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CARBON SEQUESTRATION ASSESSMENT OF SELECTED CAMPUS CHAMPION TREES

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ABSTRACT

This study aims to quantify the unique score of selected champion trees on the University of Maryland Eastern Shore (UMES) main campus. Individual trees that are evaluated as "champions" of their species are measured for their trunk's diameter at breast-height, overall tree height, and average crown spread to calculate their total score. Based on each specimen's total score, selecting the top 20 champion trees provides data that is beneficial in developing a UMES campus tree map using geospatial technology. Furthermore, finding the carbon sequestered value and emissions-storage amount per tree is a targeted topic for the next step in this study. This study also provides a pilot direction for UMES to value its forested regions, to maintain these colossal trees, and to help the campus reach its sustainability goals. Given the relationship between tree size and efficiency of carbon sequestration demonstrated here, additional studies to test the hypothesis that some open grown tree species gain greater girth in a shorter period of time when compared to forest-grown specimens are encouraged to aid in tree selection.

Contribution/Originality: This study is one of very few studies which have quantified the total score and carbon sequestration of the selected champion trees on UMES main campus. This study also addresses that the conservation and protection of large girth trees, whether as components in an old growth forest or as large individual specimens such as those of UMES's campus community, should be encouraged.

1. INTRODUCTION

Interest in terrestrial carbon sequestration has increased in an effort to explore opportunities for climate change mitigation. Carbon sequestration is the process by which atmospheric carbon dioxide is taken up by trees, grasses, and other plants through photosynthesis and stored as carbon in biomass (trunks, branches, foliage, and roots) and soils. Undeniable evidence highlights climate change as a pressing global issue, principally catalyzed by carbon dioxide abundance in the Earth's atmosphere. As a long-established mitigation mechanism to this concern, plants have absorbed the role as our natural restoration tools. However, trees retain considerable value in several different applications [1].

All across the world, colleges and universities are looking to a sustainable future by working to become carbon neutral [2]; [3]. As climate neutrality goals have been set by colleges and universities across the country, new and innovative ideas for offsets have continued to surface. Urban tree planting offset projects are growing in popularity, due to the local co-benefits they provide for educational institutions and their surrounding communities. In urban and suburban settings, historical or "landmark" trees are commonly the focal point around which entire towns are built. Retention of large trees, and therefore, the benefit that they provide, hold fundamental importance in abating climate change through their heightened carbon sequestration of our planet's atmospheric carbon dioxide [4].

The value of large trees has only recently been brought to light in scientific literature. In addition to their ecological value, gigantic trees often hold aesthetic and spiritual worth to those who experience them. By definition, champion trees are individual trees which are exceptional examples of their species because of their enormous size, great age, rarity or historical significance. Specifically, a champion tree is the largest known tree of a given species in a particular geographic area. Some champions are very large trees and some champions are rather small. For example, the largest known tree in Maryland, an American sycamore, is more than eight feet across while the largest known pawpaw in the United States is just ten inches across. Both of these trees are growing in Montgomery County. Maryland's Eastern Shore has a few notable Champion Tree species, present in Worcester County (Southern Bayberry, Loblolly Pine, Longleaf Pine), Wicomico County (Bald Cypress, Balsam Fir, Red Mulberry, Pecan, etc.), and even Somerset County (Southern Magnolia).

The University of Maryland Eastern Shore (UMES) has a very distinctive campus, largely due to its arborous grounds, which comprises over 100 different tree species. The campus of UMES has many large trees that tower over top of their neighboring trees. However, these big trees should be evaluated for their relevant sizes compared to the rest of the campus's trees; thus, ranking them as "Champions" in their own respects for the sake of this study. The objectives of this study include: (1) to select the top-20 champion trees on the UMES main campus; (2) to quantify the total score of selected UMES champion trees; (3) to create a GIS map that thematically displays the selected UMES champion trees by ranking; and (4) to quantify the amount of carbon sequestration of selected UMES champion trees.

