Carbon Sequestration of the Sac State Arboretum

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Introduction:

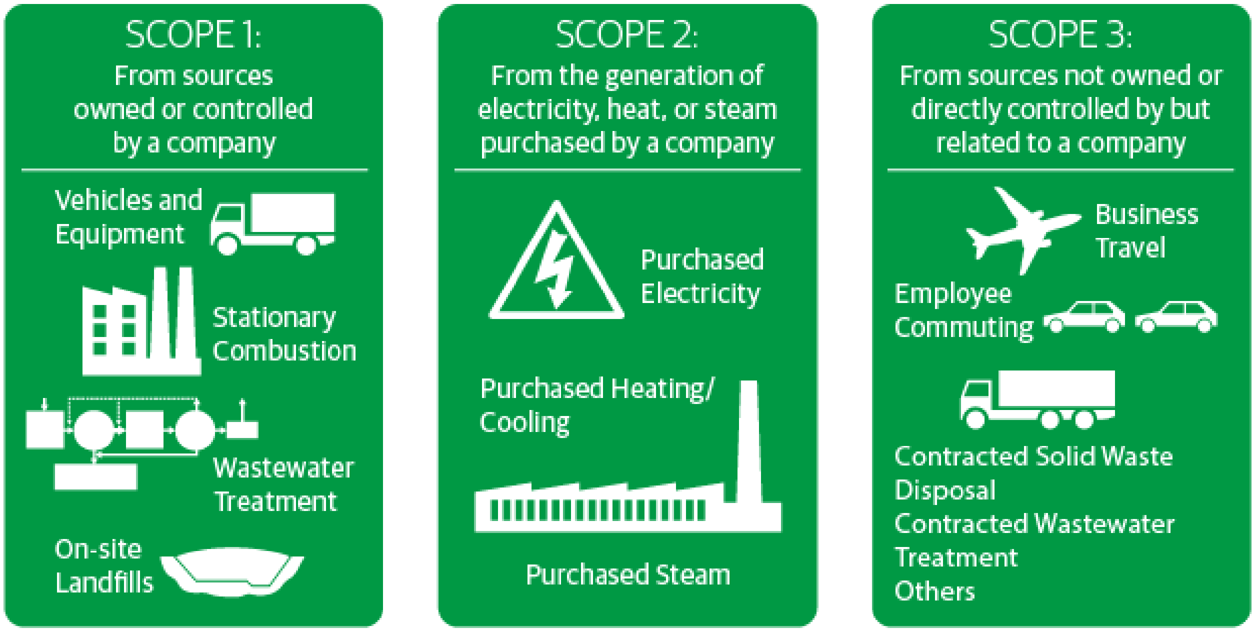
In a world increasingly affected by climate change, the bulk of responsibility for preventative and preservative actions is upon private and smaller organizations. California State University, Sacramento (CSUS), has partnered with Second Nature to complete the 2017 Carbon Commitment Report. Second Nature strives to advance sustainability through higher education institutions and in doing so, enables them to create and implement a sustainability plans within their communities. Institutions of higher education are one of the primary places sustainability advancements are made and changes ripple out to other organizations and private businesses. Therefore, it is no surprise that various colleges and institutions are taking their own initiatives to become more sustainable and environmentally conscious.

The Carbon Commitment Report is a 3 step process as listed on the CSUS website[1]:

- **STEP 1:** Within two months, create internal institutional structures to guide the development and implementation of the Plan - **Completed**
- **STEP 2:** Within one year, complete a greenhouse gas emissions inventory and identify near term opportunities for greenhouse gas reduction. Report these in the first annual evaluation of progress - **In Progress**
- **STEP 3:** Within two years, complete the Plan, which will include:
    - A target date for achieving carbon neutrality
    - Interim target dates for meeting milestones that will lead to carbon neutrality
    - Mechanisms and indicators for tracking progress
    - Actions to make carbon neutrality a part of the curriculum and other educational experiences for all students
    - Actions to expand research in carbon neutrality

Within the Carbon Commitment Report, there are 3 scopes which address the three sources of carbon emissions.

[1] CSUS REFERENCE CITATION



Scope 1 contains direct Greenhouse Gas (GHG) sources. These are greenhouse gas emission that are produced on the CSUS campus. Examples of direct GHG emissions are "on-campus power production, campus vehicle fleets, refrigerant leaks" ("Measuring Progress", 2017).

