WOOD PROPERTIES OF CITY STREET TREES FOR UTILIZATION IN FOREST PRODUCTS

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CONTENTS

TABLE OF TABLES

TABLE OF FIGURES

INTRODUCTION

Forest products are an essential part of the Canadian economy. Maximizing the number of trees we can use to make forest products will be a crucial part of continuing to produce forest products. The objective of this study is to determine the viability of using city street trees for forest products based on mechanical and physical properties.

Determining the viability of using city street trees in products is important in the future of urban forest management because it will give urban foresters more value for their trees and forest product manufacturers more wood for production. By using a combination of physical and mechanical property tests we can determine if city street trees can be used in the same products as natural trees. Testing mechanical properties such as MOE, and MOR can tell us if city street trees are as mechanically strong as natural trees. Physical properties are also an important part in forest products, value-adding features such as spalting can add significant value to a piece of lumber.

OBJECTIVES

The objectives of this study are to determine the viability of using city street trees in forest products compared to natural trees, based on mechanical and physical properties. Various mechanical and physical tests will be performed on samples of city street trees and natural trees.

LITERATURE REVIEW

TREE SPECIES

Silver maple (*Acer saccharinum*)

Silver maple is commonly found throughout Eastern North America including New Brunswick, Quebec, Ontario, Maine, Mississippi, and Georgia to name a few. Silver maple is typically found near streams, rivers, and lakes in well-drained, moist soils (Gabriel 2004). Silver maple grows extremely quickly meaning it will tend to have weaker strength properties. There are no specific climatic factors that influence the natural range of silver maple (Burns 1990).

Green ash (*Fraxinus pennsylvanica*)

The native range of green ash covers much of the eastern United States as well as from Nova Scotia, through southern Ontario, and to southern Manitoba (Burns 1990). Ash prefers relatively more humid climates, with temperatures ranging from -18^{0}c to 27^{0}c (Burns 1990). Green ash grows best on fertile, moist, and well-drained soils, it is also the best-adapted ash species as it can grow on a variety of soil types from moist clay soils to well-drained sandy soils (Burns 1990).

Eastern cottonwood *(Populus deltoides)*

Cottonwood grows from southern Quebec along the border to southwestern Manitoba, south to central Texas and east to northern Florida and Georgia (Burns 1990). Cottonwood can withstand a large range of temperatures, ranging from -45^{0}c to 46^{0}c (Burns 1990). The species prefers moist, well-drained, fine sandy or silty loams generally close to streams, but can still survive on deep, infertile sands and clays, making it able to thrive in a variety of microsites (Burns 1990).

MECHANICAL PROPERTIES

Modulus Of Elasticity

Modulus of Elasticity (MOE) is an elastic property of wood that tells you how much of a load can be applied to it before it cannot recover to its original form (USDA 2010). The test is done by applying a load onto the radial axis (Figure 1) of a 2 cm x 2 cm x 30 cm test stick. The testing machine will apply a load onto the wood and track the load being applied and deflection until the stress/strain reaches the proportional limit at which point the MOE is recorded. Deflection is the amount of give the piece of wood has or how much it will bend (Shmulsky 2011). MOE is useful to study because it can help us to understand how much weight can be applied to the structure, and therefore how big it can be. MOE is not the only test for load-bearing strength but using MOE along with other mechanical property tests can give us a really good idea of the load that can be applied. MOE is a good test on floors for houses because it will tell you how sturdy it will feel under the feet of the owner. Having floors made of wood with a low MOE will feel like walking around on a trampoline whereas floors made of wood with a high MOE will feel very sturdy (Shmulsky 2011).

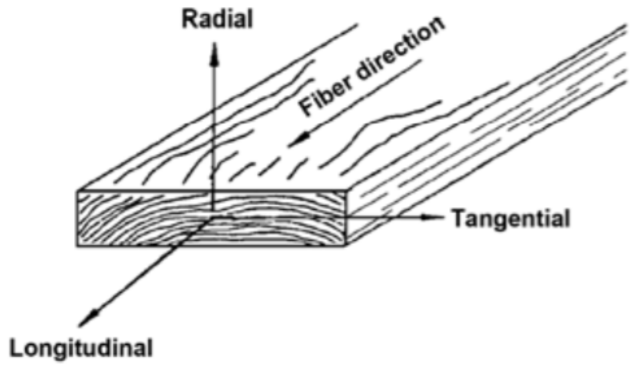

Figure 1. Picture showing radial, tangential, and longitudinal axis' of wood.