2. LOCATION

The University of Maryland Eastern Shore (UMES), the state's historically black 1890 land-grant institution, has its purpose and uniqueness grounded in distinctive learning, discovery and engagement opportunities in the arts and sciences, education, technology, engineering, agriculture, business and health professions. In 1948, the Eastern Shore Branch of the University of Maryland, then alternately known as Princess Anne College, was renamed Maryland State College, a division of the University of Maryland. Maryland State College became the University of Maryland Eastern Shore on July 1, 1970, and is today one of 12 University System of Maryland public institutions of higher education. In addition to 745 acres on its main campus in Princess Anne, UMES also operates a 385-acre research farm in southern Somerset County as well as the Paul S. Sarbanes Coastal Ecology Center on eight acres near Assateague Island in neighboring Worcester County.

3. METHODS

A. Total Score

Estimating the total score of the champion trees first requires an inventory of the types of trees that are present on campus. The methodology developed by American Forests and used by Big Tree Programs across the nation is adopted. Before nominating a champion tree, three measurements are necessary: (1) tree height (measured in feet), (2) trunk circumference (measured in inches), and (3) average tree crown spread (measured in feet) (see Figure 1).

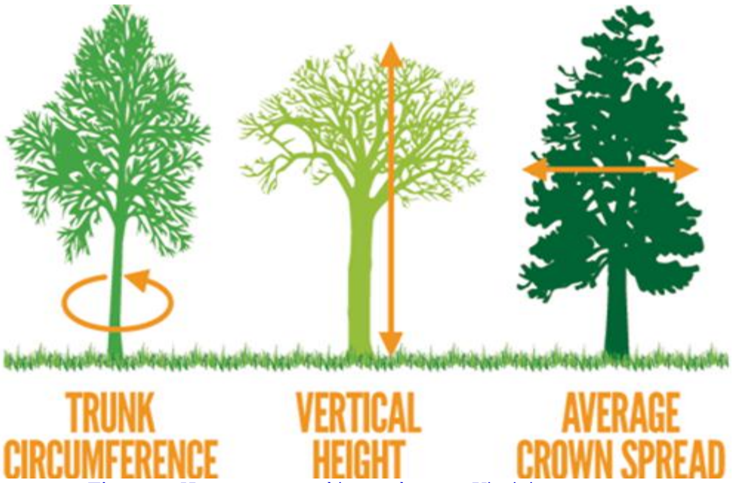

Figure-1. How to measure big tree by west Virginia commerce.
(http://www.wvcommerce.org/resources/forestry/big_tree/measuring/default.aspx).

A.1 Tree Height

Tree height is measured as the vertical distance between a horizontal plane passing through the center of the base of the tree and a horizontal plane passing through the topmost twig of the tree. Using a Laser Tech™ Impulse laser rangefinder, we are able to determine the height of the champion trees by making three simple measurements. After sighting-in on the tree's trunk (using the red-dot-sight scope), a "Horizontal Distance" measurement is taken by firing the laser, calculating the distance from the tree to the unit. The second measurement recorded an angular dimension, relying on the laser rangefinder's built-in clinometer; this "firing" of the unit is angled downward to where the base of the tree met the ground. The final "firing" is another angular measurement, this time, angled to the peak of the tree specimen's canopy. The triangulation and calculation of those three measurements are then internally computed; the total height of the tree, in feet, is automatically displayed on screen.

A.2 Trunk Circumference

This value, in inches, is found using a simple 100 foot measuring tape. Varying based on different standards of tree Diameter-Breast-Height (DBH) measurement techniques for trees, the circumference is taken at roughly 4.5 feet above the ground. DBH is not needed to calculate the total score of a tree, but its value could easily be calculated by dividing the circumference by $\pi = 3.14$.