Scope 2 is characterized as indirect emissions. These are emissions that used by CSUS to run day to today operations but are sourced by another institution. They are most closely related to utilities purchased ("Measuring Progress", 2017).

Scope 3 are Induced Emissions which are all other GHG emissions that are not owned by CSUS but are crucial to campus operations. This category mainly includes GHG emissions of commuters, "non-fleet transportation, employee/student commuting, air travel paid for by your institution" ("Measuring Progress", 2017).

CO2 is widely recognized as the leading cause for global warming. A key struggle in determining viable methods to help mitigate GHG emissions such as CO2 is a global problem. However, current research has determined that various natural processes can help sequester carbon.

Carbon sequestration is a process in which carbon within the atmosphere is captured and stored for long periods of time (Montagnini and Nair, 2004). Storage of carbon naturally occurs in the ocean and biomass such as plants and agroforestry systems can be viable and effective carbon sinks (Montagnini and Nair 2004), as such, arboretums such as the CSUS Arboretum may be used for researching carbon sequestration.

The CSUS Arboretum is home to over a thousand species of plants that provide both aesthetic and social benefits. Its most crucial purpose is probably also the most understated. The various plants and bio life hosted in the Arboretum store *a great a deal of carbon.* The project discussed in this report was overseen by the Sustainability Department at CSUS, and aims to quantify this amount. However, the purpose of this project is not only to measure the CO2 sequestered, but also help understand the ecosystem services it provides.

Background:

Measuring carbon sequestration in an extremely diverse environment such as the Arboretum, is a lofty goal for a small university project such as this one and this report is intended to be a catalyst for future research and reports on the topic. The tools used included the following: diameter at breast height (DBH) tape, Microsoft Excel, Arboretum Map, expert consultation from University professors, and the internet. Project staff also operated within the constraints of limited resources, budget, and time to calculate a rough estimate of the CO2 sequestered within the Arboretum.

Methods:

The sample size was based on the guidance of Catherine Ishikawa, an environmental studies professor at CSUS. Twenty percent of the trees were sampled in the Arboretum. However, choosing 20% as the sample size limited the use of quantitative statistical data because it fails to meet the 10% condition. The 10% condition states "in order to ensure that the assumption of independence is met (no two individuals are more related to one another than another two individuals)," meaning the sample size cannot be larger than 10% of the population (Source: Prof. Ishikawa).

The Arboretum has a highly diverse collection of trees, shrubs, flowers, and other plants, that vary in size, height, and most importantly, carbon sequestration rate. These variabilities meant that a large sample size would be needed for a reasonable margin of error, but due to the already small population size, using a representative sample without violating the 10% condition was impossible. Therefore, the 20% sample was decided to provide a rough estimation for carbon sequestration within the Arboretum.

The 2012 plant inventory for the Arboretum listed 1,398 different plants. Many of these plants are not native to California and come from a wide range of geographic locations. Only trees were measured for the purposes of this project.

Trees are unique in that they have the ability to store carbon within their trunks for a longer period of time. Their large size and spread allow for greater carbon sequestration potential than other plants. However, there is a very fine line between what constitutes as a tree versus what can be a shrub eventually growing into a small tree. This determination was made at the site of measurement rather than beforehand. If a shrub's trunk was larger than 3.5 inches in diameter and was larger than 4.5 feet in height, then the shrub would automatically be classified as a small tree and would be included in the data collected.

The 2012 Arboretum plant inventory list as well as a corresponding map was obtained from Dr. Michael Baad. This plant inventory listed the various plants within the Arboretum as well as their locations on the map. This plant inventory was then sorted and organized to only display trees or shrubs that could be characterized as small trees.

The map already had a grid placed upon it, which corresponded to a given number and letter that allowed for the plant to be easily located in the given plots. It was then cross-referenced with the plant inventory list (see Figure 1). Each plot (a total of 107) was then manually numbered to provide a point of reference as well as allow the use of a random number generator.

The random number generator was used to pick plots that would then be used to measure the DBH of the trees. The random number generator was obtained online and gave a range of numbers to input. The number generator chose numbers between 1 to 107. The trees within the plots selected by the random number generator were then measured. This technique was based on similar research conducted at Colgate University[2].

Using this technique allowed researchers to conduct field work directly, measuring each tree in the plot. Measurements were taken using a DBH measuring tape obtained from Forestry Suppliers website. This tape allowed us to convert the centimeters of a tree directly into diameters.