Modulus Of Rupture

Modulus of Rupture (MOR) is very similar to MOE in that it also tests the total load that can be applied to a piece of wood, but it measures how long it takes for the piece of wood to break or rupture (USDA 2010). MOR is widely considered to be an accepted criterion for strength, although it is not a true strength test because the formula used is only valid to the elastic limit of the piece of wood (USDA 2010). MOR is found during the same test as MOE but recorded at the point that the applied load ruptures the piece of wood rather than when it loses elasticity, i.e. maximum load applied. MOR is an important test because it tells us how much of a load can be applied until it breaks, so in the case of construction of building it would tell us how much can be built on top of it. By looking at a combination of both MOE and MOR you could determine which species of wood have the largest difference between MOE and MOR.

This could be useful in the situation of a fire where people need to get out, so using species of wood with large gaps in MOE and MOR would give people the most time to do so. As previously mentioned, the recent trend of more wood buildings will only increase the demand for more tests like these on new wood products which could be useful in building larger wood structures. MOR is a test that you could do on horizontal beams across the roof of a building.

Table 1. Published and tested MOE and MOR values for green ash, Eastern cottonwood, and silver maple (USDA 2010).

Sample ID		MOE (Mpa)	Modulus of Rupture (Mpa)
Ag	Tested	5381	66
	Published	11400	97
Pd	Tested	2707	45
	Published	9400	59
Ms	Tested	4987	55
	Published	7900	61

PHYSICAL PROPERTIES

<u>Defects</u>

Testing is typically done on clear and straight-grained wood, but due to natural variability in how trees grow not all trees are completely clear of knots and defects (USDA 2010). Defects have a significant impact on the strength properties of wood so understanding how different defects effect the wood is extremely important. Knots are the most common defect found in wood. A knot is part of a branch that has become incorporated in the tree because the tree grew over it (USDA 2010). The reason for the decrease in strength from knots is they break up the continuity of wood fibres and create weak points in the wood

(USDA 2010). The size, location, and type of knot all affect mechanical properties in different ways. Live knots have less of an effect on strength than dead knots.

MATERIALS AND METHODS

SPECIES

Three tree species will be tested to determine the properties for the utilization of street trees. Silver maple (*Acer saccharinum*), green ash (*Fraxinus pennsylvanica*), and Eastern cottonwood (*Populus deltoides*) will be tested for utilization. Silver maple, green ash, and Eastern cottonwood samples were city street or park trees.

SAMPLE PREPARATION

Samples were be cut into 2.5cm boards using the Wood-Mizer LT40 Hydraulic portable mill before further processing. These boards were stickered and dried before further processing into sample sticks for testing. Samples were cut again into 30 cm pieces and then made into 2.0 cm by 2.0 cm test sticks. Samples were then put into the conditioning chamber (set at 65% relative humidity and 20 degrees Celcius) to achieve 12% moisture content.

TESTING

Width and thickness measurements were taken of each test stick before testing. Testing was conducted in the Lakehead University Wood Science Testing Facility on the Tinius Olsen H10Kt and H50Kt testing machines using Test Navigator software and the LU Wood Science App. Tests included MOE (Modulus of Elasticity), and MOR (Modulus of Rupture) following ASTM D7341-14. MOE is a test used to determine how much pressure can be put on a board until it cannot recover to its original shape. MOR is used to test the amount of pressure that can be put on a board until it breaks.

RESULTS

The following tables and figures will show the results of MOE and MOR testing on green ash, silver maple, and Eastern cottonwood test samples. 20 samples of each species were tested for MOE and MOR.

GREEN ASH

Green ash (Ag) samples had the highest average MOE (Figure 2) and MOR (Figure 3) of the three species. The average MOE for green ash samples was 5381 MPa (Table 2) and the average MOR was 66.2 MPa (Table 3). The maximum load for green ash samples was 2031 N or 207kg (Table 4). The standard error of green ash MOE tests was 199.5 (Table 5) and the standard error on MOR tests was 3.28 (Table 6).