A.3 Average Tree Crown Spread

The Axis Method, adopted from the American Forests Champion Trees: Measuring Guidelines Handbook [5] is used to calculate the average crown spread measurement in feet. Stakes are placed directly underneath the end-points of the farthest reaching set of branches on a given tree specimen. The farthest "spread" of the crown (distance "A"), once determined, is then used to find the perpendicular measurement on a 90° angle from that axis (distance "B"). The average of those two measurements [(A+B)/2] is then calculated in order to find the average crown spread of the particular tree.

A.4 Total Score

The total score of the selected champion trees is calculated using the following formula:

Total Score (points) = Trunk Circumference (inches) + Tree Height (feet) + ¼ of Average Tree Crown Spread (feet)

B. Carbon Sequestration

The rate of carbon sequestration depends on the growth characteristics of the tree species, the conditions for growth where the tree is planted, and the density of the tree's wood. The following process can be used to calculate the amount of carbon sequestered in a tree: (1) determine the total (green) weight of the tree; (2) determine the dry weight of the tree; (3) determine the weight of carbon in the tree; and (4) determine the weight of carbon sequestered in the tree.

B.1 Green Weight

The green weight of a tree is an estimate of the weight of the tree when it is alive. This weight includes all of the wood content and any water that is in the tree. Because the water in the tree can be up to hundreds of gallons, the green weight can be quite large. To find the green weight, insert the values you obtained for diameter and height into one of the two equations listed below:

For a tree whose diameter > 11: Green Weight = $0.15DBH^2H$

For a tree whose diameter < 11: Green Weight = $0.25DBH^2H$

B.2. Dry Weight

Because of the water content in trees, the weight of the tree varies based on green weight or dry weight. Dry weight represents the weight of the wood in the tree if it was dried in an oven and all water was taken out. Estimates of dry weight to green weight show a 50:50 ratio and so, to find the dry weight, multiply green weight by 50%.

Dry Weight = Green Weight × 0.5

B.3 Carbon Storage

Carbon storage is the amount of carbon that is within the wood of the tree, negating other minerals and elements. This is the total amount of carbon that is made during photosynthesis as well as the amount of carbon sequestered from carbon dioxide by the tree. Carbon storage is about half as much as the total dry weight of the wood since the wood contains other materials and elements than just carbon. To find carbon storage, multiply dry weight by 50%.

Carbon Storage = Dry weight × 0.5

B.4 Carbon Sequestered

Carbon dioxide (CO_2) is composed of one molecule of Carbon and 2 molecules of Oxygen. The atomic weight of Carbon is 12.001115. The atomic weight of Oxygen is 15.9994. The weight of carbon dioxide is $C + 2 \times O = 43.999915$. The ratio of carbon dioxide to C is 43.999915/12.001115 = 3.6663. Therefore, to determine the weight of carbon sequestered in the tree, multiply the weight of carbon in the tree by 3.6663.

Carbon Sequestered = Carbon Storage × 3.6663

4. RESULTS

As shown in Table 1, the total score for each tree has unique weight based on their constituent measurement values. Some notable findings include: (1) Of over 27 tree species evaluated based on minimal size estimates, the list of top-20 champion trees consists of the same 5 tree species (Willow Oak, American Sycamore, Water Oak, White Ash, and one Silver Maple). (2) Though Tree #2 has the largest circumference measurement, Tree #1 is roughly 10 feet taller and has 10 feet larger of a crown spread. (3) The Silver Maple (*Acer saccharinum*), Tree #17, is the only one of its species on the UMES campus, and therefore the only one to make the list. Its circumference alone is what made this otherwise-small-tree a Champion.

Table-1. Total score measurements of UMES Champion trees.

