies the financial benefits derived from trees, such as carbon sequestration, air pollution removal, and stormwater management. Nesbitt et al. (2017) further enriched this understanding by emphasizing the social and economic value of urban forests in North America, particularly through the lens of cultural ecosystem services. They examined how urban forests provide recreational, aesthetic, and cultural benefits that contribute to human well-being and have economic implications. Isaifan & Baldauf (2020) also broadened the scope by assessing the contribution of trees to air quality, property values, and energy savings, even in arid climates.

The focus of research has also expanded to include the social benefits of urban trees. Turner-Skoff and Cavender (2019) highlighted the role of trees in enhancing community livability and sustainability, noting their positive impacts on physical and mental health, community spirit, and property values. Studies have shown that access to green spaces and trees can reduce stress, improve mental health, and promote social interaction among residents. Wolf et al. (2020) specifically underscored the substantial health benefits offered by urban forests. Research indicates that exposure to trees can lower rates of cardiovascular disease, improve immune function, and even increase longevity. Elmendorf (2008) synthesized much of this work by reviewing the broader role of trees and nature in community development. This work emphasizes how urban green spaces contribute to social cohesion, reduce crime rates, and enhance overall quality of life. Pravota et al. (2012) and Tsvuura et al. (2023) also contributed to this understanding, with their studies emphasizing the role of trees in social adaptation to climate change, community development, and supporting livelihoods. Trees can provide shade and cooling during heatwaves, reduce flood risks, and offer opportunities for urban agriculture. Kalaba (2014) provided a unifying framework by highlighting the concept of forest socio-ecological systems, which emphasizes the interplay between social and ecological aspects. This framework highlights the interconnectedness of human societies and urban forests.

Throughout this growing body of research, scientists have also addressed the challenges associated with urban forest management. Malkamäki (2018) drew attention to the potential negative impacts of large-scale tree plantations on employment, land use, and livelihoods. This research acknowledges that while trees offer numerous benefits, large-scale planting projects can sometimes have unintended consequences for local communities and economies. Widney et al. (2016) stressed the importance of proper management for the long-term survival and benefits of urban trees. Effective management practices, including species selection, planting techniques, and ongoing maintenance, are crucial for ensuring the health and longevity of urban forests. Arbab et al. (2022) evaluated the economic impacts of specific threats, such as the emerald ash borer, and demonstrated the economic value of proactive management. Invasive pests and diseases can devastate urban tree populations, leading to significant economic losses and a decline in ecosystem services.

This paper is structured to provide a comprehensive understanding of the ecosystem services offered by the TRU urban forest. It begins with a methodology, outlining the approaches used to quantify the environmental and economic contributions of campus trees. The results section presents key findings on carbon benefits, air pollution removal, stormwater interception, energy savings, and aesthetic value. The paper concludes with remarks, summarizing the study's significance and offering recommendations for the future management and preservation of urban forests.

Methodology

Study Area

This research was conducted on the TRU campus, located in Kamloops, British Columbia, Canada. The campus, known for its ecological diversity and urban greenery, hosts over 2,200 trees across its landscape. However, this study focuses on a subset of 1,806 trees that have been appraised, providing detailed insights into their quantifiable ecosystem services and economic contributions. These trees vary in species, size, and age, contributing to the campus' ecosystem services. The study area offers a representative environment to explore the valuation of natural assets within an institutional urban setting, where tree coverage supports both ecological resilience and campus livability.

***Figure 1**. Aerial view of the Thompson Rivers University (TRU) campus in Kamloops, British Columbia.*
(Thompson Rivers University/ Flickr)

Data Collection & Cleaning Process

The data used for this research were provided by Greg Houghton, a horticulturist and International Society of Arboriculture (ISA) Certified Arborist, Climber, and Tree Risk Assessor along with the Sustainability Programs team at TRU headed by James Gordon. The dataset, recorded as of January 11th, 2023, contains detailed information on 2,255 trees.

Before proceeding with the analysis, the dataset underwent a comprehensive cleaning process to ensure accuracy and reliability. Key steps included:

- **Handling missing data:** Records with missing essential variables, such as undefined appraisal values, Diametre at Breast Height (DBH), height, spread, trunk, species or condition were excluded from the dataset.
- **Removing zero values:** Trees with zero values for DBH, height, spread, trunk or condition were removed to ensure meaningful and valid analysis.
- **Standardization:** All measurements were standardized to ensure consistency, such as converting DBH, height, spread measurements into standard units of measurements.