Our sample population was 1398 plants from which only 545 were either categorized as trees or shrubs that could also be small trees. Out of the 545 trees or shrubs, 109 were sampled.

Sampling took place between February 28, 2017 and March, 17, 2017.

Measuring DBH is a complex task in which the variable growth of trees is often a factor.

DBH is the standard used to measure trees. A website article from The City of Portland, Oregon on *How to Measure a Tree* was the primary guide used to determine the DBH. The trees were manually measured up 4.5 feet and from that point, the circumference of the tree was measured using the DBH specific tape measures. Most trees have a relatively normal growth pattern and therefore are easily measured (See figure 2). However for trees with unusual growth patterns such as multiple stems or trees that branched out, different measurement techniques were used. For instance, trees that grew with an angle were measured angularly, see figure 3 (How to Measure a Tree, 2015). For trees with branches that split, the measurement was taken below the split, see figure 4 (How to Measure a Tree, 2015).

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[2] Colgate University was one of the resources provided to us by Second Nature. There are some key differences to note between the research methods of Colgate university and California State University, Sacramento. Colgate University project was in a much grander scale than CSUS. The forested acreage for each Colgate parcel was 1,058.7 while the arboretum was only 3 acres (Bick, 2013). The plots sampled by Colgate University were 1/10 acres in size, while the size of the plots sampled for CSUS were 20ft by 20ft (Bick, 2013). The plots used from this project were based off of the grids that were already present on the Arboretum map as well as a random number generator. The plot locations for Colgate University "…were established using systematic spacing within individual management units. Preliminary plot location coordinates were entered into a hand-held GPS unit...When a plot center location was located, a blue plastic stake was placed in the ground as a permanent marker and the plot center coordinates were recorded with a GPS unit." (Bick, 2013). Similar to Colgate University, CSUS also measured shrubs and trees that were 3 inches in diameter at breast height (DBH).

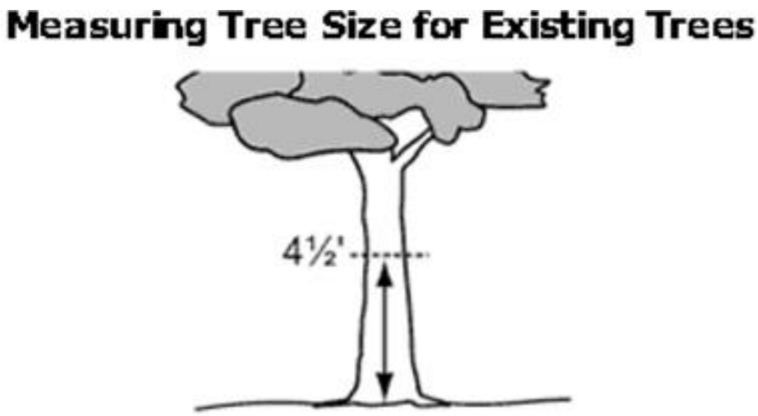

Figure 2: The measurement of most trees were taken at 4.5 ft above ground (How to Measure a Tree, 2015).