Table 2. Showing MOE of each green ash sample and average MOE for all green ash samples.

Sample ID	Sample No.	MOE (MPa)
Ag	1	2250
Ag	2	5610
Ag	3	5860
Ag	4	5790
Ag	5	4970
Ag	6	5730
Ag	7	4030
Ag	8	5400
Ag	9	5820
Ag	10	6010
Ag	11	5950
Ag	12	5470
Ag	13	5190
Ag	14	5870
Ag	15	5930
Ag	16	5900
Ag	17	5900
Ag	18	5250
Ag	19	4750
Ag	20	5940
	Average	5381

Table 3. Shows MOR for each green ash sample and average MOR for all green ash samples.

Sample ID	Sample No.	Modulus of Rupture(MPa)
Ag	1	13.19
Ag	2	71.9
Ag	3	68.3
Ag	4	80.2
Ag	5	64.6
Ag	6	66.8
Ag	7	49.8
Ag	8	70.7
Ag	9	77.2
Ag	10	68.6
Ag	11	65.5
Ag	12	74.2
Ag	13	57.4
Ag	14	65.1
Ag	15	63.4
Ag	16	79.3
Ag	17	83
Ag	18	71.9
Ag	19	66.9
Ag	20	66.3
	Average	66.2145

Table 4. Shows maximum load capacity (N and kg) for each green ash sample and average load capacity (N and kg) for all green ash samples.

Sample ID	Sample No.	Max Load(N)	Max Load(kg)
Ag	1	390	39.8
Ag	2	2190	223
Ag	3	2150	219
Ag	4	2410	246
Ag	5	2070	211
Ag	6	2040	208
Ag	7	1473	150.2
Ag	8	2120	216
Ag	9	2250	230
Ag	10	2110	215
Ag	11	1990	203
Ag	12	2420	247
Ag	13	1848	188.4
Ag	14	1916	195.4
Ag	15	1806	184.2
Ag	16	2250	229
Ag	17	2390	244
Ag	18	2400	245
Ag	19	2400	245
Ag	20	2010	205
	Average	2031.65	207.2

Table 5. Descriptive stats on green ash MOE.

MOE	
Mean	5381
Standard Error	199.553317
Median	5760
Mode	5900
Standard Deviation	892.429564
Sample Variance	796430.526
Kurtosis	7.89624165
Skewness	-2.6330109
Range	3760
Minimum	2250
Maximum	6010
Sum	107620
Count	20

Table 6. Descriptive stats on green ash MOR.

MOR	
Mean	66.2145
Standard Error	3.284599589
Median	67.6
Mode	71.9
Standard Deviation	14.68917592
Sample Variance	215.7718892
Kurtosis	9.109446626
Skewness	-2.623642857
Range	69.81
Minimum	13.19
Maximum	83
Sum	1324.29
Count	20

EASTERN COTTONWOOD

Eastern cottonwood (Pd) samples had a significantly lower average MOE (Figure 2) and MOR (Figure 3) than both green ash and silver maple. The average MOE for Eastern cottonwood samples was 2707 MPa (Table 7) and the average MOR was 45.9 MPa (Table 8). Eastern cottonwood samples had the highest load capacity at 2928 N or 298kg (Table 9). The standard error of Eastern cottonwood MOE tests was 71.1 (Table 10) and the standard error of Eastern cottonwood MOR tests was 0.5 (Table 11).

Table 7. Shows MOE for each Eastern cottonwood sample and average MOE for all Eastern cottonwood samples.

Sample ID	Sample No.	MOE (MPa)
Pd	1	2820
Pd	2	2310
Pd	3	2150
Pd	4	2100
Pd	5	2830
Pd	6	2570
Pd	7	2880
Pd	8	2580
Pd	9	2580
Pd	10	2740
Pd	11	2450
Pd	12	2990
Pd	13	2630
Pd	14	2560
Pd	15	2560
Pd	16	2950
Pd	17	3290
Pd	18	3010
Pd	19	2980
Pd	20	3170
	Average	2707.5

Table 8. Shows MOR for each Eastern cottonwood sample and average MOR for all Eastern cottonwood samples.