Table 1: *Data Available After Removal of Missing Observations*

Removal of Observations	Original Dataset	Amount Removed	# of Trees Remaining
Original Observations	2,255	–	–
Unrecorded Species	–	20	2,235
Removed Zero/Missing DBH values	–	153	2,082
Removed Zero/Missing Height Values	–	29	2,053
Removed Zero/Missing Appraisal Values	–	247	1,806
Remaining Trees	**–**	**–**	**1,806**

After data cleaning, the final dataset consisted of 1,806 trees, providing a robust foundation for subsequent analyses. To evaluate the economic and ecological benefits of the trees, we employed a structured approach comprising different evaluation methods:[1]

Tree Appraisal Using Tree Works

Tree Works adopts a formulaic approach to appraise tree values, incorporating species ratings, condition, and location (Kenerson Group, n.d.). The valuation formula is as follows:

$$Appraised\ value\ =\ Basic\ value * \ Condition * \ Location \quad (1)$$

Here, Basic value signifies the tree's fundamental monetary worth, calculated as:

$$Basic\ value\ =\ Replacement\ cost\ +\ (Basic\ price * \ [TA(A) - TA(R)] * \ Species) \quad (2)$$

Where:

- **Replacement cost:** The cost to purchase and install the largest suitable and transportable tree available locally.

1 See supplementary file for detail information on the calculation of each ecosystem service benefits.

- **Basic price:** Determined per square inch of the trunk area, adhering to American Nursery Standards.
- **TA(A):** Trunk area of the appraised tree, measured 4.5 feet above ground.
- **TA(R):** Trunk area of the replacement tree, typically measured at 6 or 12 inches above ground.
- **Species factor:** Adjusts value based on the desirability and ecological suitability of the species.

Condition evaluates the tree's structural health and quality, expressed as a percentage. Higher ratings indicate better health and structural integrity, enhancing the tree's appraised value.

Location encompasses three sub-factors:

- **Site:** The physical placement of the tree.
- **Contribution:** Functional and aesthetic impacts on its surroundings.
- **Placement:** Appropriateness of the tree's position within the landscape.

These factors collectively assess the tree's interaction with and importance to its environment. The tree appraisals used in this study were provided by TRU and computed using Tree Works.

Carbon Storage & Sequestration

Trees at the TRU campus play a critical role in mitigating climate change by storing carbon and sequestering CO_2 annually. This is quantified using methodologies from Xia et al. (2020), McPherson et al. (2005), and Andrew et al. (2008). Carbon storage varies by tree size, species, and growth conditions, with significant contributions from mature trees. For example, species such as Norway maple and silver maple can store up to 181 kg of carbon each. The TRU campus uses a conservative estimate of 200–300 kg of carbon stored per tree, consistent with the i-Tree software average of 260 kg.

Annual carbon sequestration rates vary by species and maturity, estimated between 3 and 30 kg per tree. These benefits are monetized at a rate of CAD170 per ton of carbon, aligning with the national carbon pricing framework.

Figure 2. *One of the largest Diametre at Breast Height (DBH) trees on campus, highlighting the scale and maturity of this Ponderosa pine. (Photo credit: Peter Tsigaris)*

Storm Water Reduction

The TRU campus trees significantly mitigate stormwater by intercepting rainfall, thereby reducing runoff and alleviating flood risks. This is calculated using the Canopy Projected Area (CPA), derived from the tree canopy spread, combined with local precipitation statistics and interception efficiencies from urban forestry research (Xiao et al., 2000; McPherson et al., 2005).

The monetary value of this ecosystem service is estimated using average stormwater management costs, representing avoided stormwater treatment expenses (Millward and Sabir, 2011).

Air Pollution Removal

Using data from Nowak et al. (2006), this study estimates the pollution removal capabilities of campus trees based on standardized rates from urban settings such as

Baltimore. These rates were adapted for TRU, yielding an estimated value of CAD7.30 per kilogram of pollution removed.

Energy Savings

Energy savings were calculated by assessing the reduction in heating and cooling demands attributable to tree shading. This calculation used species-specific data and local energy costs, following a proportional approach from the Allan Gardens study in Toronto (Millward and Sabir, 2011).

Energy contributions from species such as Norway maple, sugar maple, and Siberian elm were scaled to match the TRU tree population. Savings from electricity and natural gas were calculated using adjusted rates from comparable species in the Allan Gardens study.

The valuation used rates of CAD0.135 per kWh for electricity and CAD14.30 per GJ (gigajoule) for natural gas.