ID	Genus-species	Common Name	Location	Circumference	Height	Crown Spread	Total Score
1	*Quercus phellos*	Willow Oak	O. Tanner (NW)	172	96.17	95.75	292.11
2	*Quercus phellos*	Willow Oak	Mid-Quad (SE)	182	87.60	87.75	291.54
3	*Fraxinus americanus*	White Ash	Trigg (East)	154	90.98	96.75	269.17
4	*Quercus phellos*	Willow Oak	Spaulding (SE)	147	94.41	87.00	263.16
5	*Quercus phellos*	Willow Oak	J.T. Williams (North)	157	85.72	81.00	262.97
6	*Quercus phellos*	Willow Oak	Quad (East) - Painted	137	90.98	79.00	247.73
7	*Quercus nigra*	Water Oak	Trigg (NW)	151	66.13	82.00	237.63
8	*Platanus occidentalis*	American Sycamore	Trigg (North)	121	94.77	73.25	234.08
9	*Quercus phellos*	Willow Oak	Library (SW)	130	81.37	80.00	231.37
10	*Quercus phellos*	Willow Oak	Spaulding (SW)	123	88.78	71.38	229.63
11	*Platanus occidentalis*	American Sycamore	Somerset (SW)	126	88.47	55.75	228.41
12	*Platanus occidentalis*	American Sycamore	Carver-Waters (W1)	116	90.98	72.50	225.11
13	*Quercus phellos*	Willow Oak	Quad (West) - Painted	125	78.23	70.00	220.73
14	*Platanus occidentalis*	American Sycamore	Steam Plant (NE)	103	94.93	84.00	218.93
15	*Platanus occidentalis*	American Sycamore	Carver-Waters (W2)	110	90.53	68.50	217.66
16	*Quercus phellos*	Willow Oak	Trigg (SW)	128	69.67	78.00	217.17
17	*Acer saccharinum*	Silver Maple	Carver (NW)	142	58.66	52.50	213.79
18	*Platanus occidentalis*	American Sycamore	Carver-Waters (W3)	109	85.12	73.00	212.37
19	*Quercus phellos*	Willow Oak	J.T. Williams (SE)	108	86.98	55.00	208.73
20	*Platanus occidentalis*	American Sycamore	Carver-Waters (E1)	102	82.07	65.50	200.45
21	*Quercus phellos*	Willow Oak	Spaulding (North)	107	74.98	63.75	197.92
22	*Quercus phellos*	Willow Oak	J.T. Williams (SW)	107	74.16	60.50	196.29
23	*Platanus occidentalis*	American Sycamore	Carver-Waters (E3)	93	81.92	65.00	191.17
24	*Pinus Taeda*	Loblolly Pine	F.L. Trailers (South)	79	87.19	44.63	177.35
25	*Pinus Taeda*	Loblolly Pine	F.L. Trailers (North)	74	84.84	48.50	170.97
26	*Platanus occidentalis*	American Sycamore	Carver-Waters (E2)	85	63.70	61.50	164.08
27	*Pinus Taeda*	Loblolly Pine	Carver (NE)	70	71.10	44.25	152.16

Descriptive statistics for trunk circumference, tree height, average crown spread, and total score of champion trees are presented in Table 2. Average total score of champion trees (n = 27) is 221.21 with median = 218.93 and standard error of the mean = 6.80.

Table-2. Descriptive Statistics of UMES Champion Trees

Measurements	Circumference	Height	Crown Spread	Total Score
Mean	120.67	82.98	70.25	221.21
Median	121.00	85.72	71.38	218.93
Std. Deviation	28.65	10.20	14.50	35.33
Std. Error	5.51	1.96	2.79	6.80
Minimum	70.00	58.66	44.25	152.16
Maximum	172.00	96.17	96.75	292.11

The project output of the GIS map see Figure 2 provides an opportunity to publically display the information on the UMES school website. Completing the processes of data collection and data representation can prove to be beneficial for future natural science courses such as Dendrology, Ecology, Forest Mensuration, etc. The confirmation of the largest tree(s) on campus can also yield an opportunity for signage to be produced, highlighting the "champions" that reside on the university grounds.