Sample ID	Sample No.	Modulus of Rupture(MPa)
Pd	1	49.1
Pd	2	44.2
Pd	3	42.4
Pd	4	40.1
Pd	5	46.3
Pd	6	45.8
Pd	7	46.3
Pd	8	48
Pd	9	45.9
Pd	10	43.7
Pd	11	46.2
Pd	12	48.9
Pd	13	44.1
Pd	14	42.9
Pd	15	45.8
Pd	16	47.9
Pd	17	48.5
Pd	18	47
Pd	19	46.9
Pd	20	48.2
	Average	45.91

Table 9. Shows load capacity (N and kg) for each Eastern cottonwood sample and average load capacity (N and kg) for all Eastern cottonwood samples.

Sample ID	Sample No.	Max Load(N)	Max Load(kg)
Pd	1	3170	324
Pd	2	2960	302
Pd	3	2930	298
Pd	4	2620	267
Pd	5	3060	312
Pd	6	2990	305
Pd	7	3000	306
Pd	8	3120	318
Pd	9	3020	308
Pd	10	2820	287
Pd	11	2960	302
Pd	12	3090	315
Pd	13	2860	292
Pd	14	2840	290
Pd	15	3020	308
Pd	16	2690	274
Pd	17	2820	287
Pd	18	2880	294
Pd	19	2900	296
Pd	20	2810	286
	Average	2928	298.55

Table 10. Descriptive stats on Eastern cottonwood MOE data.

MOE	
Mean	2707.5
Standard Error	71.1036123
Median	2685
Mode	2580
Standard Deviation	317.985021
Sample Variance	101114.474
Kurtosis	-0.3603747
Skewness	-0.1841674
Range	1190
Minimum	2100
Maximum	3290
Sum	54150
Count	20

Table 11. Descriptive stats on Eastern cottonwood MOR data.

MOR	
Mean	45.91
Standard Error	0.533602454
Median	46.25
Mode	46.3
Standard Deviation	2.38634272
Sample Variance	5.694631579
Kurtosis	0.269247591
Skewness	-0.776192872
Range	9
Minimum	40.1
Maximum	49.1
Sum	918.2
Count	20

SILVER MAPLE

Silver maple (Ms) samples tested slightly lower in MOE (Figure 2) and MOR (Figure 3) than green ash but significantly higher than Eastern cottonwood. The average MOE of silver maple samples was 4897 MPa (Table 12) and the average MOR was 55 MPa (Table 13). Silver maple samples had the lowest load capacity of the three at 1945 N or 198kg (Table 14). The standard error for MOE tests on silver maple was 99.9 (Table 15) and the standard error for MOR tests on silver maple was 0.96 (Table 16).

Table 12. Shows MOE (MPa) for each silver maple sample and average MOE (MPa) for all silver maple samples.

Sample ID	Sample No.	MOE (MPa)
Ms	1	4490
Ms	2	4900
Ms	3	4850
Ms	4	4080
Ms	5	4770
Ms	6	4610
Ms	7	4760
Ms	8	5700
Ms	9	4730
Ms	10	5400
Ms	11	4590
Ms	12	4340
Ms	13	5180
Ms	14	4870
Ms	15	5550
Ms	16	4560
Ms	17	4740
Ms	18	4910
Ms	19	5800
Ms	20	5120
	Average	4897.5

Table 13. Shows MOR (MPa) for each silver maple sample and average MOR (MPa) for all silver maple samples.

Sample ID	Sample No.	Modulus of Rupture(MPa)
Ms	1	55.2
Ms	2	56.6
Ms	3	52.9
Ms	4	54.2
Ms	5	51.2
Ms	6	53.5
Ms	7	55.7
Ms	8	64.2
Ms	9	52.4
Ms	10	57.9
Ms	11	52.5
Ms	12	47.7
Ms	13	59.3
Ms	14	60.8
Ms	15	59.7
Ms	16	48.2
Ms	17	49.7
Ms	18	55.7
Ms	19	59.1
Ms	20	53.6
	Average	55.005

Table 14. Shows load capacity (N and kg) for each silver maple sample and average load capacity (N and kg) for all silver maple samples.