Figure 3. *A mature honey locust, among the widest on the Thompson Rivers University campus near the Science building, providing shade and aesthetic value as part of the campus's urban forest. (Photo credit: Kris Kadaleevanam)*

Aesthetic Value

The aesthetic and amenity contributions of trees to urban environments are evaluated using the hedonic pricing method. Studies by Millward and Sabir (2011) and McPherson et al. (2005) have quantified these benefits, which are integrated into the appraisal to reflect the economic value derived from tree presence and canopy cover. For the TRU campus, aesthetic value was calculated by adopting a per-tree value of CAD42.22 annually, based on findings from Millward and Sabir (2011) for a public park with mixed tree species.

Results

Descriptive Statistics

The descriptive analysis of the 1,806 trees on the TRU campus provides a comprehensive overview of their key characteristics and appraised values. The results highlight significant variability across the population, reflecting the diversity in species, size, and condition of the campus trees. Table 2 summarizes the primary descriptive statistics for tree Diametre at Breast Height (DBH), height, canopy spread, condition ratings, basic value, and appraisal value.

Table 2: *Summary Descriptive Statistics of 1,806 of Trees on Campus*

Characteristics	Median	Mean	Std. dev.	95% CI [lower, upper]		Min	Max
DBH (centimetres)	15	20.6	20.0	19.7	21.5	1	155
Height (metres)	6	7.2	5.0	7.0	7.4	1	38
Spread (metres)	4	4.9	3.6	4.7	5.0	1	25
Condition (%)	70	70.8	6.7	70.5	71.2	25	85
Basic value (CAD$)	5,100	36,108	70,546	32,847	39,369	324	608,000
Appraisal (CAD$)	8,876	18,992	36,955	17,283	20,700	120	319,200

The dataset reveals considerable variation in tree size, with DBH ranging from 1 cm to an impressive 155 cm, and a mean of 20.6 cm. This wide range captures both young saplings and fully mature trees, indicating a diverse mix of growth stages and species. Tree height follows a similar trend, varying from as low as 1 metre to a maximum of 38 metres, with an average height of 7.2 metres. Canopy spread averages 4.9 metres, with larger trees extending up to 25 metres, contributing significantly to shading and ecological benefits.

The health of the TRU urban forest is reflected in the condition ratings, with a mean of 70.8% and a narrow standard deviation of 6.7%, indicating a relatively consistent health profile across the tree population. Most trees are in moderate to good health, with condition ratings ranging between 25% and 85%.

Economic valuation of the trees shows striking variability. Basic values range from CAD324 to CAD608,000, with a mean of CAD36,108 and a high standard deviation of CAD70,546. This substantial variability highlights the influence of outliers, such as large, high-value trees that significantly elevate the mean. Similarly, appraisal values span from a minimum of CAD120 to a maximum of CAD319,200, with a mean of CAD18,992 and a standard deviation of CAD36,955. The positive skew in both basic and appraisal values suggests the presence of a small number of highly valuable trees, which disproportionately contribute to the total valuation of the urban forest.

Distribution of Trees

The TRU campus consists of a diverse array of tree species, with Ponderosa pine being the most prevalent, accounting for 24.2% (437 trees) of the total tree population. This species is followed by green ash, representing 8.4% (151 trees), and Austrian pine, which constitutes 7.4% (133 trees). Other notable species include quaking aspen with 4.3% (78 trees) and crabapple, making up 3.9% (70 trees).

Maples contribute significantly to the distribution, with Norway maple (3.0%, 55 trees) and red maple (2.7%, 48 trees) being the most common among them.