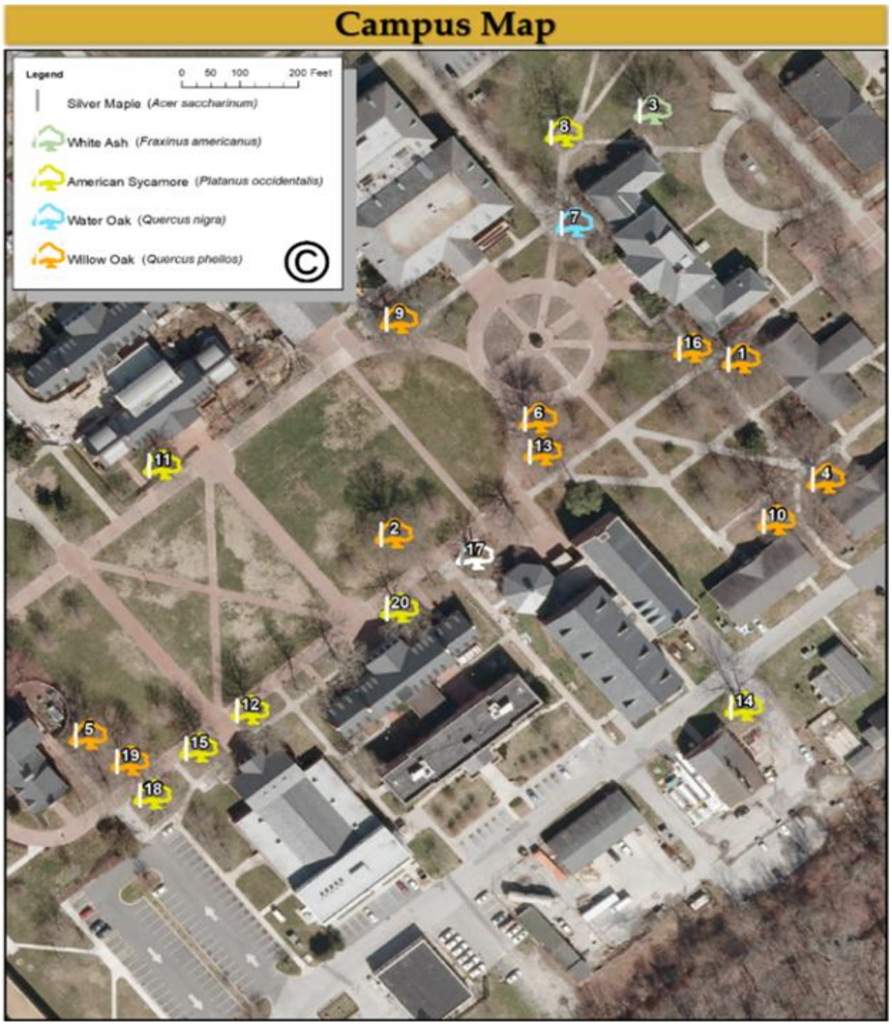

Figure-2. Champion Trees on UMES Campus. Thank you for your reminder.
Source: Produced in the UMES geospatial information technologies Laboratory using ESRI's ArcGIS software.

Table-3. Carbon sequestration measurements of UMES champion tree.