Sample ID	Sample No.	Max Load(N)	Max Load(kg)
Ms	1	1894	193.1
Ms	2	1927	196.5
Ms	3	2140	218
Ms	4	1988	203
Ms	5	1810	184.6
Ms	6	2170	221
Ms	7	2070	211
Ms	8	2370	242
Ms	9	1844	188.1
Ms	10	1769	180.4
Ms	11	1682	171.5
Ms	12	1726	176
Ms	13	2100	214
Ms	14	1950	198.8
Ms	15	2330	238
Ms	16	1809	184.5
Ms	17	1635	166.7
Ms	18	1912	195
Ms	19	2140	218
Ms	20	1647	167.9
	Average	1945.65	198.405

Table 15. Descriptive stats on silver maple MOE data.

MOE	
Mean	4897.5
Standard Error	99.9154248
Median	4810
Mode	-
Standard Deviation	446.835364
Sample Variance	199661.842
Kurtosis	-0.0353268
Skewness	0.52319791
Range	1720
Minimum	4080
Maximum	5800
Sum	97950
Count	20

Table 16. Descriptive stats on silver maple MOR data.

	MOR
Mean	55.005
Standard Error	0.962438651
Median	54.7
Mode	55.7
Standard Deviation	4.304156498
Sample Variance	18.52576316
Kurtosis	-0.262191887
Skewness	0.21536904
Range	16.5
Minimum	47.7
Maximum	64.2
Sum	1100.1
Count	20

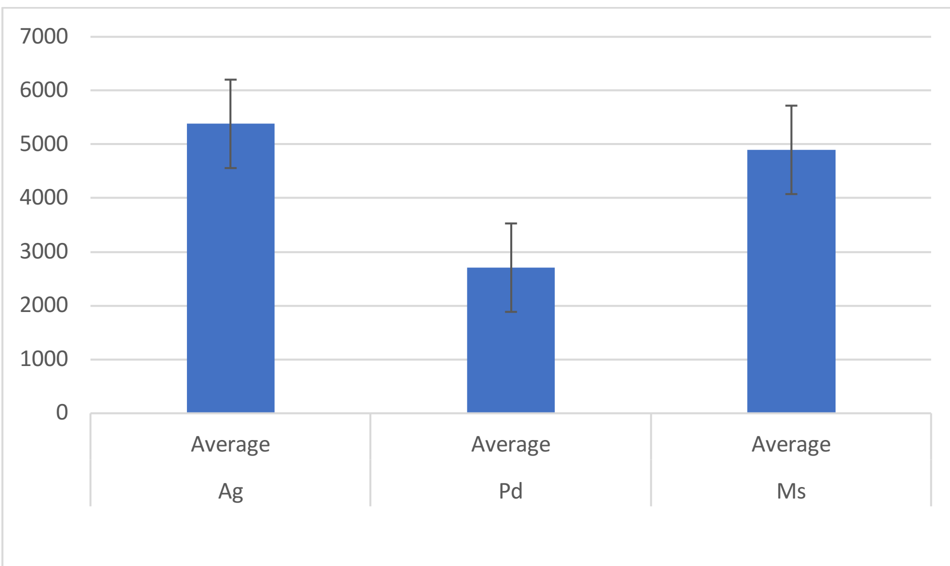

Figure 2. Shows the average MOE for green ash, Eastern cottonwood, and silver maple.