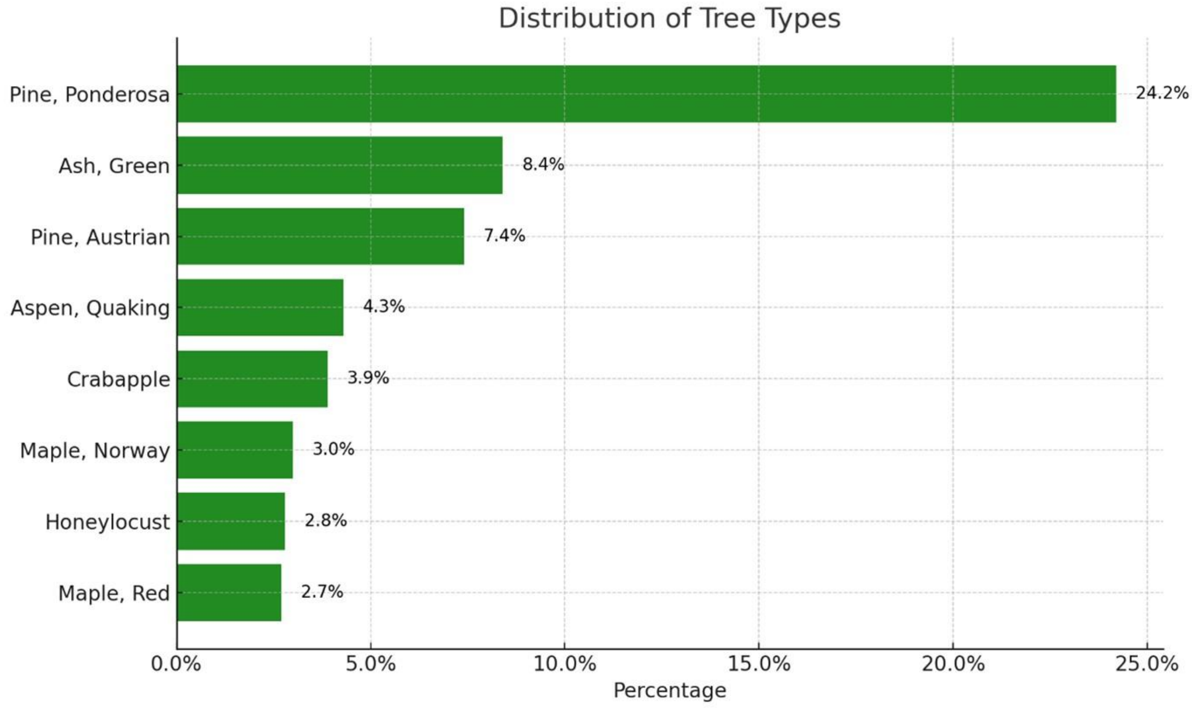

Figure 4. *Most Common Trees on Campus.* Long description

Additional species, such as Colorado spruce (2.3%, 41 trees), Douglas-fir (2.2%, 40 trees), and red oak (2.1%, 39 trees), enhance forest diversity. Smaller populations of littleleaf linden (31 trees, 1.7%), white ash (30 trees, 1.6%), and common hackberry (29 trees, 1.6%) further contribute to species richness. Less common species, such as Siberian elm (20 trees), European beech (13 trees), and flowering pear (13 trees), represent a smaller but significant component of the urban forest. Rare species like western redcedar (2 trees), eastern redbud (2 trees), and Amur corktree (1 tree) reflect additional ecological variety. The presence of over 1,800 trees across 75+ species demonstrates the ecological and cultural value of the TRU campus.

Ecosystem Services Yield

The Ecosystem Service Yield Analysis provides a framework to estimate the annual contributions of the TRU urban forest by translating its appraisal value into a quantifiable monetary representation of its ecosystem services. This approach simplifies complex ecological functions into an economic metric, facilitating effective decision-making for sustainability planning and resource allocation.

By focusing on the total appraisal value and applying a fixed yield rate, the analysis offers a practical method for assessing the financial benefits provided by campus trees. The calculation is based on:

$$E_{yield} = A_{total} \times r \tag{3}$$

Where E_{yield} represents the total annual monetary contribution of ecosystem services, A_{total} is the total appraisal value of the trees, and r is the yield rate reflecting the proportion of the appraisal value attributed to annual ecosystem services.

For this study, the total appraisal value of the 1,806 trees on the TRU campus was determined to be CAD34,299,020, reflecting the combined economic value of the trees based on their size, species, health, and location. A very conservative rate of return of 1% was applied, representing the portion of the appraisal value realized annually as ecosystem service benefits:

$$E_{yield} = \$34{,}299{,}020 \times 0.01 = \$342{,}990.2\ CAD \text{ per year}$$

This result demonstrates that the 1,806 TRU campus trees provide an estimated CAD342,990.20 annually in ecosystem services, which is considered a minimum rate of return.

Campus trees offer regulating, maintenance, supporting, and cultural services, with the exception of provisioning services. They play a crucial role in regulating services: significantly improving air quality by filtering pollutants, storing and sequestering carbon, and producing oxygen, which collectively contribute to climate regulation.

They also manage rainfall through canopy interception, effectively reducing stormwater runoff and mitigating flood risks, while providing natural insulation and shade that decrease energy consumption in nearby buildings. Additionally, campus trees serve as effective noise barriers, creating quieter environment, and regulate the microclimate by reducing heat island effects and providing windbreaks that protect against wind damage.

In terms of maintenance and support, trees support biodiversity by providing vital habitats for wildlife and stabilize the soil to prevent erosion. Culturally, trees are invaluable to TRU employees and students, promoting mental health and psychological well-being, contributing to campus aesthetics and the cultural fabric of the landscapes. Moreover, they offer educational opportunities, serving as practical tools for environmental education and raising awareness about ecological issues.