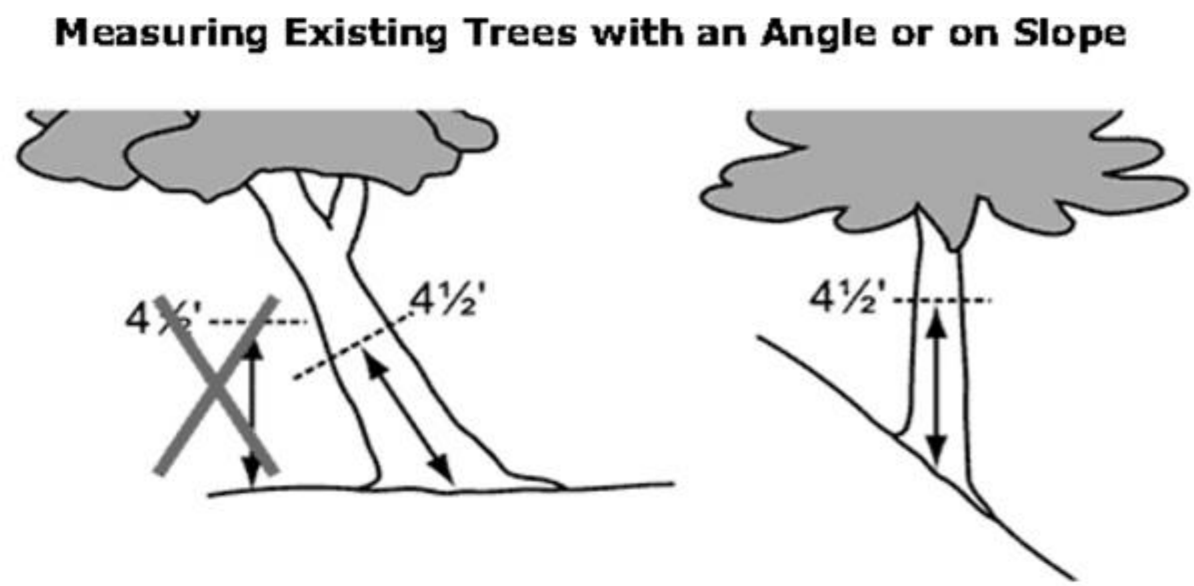

Figure 3: The DBH of trees on slopes or angles were measured at right angles (How to Measure a Tree, 2015).

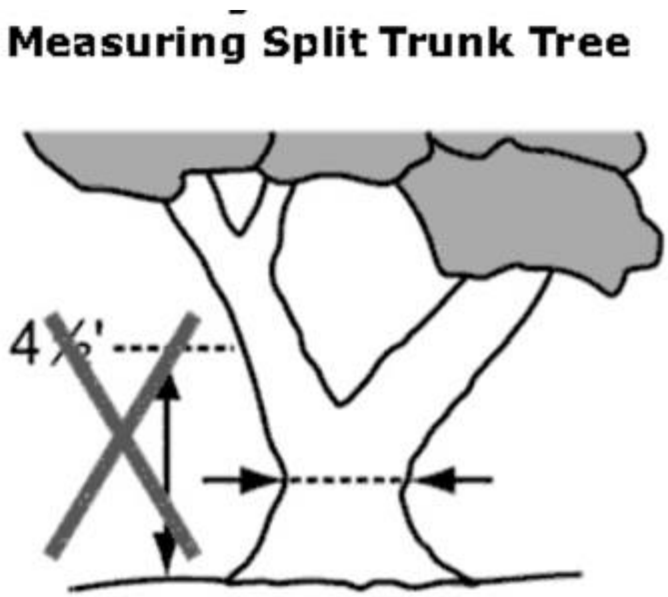

Figure 4: Trees with trunks that split and branched out, were measured right below the split (How to Measure a Tree, 2015).

However, for multi-stemmed trees (see figure 5) where the growth of the stems began from the ground, each trunk was measured. Once all the trunks were measured, the largest trunk diameter was then added to one half the diameter of each additional trunk (How to Measure a Tree, 2015).

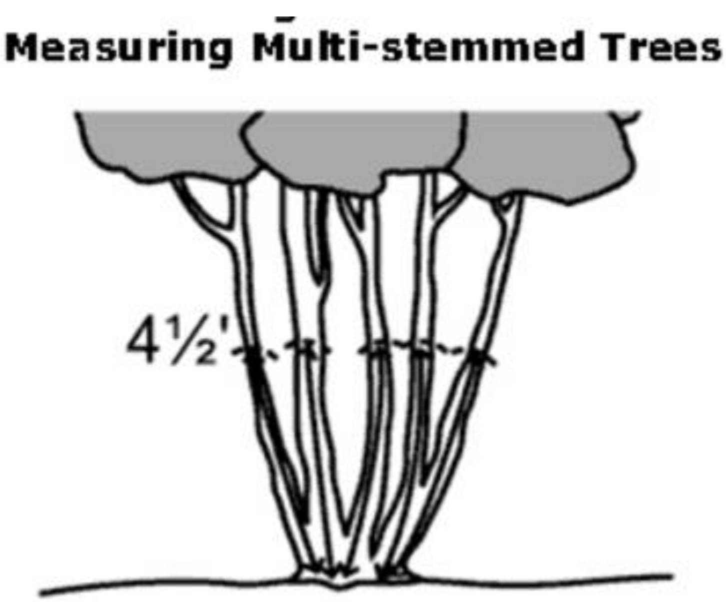

Figure 5: All stems of multi-stemmed trees were measured at breast height (How to Measure a Tree, 2015).