ID	Common Name	Circumference	DBH	Height	Crown Spread	Total Score	Green Weight	Dry Weight	Carbon Storage	Carbon Sequestered
1	Willow Oak	172	54.75	96.17	95.75	292.11	43240.31	21620.15	10810.08	39632.98
2	Willow Oak	182	57.93	87.60	87.75	291.54	44100.05	22050.03	11025.01	40421.01
3	White Ash	154	49.02	90.98	96.75	269.17	32792.88	16396.44	8198.22	30057.14
4	Willow Oak	147	46.79	94.41	87.00	263.16	31005.94	15502.97	7751.49	28419.27
5	Willow Oak	157	49.97	85.72	81.00	262.97	32112.47	16056.24	8028.12	29433.49
6	Willow Oak	137	43.61	90.98	79.00	247.73	25952.51	12976.25	6488.13	23787.42
7	Water Oak	151	48.06	66.13	82.00	237.63	22916.31	11458.15	5729.08	21004.52
8	American Sycamore	121	38.52	94.77	73.25	234.08	21087.93	10543.96	5271.98	19328.67
9	Willow Oak	130	41.38	81.37	80.00	231.37	20899.85	10449.93	5224.96	19156.28
10	Willow Oak	123	39.15	88.78	71.38	229.63	20413.51	10206.75	5103.38	18710.51
11	American Sycamore	126	40.11	88.47	55.75	228.41	21346.63	10673.32	5336.66	19565.79
12	American Sycamore	116	36.92	90.98	72.50	225.11	18606.05	9303.02	4651.51	17053.84
13	Willow Oak	125	39.79	78.23	70.00	220.73	18577.43	9288.71	4644.36	17027.61
14	American Sycamore	103	32.79	94.93	84.00	218.93	15306.30	7653.15	3826.57	14029.37
15	American Sycamore	110	35.01	90.53	68.50	217.66	16648.31	8324.15	4162.08	15259.42
16	Willow Oak	128	40.74	69.67	78.00	217.17	17348.34	8674.17	4337.09	15901.06
17	Silver Maple	142	45.20	58.66	52.50	213.79	17976.74	8988.37	4494.19	16477.03
18	American Sycamore	109	34.70	85.12	73.00	212.37	15370.11	7685.05	3842.53	14087.85
19	Willow Oak	108	34.38	86.98	55.00	208.73	15419.10	7709.55	3854.78	14132.77
20	American Sycamore	102	32.47	82.07	65.50	200.45	12977.08	6488.54	3244.27	11894.47
21	Willow Oak	107	34.06	74.98	63.75	197.92	13046.84	6523.42	3261.71	11958.40
22	Willow Oak	107	34.06	74.16	60.50	196.29	12904.15	6452.08	3226.04	11827.62
23	American Sycamore	93	29.60	81.92	65.00	191.17	10768.32	5384.16	2692.08	9869.98
24	Loblolly Pine	79	25.15	87.19	44.63	177.35	8270.14	4135.07	2067.54	7580.21
25	Loblolly Pine	74	23.55	84.84	48.50	170.97	7060.84	3530.42	1765.21	6471.79
26	American Sycamore	85	27.06	63.70	61.50	164.08	6994.71	3497.35	1748.68	6411.17
27	Loblolly Pine	70	22.28	71.10	44.25	152.16	5294.90	2647.45	1323.73	4853.17

The value of trees has become increasingly more popular in today's "green-conscious" society. When it comes to land planning, urban forestry, or even landscape design, trees are among the most critically needed aspects of consideration in order to be environmentally responsible for the future. Traditional, commercial forestry textbooks even elude to relating carbon sequestration values with tree worth. This study has the potential for relating its data to carbon sequestration values, where a carbon stock assessment could be made of selected champion trees on the UMES campus Table 3.

Descriptive statistics for green weight, dry weight, carbon storage, and carbon sequestered of selected champion trees are presented in Table 4. Average carbon storage of selected champion trees (n = 27) is 4892.94 with median = 4494.19 and standard error of the mean = 1767.27. Average carbon sequestered of selected champion trees (n = 27) is 17938.99 with median = 16477.03 and standard error of the mean = 1767.27.

Table-4. Descriptive statistics of carbon sequestration.