Justification of Using a 1% Yield

Justification for using a 1% yield is based on the returns of financial assets (Figure 4). The S&P 500 index offers a 6.5% annual real return, including compensation to investors for systematic risk (e.g., economy wide shocks), while corporate bonds offer 3.5%, as they also carry risk. In contrast, gold and real estate, over the long run, offer a dismal real rate of return of 1.8% and 1.2%, respectively. Long-term treasury bonds offer a return of 1.5%.

Assuming that trees offer a 1% return, which is lower than the average 2.5% for financial and real assets of and lower than the 10-year treasury bonds of 1.5%, implies that this is a conservative minimum estimate of the return on investment in natural assets (trees).

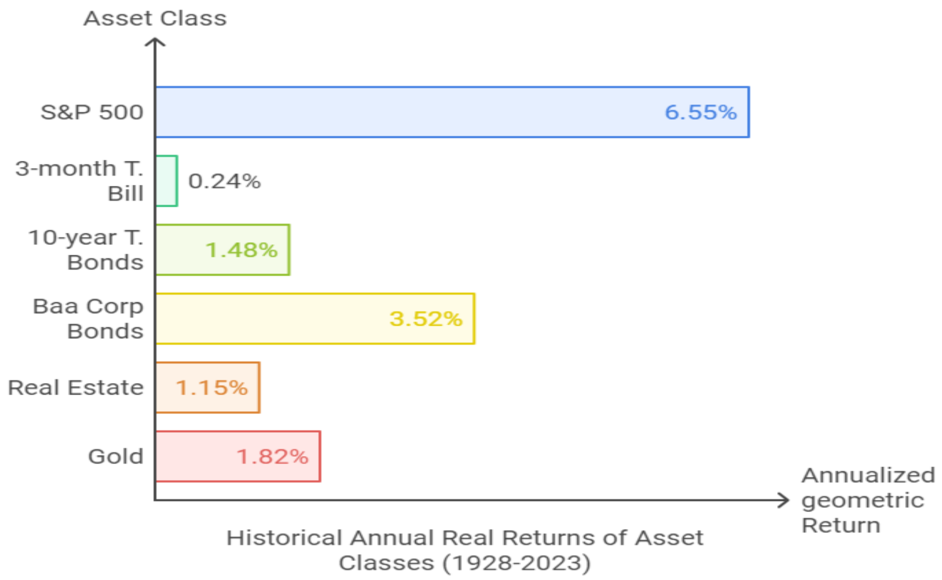

Figure 5. *Yield From Different Financial Instruments.* [Long description]

Carbon Benefits

The total carbon storage of TRU campus trees ranges from 361,200 to 541,800 kg (or 361.2 to 541.8 tons). This significant capacity to store carbon highlights the vital role of campus trees as a long-term carbon sink. Annual carbon sequestration, representing the yearly uptake of CO_2, was estimated to range from 5,418 to 54,180 kg (or 5.4 to 54.18 tons per year). Using a carbon market price of CAD170 per ton, the monetary value of this storage was calculated as CAD61,404 to 92,106, while the value of annual sequestration was estimated at CAD918 to 9,211 per year[2]. The value for storage uses the mid-point at CAD76,755, and sequestration at CAD5,065 annually.[3]

These results are consistent with Xia et al. (2020), who reported annual economic benefits ranging from USD0.34 to 13.38/tree/year (CAD0.45 to 18/tree/year), depending on species and avoided emissions. While TRU's values are slightly lower than those in regions with larger canopies and higher sequestration rates, they reflect the moderate size of its trees and temperate climate.

Incorporating avoided emissions, as done by McPherson et al. (2005), could further raise these valuations, aligning them more closely with urban forests in denser urban areas or under more intensive management strategies.

Air Pollution Removal Benefits

The total air pollution removed by campus trees was estimated to be 632.97 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), with a range from 0.0045 to 0.0171. The corresponding economic value was calculated to be approximately CAD4,615 per year and ranges from CAD1,583 to CAD6,919 per year. This reflects societal benefits such as improved air quality, enhanced public health, and reduced environmental damage.

This valuation is consistent with the results reported for Baltimore by Nowak et al. (2006), where similar canopy cover and pollution removal rates demonstrated significant environmental and economic benefits. The findings emphasize the importance of urban forests in contributing to air pollution mitigation and highlight the value of maintaining and expanding tree cover in urban areas.

Stormwater Reduction Benefits

The TRU campus trees intercept an estimated 3,065.57 m³ of rainfall annually. This represents the water retained by tree canopies and prevented from becoming surface runoff, significantly reducing the load on stormwater infrastructure. The economic value of this interception yields a total annual benefit of CAD7,980 and varies between CAD3,756 and

2 For further details check section – 'Carbon Storage & Sequestration' in supplementary file.

3 For further details check section – 'Carbon Storage & Sequestration' in supplementary file.

CAD13,718 per year[4]. On a per-tree basis, this translates to an economic benefit of approximately CAD4.42 per tree annually.