Measurement data was inputted into a Microsoft Excel file, which listed the tree by species, its location, and the diameter (see Figure 1). To calculate the carbon sequestration of a given tree, the DBH was measured and used to calculate the dry weight of the tree. The dry weight was converted into CO2 sequestered. The CO2 sequestration rate was calculated using a formula derived from a Biology Lab course from Furman University[3]. The formula, Log 10 M = -1.247 + 2.663 Log10 DBH, was used where M= the dry weight of the tree in kilograms (kg) and DBH= the diameter of the tree at breast height (4.5 feet or 1.4 meter). After calculating the measurement of the dry weight using this formula, the dry weight was then converted into CO2 sequestered by multiplying it by 1.65. The laboratory manual specified that 1 kg of dried weight = 1.65kg of CO2.

A	B	C	D	E	F	G
Tree Name	Type	Plot	DBH(cm)	Trees	Dry Weight	Kg of Co2
Banksia Saxicola	U	Plot 40	8.077	1	1.2885168	2.126053
Loropetalum Chinensis	U	Plot 40	10.668	1	1.4500629	2.392604
Rhus potaanili	T	Plot 40	3.23	1	0.2140726	0.35322
Trisitinia Laurina à	T	Plot 40	33.99	1	1.8486865	3.050333
Picea Omorika	U	Plot 44	3.6	1	0.4214138	0.695333
Podocarpus Salignus	T	Plot 44	12.1	1	1.5113406	2.493712

Figure 1: Column A listed the plant species, column B determined whether the plant was a tree (T), a shrub or small tree (U). Column C lists the rough location of the trees and column D - the DBH in centimeters. Column E was to clarify how many of the same species of plants were within the plot as well as to help Microsoft Excel calculate the formula. The dry weight (column F) of the trees was calculated through Excel using the formula, Log 10 M = -1.247 + 2.663 Log10 DBH[4]. Column G yields the kg of CO2 by multiplying the dry weight of the tree by 1.65.

After recording the DBH value in one of the columns (for our purposes we had our data in column D2). Using the formula highlighted in green [=(1.247+2.663*LOG10(D2))/LOG10(D2)] into a separate column designated for the dry weight. D2 is referring to the column with the DBH measurement that was recorded. For example, entry 1 for Banksia Saxicola, the DBH (8.077) was inputted into the formula for the dry weight. After getting the output (1.2885168), it was then multiplied by 1.65 to yield 2.126053 kg of CO2 sequestered.

Once the calculations for each tree measured was complete, the kg of CO2 were then summed up and multiplied by five. The sum of the samples was 20% of the sampled trees, and multiplying this sum by five allowed us to determine the approximate CO2 sequestered for the Arboretum. Twenty percent of the Arboretum sequestered 291.61 kg of CO2 resulting in a total of 1458.07 CO2 sequestered.

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[3] The formulas used in this project are mainly derived from a Bio 102 lab course from Furman University. Furman University a private liberal arts college that is located in Greenville, South Carolina. Calculations for the dry weight of trees as well as the kg of CO2 sequestered in the dry weight were determined based off of this laboratory.

[4] See Footnote 3

Results:

Twenty percent of the Arboretum sequestered 291.61 kg of CO_2 resulting in a total of 1458.07 CO_2 sequestered.

Discussion:

Urban forestry is the practice of using trees in urban areas to create aesthetic and social changes. Urban forests can be used to help global warming issues by reducing CO_2 (Liu and Li, 2012). Adding small urban forests in local settings such as school campuses in the form of arboretums can help provide various ecosystem services. These ecosystem services "include air filtering, micro-climate regulation, noise reduction, rainwater drainage, sewage treatment, recreation and cultural values" (Bolund and Hunhammar, 1999 as cited in Martin, Chappelka, Loewenstein, & Keever, 2012).

After the conclusion of the project, the CO_2 sequestered amounted to 1458.07 kg. Better resources and stratification methods might have yielded more accurate results. The largest challenge remained that the various plant species in the Arboretum meant that no one allometric equation would be able to determine the exact amount of CO_2 sequestered. With sufficient resources, a detailed survey that includes soil types and climate patterns effecting carbon sequestration can also yield accurate results in greater depth.

The carbon sequestration of trees in the Arboretum accounted for only a small portion of the Carbon Commitment Report. However, it helped gain a better understanding of carbon offsets within the campus. It also aided efforts for CSUS to eventually become a carbon neutral campus. Projects such as these rely on commitment from both students and faculty to strengthen community ties. They allow opportunities for growth and development, allowing for a holistic process.

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