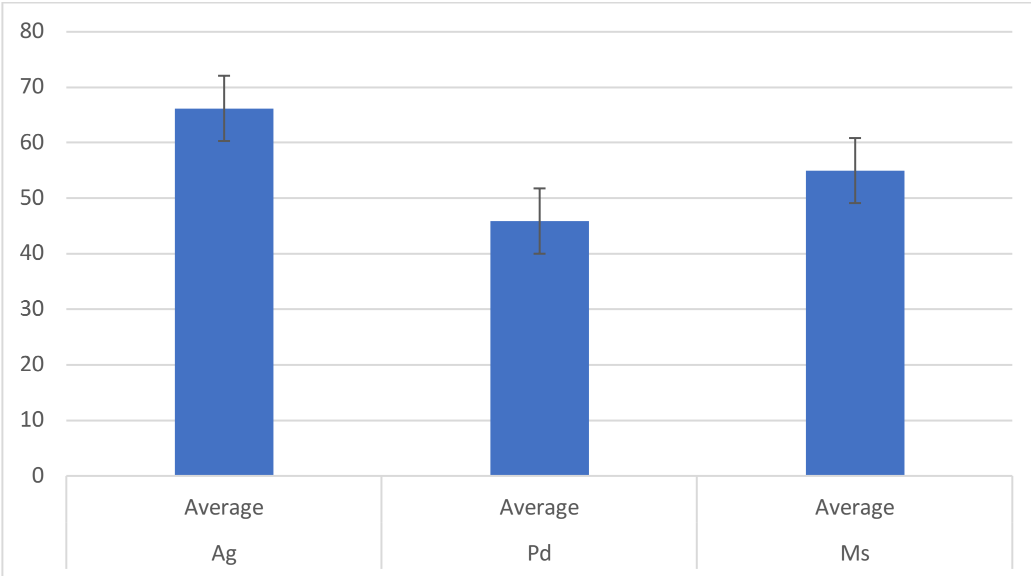

Figure 3. Shows the average MOR for green ash, Eastern cottonwood, and silver maple.

STATS

After running an ANOVA test between the species for both MOE and MOR the F value was higher than the F crit value in both, meaning not all the means are equal. The ANOVA on MOE data (Table 17) shows an F value of 110.98 which is greater than the F crit value of 3.15 and the ANOVA on MOR data (Table 18) shows and f value of 25.86 which is also greater than the F crit value of 3.15.

Table 17. ANOVA on MOE data.

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Green ash	20	107620	5381	796430.5
Eastern cottonwood	20	54150	2707.5	101114.5
Silver maple	20	97950	4897.5	199661.8

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	81183163.33	2	40591581.7	110.9861	2.20772E-20	3.158843
Within Groups	20846930	57	365735.614			
Total	102030093.3	59				

Table 18. ANOVA on MOR data.

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Green ash	20	1324.29	66.2145	215.7719
Eastern cottonwood	20	918.2	45.91	5.694632
Silver maple	20	1100.1	55.005	18.52576

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4137.630903	2	2068.81545	25.86102	1.01714E-08	3.158843
Within Groups	4559.853395	57	79.997428			
Total	8697.484298	59				

DISCUSSION

Published MOE and MOR for green ash, Eastern cottonwood, and silver maple vary quite significantly from the tested results, as seen in table 1. The published values come from the USDA Wood Handbook. By comparing the tested data to published data we have a basis to compare the tested city trees to see if they are viable for use on wood products. Based on the mechanical properties of the tested species they are not viable for use in wood products. Mechanical properties, whether elastic or strength properties are the most commonly used properties to evaluate wood for both structural and non-structural applications (USDA 2010). Hardwoods are not generally used in structural applications, they are more often used in woodworking, or small scale business. Products such as tables, desks and cutting boards are going to get the most value from these trees. Hardwoods often have value-adding defects such as spalting or wavy grain patterns that are extremely enticing to buyers. A table that has features like live edge or spalting can be worth more than double the amount of a table without these features.

The city of Toronto has a massive urban forest consisting of 10.2 million trees (City of Toronto 2016). Urban forests provide shade and green areas for people to enjoy. Toronto's urban forest consists of 860,000 ash trees, most of which will die in 5 to 10 years due to the Emerald Ash Borer (City of Toronto 2016). The city of Toronto offers many services to residents who wish to remove a tree from their property or even turn it into something for their home. There is a directory of companies that will come advise the homeowner on the health of the tree and whether it should be taken down. Custom products that can be made include furniture, cabinetry, carvings, and flooring. Removing trees is costly so doing it in a way where the homeowner can get money back makes a lot of sense. Live edge products are extremely valuable and in very high demand. There could be a large spike in available live edge products due to the presence of the Emerald Ash Borer. The EAB only attacks the wood on the surface just underneath the bark, meaning the interior wood is unaffected. The strength of EAB infested ash trees is affected by the presence of EAB within just a couple of years of the infection (Persad 2013). The cost to remove the ash trees from the city will be around $500,000,000 (McMonagle 2016) so being able to use these trees to make products such as tables, chairs, desks, etc is a great way to recoup a lot of the money used to cut the trees down. Removal of the ash trees in Toronto is inevitable due to the EAB so doing it in the most economically sound way that prevents the loss of money is ideal.