The estimated stormwater interception benefits for the TRU urban forest are consistent with findings from similar studies. Xiao et al. (2000) documented interception rates ranging from 0.28 to 11.3 m³/tree/year, with economic benefits of USD0.28 to 54.61 per tree annually (approximately CAD0.37 to 72.50). McPherson et al. (2005) reported interception volumes of 11.3 m³/tree/year in Bismarck, where larger trees and higher rainfall contributed to benefits of USD 28 per tree annually (approximately CAD37). Similarly, Andrew et al. (2008) valued stormwater interception benefits in Toronto at USD12 per tree annually (approximately CAD15.96). While TRU's annual benefits of CAD4.24 per tree are lower, they reflect the temperate climate and moderate rainfall of Kamloops, as well as the mid-sized structure of TRU's trees. These findings emphasize the ecological and economic contributions of the TRU urban forest in providing stormwater management services, aligning with global efforts to mitigate flooding and reduce pressure on urban infrastructure.

Energy Savings Benefits

Using the proportionality method derived from the Allan Gardens study (Millward & Sabir, 2011), the TRU campus trees were estimated to provide substantial energy savings. Electricity savings totalled 87 gigajoules (GJ), while natural gas savings were 933 GJ. When combined, these energy savings were valued at CAD21,085 and a 95% CI [CAD20,674, CAD21,496][5], after accounting for adjustments related to inflation and exchange rates to reflect present-day economic conditions.

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4 For further details check section – 'Storm Water Reduction' in supplementary file.

5 For further details check section – 'Enerrgy Savings' in supplementary file.

Table 3: *Summary of Species-Specific Energy Savings Benefits*

Species	Tree Count	Electricity (CAD$)	NG (CAD$)	Total Value (CAD$)	Value per Tree
Norway Maple	55	71.64	602.19	673.83	12.25
Sugar Maple	9	6.04	58.10	64.14	7.13
Siberian Elm	20	18.87	166.40	185.27	9.26
Silver Maple	25	53.57	408.68	462.25	18.49
Green Ash	151	394.71	3,648.69	4 043.40	26.79
Austrian Pine	133	97.35	821.15	918.5	6.9
Other	1413	1,553.16	12,185	13 738.16	9.72
Total	**1806**	**2,195.34**	**18,890**	**21,085.55**	

Table 3 shows species-specific analysis for energy savings which revealed notable variations in contributions. Green ash trees provided the greatest saving at CAD26.79 per tree, followed by Silver Maple at CAD18.49 per tree. However, the largest contribution to the total energy savings of CAD21,085 came from the "Other" category, whose 1,413 trees contributed CAD13,738. Across all 1,806 trees, the average annual saving is CAD11.68 per tree, showing that both high-value species and the broader canopy are important for overall campus savings. The supplementary file explains in detail how values in this table was derived using the proportionality method.

Aesthetic Benefits

The total annual aesthetic value of TRU's urban forest was estimated at CAD76,297 and varies between CAD36,571 and CAD163,352. The per-tree value was estimated CAD42.22 and ranged from CAD20.25 to CAD90.45 annually[6]. This valuation highlights the significant contribution of campus trees to enhancing the aesthetic appeal of the university environment and its surroundings. This estimate falls in the ranges provided by McPherson et al. (2005) as well as Xiao et al. (2018).

6 For further details check section – 'Aesthetic Value' in supplementary file.

Existence and Bequest Value

The Existence & Bequest component captures highly valuable, yet inherently unquantified benefits provided by TRU's urban forest. These are the benefits that go well beyond the previously mentioned ecosystem services we were able to price. Existence value reflects the satisfaction and sense of wonder individuals experience simply knowing that mature trees and green spaces exist on campus, while bequest value represents our collective responsibility to hand down a healthy, thriving urban forest to future generations. Moreover, the trees provide critical habitat for birds, insects, and other wildlife, enhance mental health and well-being by creating calm, restorative retreats, and build community by beautifying the campus and fostering a shared sense of place.

Further, the forest holds cultural and educational significance, serving as a living laboratory for sustainability research and a daily reminder of TRU's commitment to environmental stewardship. Because these values cannot be readily expressed in dollars, the Existence & Bequest was calculated as the difference between the total annual ecosystem yield and the sum of all monetized services.