	Green Weight	Dry Weight	Carbon Storage	Carbon Sequestered
Mean	19571.77	9785.88	4892.94	17938.99
Median	17976.74	8988.37	4494.19	16477.03
Std. Deviation	10018.82	5009.41	2504.71	9183.00
Std. Error	1928.12	964.06	482.03	1767.27
Minimum	5294.90	2647.45	1323.73	4853.17
Maximum	44100.05	22050.03	11025.01	40421.01

Among the UMES selected champion trees, a significantly positive correlation is drawn between overall tree size (total score) and annual carbon sequestered ($r = 0.977$, $p < 0.01$). This relationship can allude to many weighty conclusions about the importance of preserving large trees, such as landscape-design policy or green industry standards for forested development sites. Among the many factors that influence our climate, the atmospheric concentration of greenhouse gases like carbon dioxide plays a central role. In a recent study, scientists found that while tree growth rates — and thus carbon capture rates — slowed with increasing tree size at the stand level and at the leaf level, they overwhelmingly increased with size at the scale of the individual tree. Their analysis confirms that large trees can capture carbon more efficiently than smaller-sized trees [6].

To estimate carbon sequestered per selected champion tree, allometric equation [7] is derived from the data as follows Figure 3:

$CARBON\ SEQUESTERED = -173120.095 + 16398.683 \ln DBH^2H$

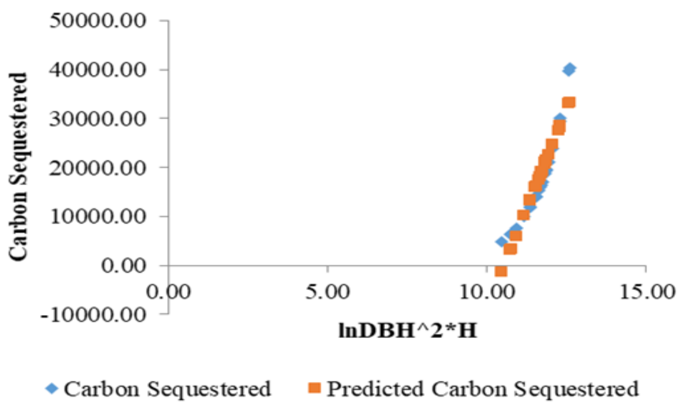

Figure-3. Relationship between carbon sequestration and tree DBH & height.

5. DISCUSSION AND CONCLUSIONS

In this study, the twenty-largest "Champion Trees" that exist on the UMES main campus are determined. To calculate the total score of these "Champion Trees", measuring the circumference, overall height, and average crown spread. Those dimensional measurements are then used to calculate each tree's green weight, dry weight, and finally, carbon sequestration values. The top-20 trees exhibited many significant characteristics and observable phenomena, many of which hold the potential to become their own individual research topics for future study. For example, overall size traits varied based on compaction/natural form, which are especially shown in Willow Oaks.

One thing as something frequently overlooked is how tree form and competition affect biology and carbon uptake and storage that varies for each species. For example, under natural conditions, tree circumference (girth) and canopy, and perhaps overall biomass, are negatively affected by competition. The exception to this is tree height which may be greater (particularly in an intolerant species) when compared to the same species that is open grown or has less competition. However, though such specimens in less competitive realms tend to be of shorter stature, they might be expected to have a substantially wider average canopy, and a greater girth. The best tree species selected for sequestering carbon in campus environments may be those that attain the greatest girth in the shortest period of time.In essence, anything that impacts tree biology should affect a tree's growth and survival and therefore its ability to sequester carbon. The conservation and protection of large girth trees, whether as components in an old growth forest or as large individual specimens such as those of UMES's campus community, should be encouraged. Replacing large older trees with new growth may seem sustainable at face value but the losing the more efficient mechanism of carbon sequestration as a means of mitigating the effects of elevated atmospheric carbon dioxide cannot be overstated.The thematic display of the "Champion Trees of UMES" can be seen as enriching or even enlightening for those that would have never viewed the campus trees in such a way. Moving forward, the sustainability goals of UMES could absolutely benefit from exploring more forestry-related research. Topics such as carbon footprint reduction, building heating and cooling energy savings due to shade-tree influence, parking lot nutrient runoff/uptake, as well as many more focuses of study, could all be experimentally investigated now that the "ice has been broken" on campus-wide tree research.

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