Urban forests provide many benefits to the people of the city. In the City of Thunder Bay's 2011 Urban Forest Management Plan, they state that inventoried urban trees in Thunder Bay provide $1,555,888 of annual benefits to the city, 74% of which are environmental benefits (Davey Resource Group 2011). Environmental benefits include energy savings which account for 29% of the annual benefits, stormwater mitigation which accounts for 36% of annual benefits, air quality improvements account for 5% and reduction in CO^2

accounts for 4% of annual improvements (Davey Resource Group 2011). The other 26% of annual benefits from urban trees come from property and aesthetic value. The presence of large trees on your property can have a significant impact on the aesthetic value and make it more attractive to buyers. This increase in property value from urban trees is quantifiable and can be reported as an annual benefit.

CONCLUSION

In conclusion, based on the tests on the samples obtained from the city, trees grown in the city would only be viable for use in small scale industries in specialized products. The mechanical properties of the city trees are not strong enough to be used for construction. Of the three species that were tested green ash tested the best in MOE and MOR while Eastern cottonwood tested the worst in MOE and MOR. The way to get the most value out of these trees is to use them in small scale industry. Companies making tables, doors or other specialized products would benefit the most from these trees. Products made with hardwoods such as green ash and Eastern cottonwood can have lots of value due to unique grain patterns in the wood and products made with silver maple can have added value from spalting in the wood. Many products could be made of urban trees to help get more value from the trees when they need to be cut down due to disease such as EAB or by natural disturbances such as wind.

APPENDICES

GREEN ASH DATA

Sample ID	Sample No.	Max Load(N)	Max Load(kg)	Support Span(mm)	Thickness (mm)	Width (mm)	PPL (N)	PPL Distance (mm)	MOE (MPa)	Modulus of Rupture(MPa)	Modulus (MPa)
Ag	1	390	39.8	240	21.7	22.6	365	2.43	2250	13.19	28200
Ag	2	2190	223	240	22.8	21.1	1470	3.62	5610	71.9	69700
Ag	3	2150	219	240	22.6	22.2	1487	3.42	5860	68.3	74200
Ag	4	2410	246	240	22.2	22	1600	3.97	5790	80.2	73100
Ag	5	2070	211	240	22.8	22.2	1314	3.47	4970	64.6	64600
Ag	6	2040	208	240	22.3	22.1	1360	3.35	5730	66.8	72400
Ag	7	1473	150.2	240	21.9	22.2	1143	4.2	4030	49.8	48600
Ag	8	2120	216	240	22.1	22.1	1435	3.85	5400	70.7	67300
Ag	9	2250	230	240	21.8	22.1	1451	3.76	5820	77.2	73600
Ag	10	2110	215	240	22.4	22.1	1422	3.29	6010	68.6	74600
Ag	11	1990	203	240	22.2	22.2	1220	2.92	5950	65.5	72800
Ag	12	2420	247	240	23.1	22	1554	3.62	5470	74.2	70200
Ag	13	1848	188.4	240	22.9	22.1	1340	3.36	5190	57.4	61500
Ag	14	1916	195.4	240	22	21.9	1406	3.55	5870	65.1	73700
Ag	15	1806	184.2	240	21.5	22.2	1283	3.39	5930	63.4	73700
Ag	16	2250	229	240	21.5	22.1	1544	4.12	5900	79.3	71300
Ag	17	2390	244	240	21.6	22.2	1517	3.97	5900	83	72300
Ag	18	2400	245	240	23.6	21.6	1550	3.59	5250	71.9	60900
Ag	19	2400	245	240	24.2	22.1	1550	3.6	4750	66.9	60300
Ag	20	2010	205	240	22.2	22.2	1437	3.44	5940	66.3	73800
	Average	2031.65	207.2	240	22.37	22.065	1372.4	3.546	5381	66.2145	66840