Summary of Results

The TRU campus trees deliver significant ecosystem services, valued at CAD343,000 annually. Key quantifiable benefits include carbon storage of CAD76,755 and annual carbon sequestration valued at CAD5,065. Trees also remove approximately 632.97 kg of air pollution annually, valued at CAD4,620, and intercept 3,065.57 m^3 of rainfall, providing CAD7,980 in stormwater management savings. Energy savings totalled 1,020 GJ, valued at CAD21,000 annually, while aesthetic contributions were estimated at CAD76,250 per year.

In addition to these measurable services, the trees contribute CAD151,200 annually in existence and bequest value, reflecting the satisfaction derived from the mere presence of trees, their preservation for future generations, and their role in supporting biodiversity and enhancing campus culture.

Table 4: *Summary of Results*[7]

Ecosystem Value	Economic Value $ (CAD)	95% CI
Basic Value	65.2 million	[59.3; 71.1]
Total Appraisal Value	34.3 million	[31.2; 37.4]
Annual Ecosystem Yield of 1%	343,000	[312,000, 374.,000]
Ecosystem Services	**Value**	**Potential range**
Carbon Storage	76,755	[61,404; 92,106]
Carbon sequestration	5,065	[918;9,211]
Air Pollution Removal	4,615	[1,702; 6,466]
Stormwater Management	7,980	[4,044; 12,846]
Energy Savings	21,085	[13983; 17900]
Aesthetic Value	76,297	[36,571; 163,352]
Existence – Bequest Value	151,203	[114,000; 190,000]

Note. *The existence–bequest value was estimated as an annualized component of total ecosystem service flows and reflects non-use values such as legacy, cultural significance, and intergenerational benefits. A ±25% uncertainty range was applied to reflect plausible variation in these non-market estimates, consistent with benefit transfer and sensitivity analysis guidance (Johnston et al., 2015; OECD, 2006).*

Limitations

This analysis provides a valuable framework for estimating the ecosystem services of the TRU urban forest; however, several limitations should be noted. These limitations arise from data constraints and methodological assumptions, which may influence the accuracy and applicability of the results.

First, the valuation of non-quantifiable benefits, such as existence value and bequest value, was not directly addressed in this study. While these services significantly contribute to the overall value of the urban forest, their monetary estimation typically requires methods such as contingent valuation or stated preference surveys, which were beyond the scope of this analysis. As a result, the total appraisal value reflects some intangible benefits that are not explicitly quantified in the environmental benefits calculations.

[7] Refer to the supplementary file for detailed calculation of economic values and ranges.

Second, the rates and parameters used in this study—such as stormwater interception costs, energy savings, and aesthetic values—were adapted from external studies and serve primarily as benchmarks rather than precise measurements. These rates were derived from urban forests in contexts such as Allan Gardens in Toronto and municipal forests in U.S. cities. While adjustments were made to align them with TRU's conditions, these generalized rates may not fully capture the specific characteristics of TRU's forest, including its species composition, climatic conditions, and local infrastructure.

Additionally, assumptions for key variables such as interception efficiency, carbon pricing, and stormwater management costs were drawn from averages reported in the literature. While these provide a consistent basis for analysis, they may not fully reflect local variability or current market dynamics. For instance, changes in carbon market prices or differences in stormwater infrastructure costs could significantly influence the valuation.

Moreover, this analysis assumes a static forest structure, which does not account for changes over time due to growth, mortality, or climate-related impacts. Dynamic models or longitudinal studies could offer a more detailed understanding of the forest's long-term service provision. The use of generalized data for metrics such as carbon sequestration and canopy area, rather than direct field measurements, also introduces a degree of uncertainty into the results.

Despite these limitations, the findings of this study provide a credible basis for understanding the ecosystem services provided by the TRU urban forest. Future research should focus on incorporating localized data, employing dynamic modelling, and exploring methods to quantify currently non-tangible benefits. Such refinements would enable more precise and comprehensive valuation, supporting more effective urban forest management and policy decisions.

Trade-offs and Management Considerations

While urban trees offer significant ecological and economic benefits, it is equally important to acknowledge the potential trade-offs and management challenges they present. Maintenance costs—including pruning, irrigation, pest control, and replacement—can be substantial, particularly in urban environments with diverse infrastructure demands (Hauer, Vogt, & Fischer, 2015). Certain species, such as Boxelders (*Acer negundo*), are prone to structural weakness and pest susceptibility, increasing risks of limb failure and storm damage (Dirr, 2009). In fire-prone regions like Kamloops, dense vegetation and unmanaged dry biomass can elevate wildfire risks in urban-forest interfaces (Gill, Stephens, & Cary, 2013).

Furthermore, tree roots may damage sidewalks, underground utilities, and building foundations, leading to considerable infrastructure repair costs (McPherson & Peper, 1995). Some trees also emit biogenic volatile organic compounds (BVOCs), which under high temperatures and sunlight can contribute to ozone formation, thus potentially degrading urban air quality (Calfapietra et al., 2013). Including these considerations alongside ecosystem benefits presents a more holistic view of urban forestry and supports informed policy on species selection, spatial planning, and long-term management strategies.

Policy Implications

The TRU urban forest provides significant benefits to the campus community, including environmental, social, and economic services. To sustain and enhance these benefits, campus policies must prioritize the effective management and integration of these trees into university planning and operations.

The campus trees are an integral part of the campus environment, contributing to carbon storage, stormwater management, energy savings, and the overall aesthetics of TRU. Regular maintenance, including pruning, pest control, and replanting, is essential to ensure the forest remains healthy and continues to support campus sustainability goals. Expanding tree cover where possible, particularly in areas that experience heavy foot traffic or are prone to heat, could further enhance these benefits and improve the campus experience.

Funding mechanisms are necessary to support urban forest management on campus. TRU could explore green infrastructure grants, stormwater management incentives, or carbon offset funding to cover maintenance costs and invest in tree planting programs. Allocating university resources to the forest would reflect TRU's commitment to sustainability and reinforce its role as a leader in climate action among academic institutions.

The non-quantifiable benefits of the campus forest, such as its contributions to mental well-being, biodiversity, and the enjoyment of students, staff, and visitors, should also be considered in policy decisions. Initiatives like guided nature walks, educational campaigns, or tree stewardship programs could foster a greater connection between the campus community and its green spaces. These programs would also encourage shared responsibility for the trees' health and preservation.

Finally, decisions about the campus forest should be informed by reliable data. Tools like i-Tree and GIS mapping can help track tree health, canopy coverage, and the forest's contribution to TRU's sustainability goals. By adopting evidence-based strategies, the university can effectively manage its trees and maximize its value for both environmental and community well-being. These actions will ensure that the TRU campus trees continue to enhance the campus experience, support sustainability goals, and serve as a vital resource for future generations of students and staff.

Conclusion

The TRU campus trees demonstrate immense value, providing a wide range of ecosystem services that support both environmental sustainability and community well-being. With an estimated annual worth of CAD342,990.20, these contributions highlight the forest's role in carbon sequestration, stormwater management, energy savings, and aesthetic enhancements. While this analysis successfully quantifies many of these services, it also reveals the limitations of conventional valuation methods in capturing the full scope of non-market benefits, such as cultural significance, biodiversity support, and intergenerational legacy.

Moving forward, it is imperative to integrate these findings into campus planning and sustainability strategies, ensuring that the forest's value is recognized and preserved. By committing to proactive management, expanding research, and fostering community engagement, TRU can continue to leverage its urban forest as a critical asset in addressing climate challenges and enhancing the quality of life for present and future generations.

Figure 6. *A towering Ponderosa pine, among the tallest trees on the Thompson Rivers University campus, located in the central Commons area, near the International Building. This mature specimen contributes significantly to canopy cover, shade provision, and the ecological character of the campus landscape. (Photo credit: Kris Kadaleevanam)*

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Ethical Consideration

This study received approval from the Research Ethics Board at Thompson Rivers University (REB File:103867).

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Long Descriptions

Figure 4 Long description:

Horizontal bar chart showing the most common tree species on the Thompson Rivers University (TRU) campus. Ponderosa pine is the most prevalent at 24.2%, followed by green ash (8.4%), Austrian pine (7.4%), quaking aspen (4.3%), crabapple (3.9%), Norway maple (3.0%), honey locust (2.8%), and red maple (2.7%). A central circle with tree icons symbolizes the campus urban forest, surrounded by concentric dashed rings with smaller tree-related icons.

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Figure 5 Long description: Horizontal bar chart titled "Historical Annual Real Returns of Asset Classes (1928–2023)." The x-axis represents the Annualized Geometric Return and the y-axis lists various asset classes. Bars show the following returns:

- S&P 500: 6.55% (blue)
- Baa Corporate Bonds: 3.52% (yellow)
- 10-year Treasury Bonds: 1.48% (light green)
- Gold: 1.82% (pink)
- Real Estate: 1.15% (light red)
- 3-month Treasury Bill: 0.24% (light green)

The chart visually demonstrates that the S&P 500 had the highest historical real return over the period, while the 3-month Treasury Bill had the lowest.

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Author

Kris Kadaleevanam is an Economics major at Thompson Rivers University with a strong interest in applied econometrics, environmental economics, and public policy. His research focuses on how economic tools and data analysis can be used to address real-world challenges, particularly those related to sustainability and community development.

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