EASTERN COTTONWOOD DATA

Sample ID	Sample No.	Max Load(N)	Max Load(kg)	Support Span(mm)	Thickness (mm)	Width (mm)	PPL (N)	PPL Distance (mm)	MOE (MPa)	Modulus of Rupture(MPa)	Modulus (MPa)
Pd	1	3170	324	240	29.8	26.2	1012	1.786	2820	49.1	3540
Pd	2	2960	302	240	30.2	26.4	969	1.993	2310	44.2	2960
Pd	3	2930	298	240	30.6	26.5	959	2.03	2150	42.4	2490
Pd	4	2620	267	240	29.8	26.5	924	2.17	2100	40.1	2730
Pd	5	3060	312	240	29.9	26.6	1062	1.822	2830	46.3	3460
Pd	6	2990	305	240	29.7	26.7	1008	1.936	2570	45.8	3270
Pd	7	3000	306	240	29.6	26.6	1007	1.754	2880	46.3	3530
Pd	8	3120	318	240	29.7	26.5	1192	2.3	2580	48	3210
Pd	9	3020	308	240	29.9	26.5	1013	1.914	2580	45.9	2850
Pd	10	2820	287	240	29.6	26.5	937	1.719	2740	43.7	3280
Pd	11	2960	302	240	29.5	26.5	1312	2.72	2450	46.2	2830
Pd	12	3090	315	240	29.3	26.5	1045	1.813	2990	48.9	3510
Pd	13	2860	292	240	29.7	26.5	982	1.856	2630	44.1	3030
Pd	14	2840	290	240	30	26.5	927	1.752	2560	42.9	3010
Pd	15	3020	308	240	30	26.4	995	1.882	2560	45.8	2990
Pd	16	2690	274	240	27.5	26.7	961	2.03	2950	47.9	3400
Pd	17	2820	287	240	28.1	26.5	962	1.719	3290	48.5	4140
Pd	18	2880	294	240	28.9	26.4	927	1.672	3010	47	3330
Pd	19	2900	296	240	28.9	26.7	950	1.712	2980	46.9	3940
Pd	20	2810	286	240	28.3	26.2	992	1.824	3170	48.2	3950
	Average	2928	298.55	240	29.45	26.495	1006.8	1.9202	2707.5	45.91	3272.5

SILVER MAPLE DATA

Sample ID	Sample No.	Max Load(N)	Max Load(kg)	Support Span(mm)	Thickness (mm)	Width (mm)	PPL (N)	PPL Distance (mm)	MOE (MPa)	Modulus of Rupture(MPa)	Modulus (MPa)
Ms	1	1894	193.1	240	22	25.5	1038	2.94	4490	55.2	5450
Ms	2	1927	196.5	240	21.8	25.8	1105	2.91	4900	56.6	5350
Ms	3	2140	218	240	23.9	25.5	878	1.797	4850	52.9	5440
Ms	4	1988	203	240	22.9	25.2	1013	2.84	4080	54.2	4610
Ms	5	1810	184.6	240	22.6	24.9	785	1.978	4770	51.2	5380
Ms	6	2170	221	240	23.9	25.5	826	1.777	4610	53.5	4990
Ms	7	2070	211	240	23	25.3	879	2.07	4760	55.7	5450
Ms	8	2370	242	240	23.2	24.7	1135	2.23	5700	64.2	6420
Ms	9	1844	188.1	240	22.2	25.7	887	2.3	4730	52.4	5190
Ms	10	1769	180.4	240	20.9	25.2	897	2.49	5400	57.9	5860
Ms	11	1682	171.5	240	21.4	25.2	941	2.87	4590	52.5	5200
Ms	12	1726	176	240	22.6	25.5	891	2.41	4340	47.7	4680
Ms	13	2100	214	240	22.5	25.2	827	1.924	5180	59.3	5720
Ms	14	1950	198.8	240	21	26.2	1228	3.59	4870	60.8	5580
Ms	15	2330	238	240	23.5	25.5	952	1.791	5550	59.7	6100
Ms	16	1809	184.5	240	23.1	25.3	703	1.708	4560	48.2	5080
Ms	17	1635	166.7	240	21.6	25.4	824	2.35	4740	49.7	5170
Ms	18	1912	195	240	22.1	25.3	1094	2.82	4910	55.7	5390
Ms	19	2140	218	240	22.7	25.3	955	1.921	5800	59.1	6400
Ms	20	1647	167.9	240	21	25.1	839	2.44	5120	53.6	5790
	Average	1945.65	198.405	240	22.395	25.365	934.85	2.3578	4897.5	55.005	5462.5

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