Urban Forestry Project, University of Arkansas Fall 2013

Supriya Thote, Katherine Ferran, and Justin Angel
University of Arkansas Office for Sustainability
3/17/14

Abstract: Increasing concentrations of carbon dioxide (CO2) in the atmosphere may be contributing to changes in atmospheric temperatures and global climate change. Urban areas are subject to such temperature changes due to heat retaining land modifications and high levels of CO2 emissions. The University of Arkansas and its partnership with The American College & University Presidents' Climate Commitment has committed itself to a climate action plan that aims to reduce CO2 and greenhouse emissions, with a specific focus on carbon sequestration in the campus's urban forest. This study surveyed the tree population of roughly half the campus, and calculated the amount of carbon dioxide sequestered and stored and the above ground biomass, using the CFUR Tree Carbon Calculator (CTCC) program developed by Center for Urban Forest Research. The results found that the survey area stored 2588.8 tons of CO2, and was composed many of oaks and maples.

Contents

Introduction

Increasing emissions of carbon dioxide (CO_2), and other greenhouse gases such as methane (CH_4), chlorofluorocarbons, nitrous oxide (N_20), and ozone (O_3), accumulating in the atmosphere can contribute to changes in atmospheric temperatures by trapping certain wavelengths of radiation and preventing heat from leaving the atmosphere. (Nowak, Stevens, Sisinni & Luley, 2002) These long term changes in temperature can also contribute to the risk of global climate change. Urban areas experience these effects on a much smaller scale due to land modification and fuel combustion that retains heat and creates a heat island effect. (Nowak & Crane, 2002) Fossil fuel combustion and worldwide deforestation have made CO_2 the most abundant greenhouse gas in the atmosphere, making carbon emission reduction the priority in efforts to combat climate change. It is for this reason that tree planting and stewardship in urban settings is recognized as a particularly crucial emission reduction strategy. (McPherson, 1998)

Trees are a natural step in the carbon cycle that has been drastically disrupted by human activity. CO_2 is pulled from its atmospheric stage to be incorporated and stored in a tree's biomass, acting as a CO_2 sink, even after the tree has stopped growing. Therefore, urban forests can potentially offset the accumulation of atmospheric carbon and improve the climatic conditions of the urban area. (Nowak & Crane, 2002) The practice of urban forestry management seeks to encourage this emission reduction by observing the forest's current carbon storage capacities and estimating its future capacities, to determine if the forest can eventually fully offset carbon emissions. With this information, cities and rural communities can take measures to ensure the ongoing health of urban forests to combat atmospheric CO_2 accumulation and climate change. (Nowak & Crane, 2002)

The University of Arkansas, Fayetteville, Arkansas, has already made clear its intentions to combat climate change by joining the American College & University Presidents' Climate Commitment (ACUPCC), a network of colleges and universities working together to address global climate change and to eliminate greenhouse gases. The University of Arkansas has enacted a climate action plan that aims to reduce greenhouse gas emissions by 50% by 2021, and achieve climate neutrality by 2040. (Brown, 2013) To achieve this goal, the Office for Sustainability was commissioned to conduct a study to estimate the campus-wide carbon storage and sequestration rates by surveying the urban forest population. A similar study was conducted in the summer of 2013 that provided data on central campus arboretums that was incorporated into the later survey. (Avila & Hardison, 2013) The extension of the survey during the fall of 2013 covered about 210 acres of campus, roughly half of the total area of campus (425 acres), and included the previous study's data. (Figure 8) The amount of carbon dioxide sequestered and stored and the above ground biomass were calculated using the CFUR Tree Carbon Calculator (CTCC) program developed by Center for Urban Forest Research. This data produced a carbon sequestration estimate of all tree species on campus, which was used to identify the forest structure and total amount of carbon sequestered. These findings will help the University better understand the current dynamics of the campus's forestry, identity the species that are most or least beneficial, and ultimately aid in the effort to become carbon neutral.

Methods

The circumference of the trees measured at a standard height of 4.5 ft using a flexible, non-stretching measuring tape. After recording the circumference, the circumference was divided by π (pi) to obtain the diameter at breast height (DBH). Only those trees having a DBH larger than 3 inches were included in the survey. Trees smaller than 3 inches DBH did not sequester or store enough carbon dioxide to make a significant impact. Many of the trees recorded during the survey contained multiple trunks at breast height in which all were recorded. In order to provide a more accurate DBH value for the carbon analysis, an equation was used to obtain a theoretical DBH with equal area to the sum of the areas of the actual stems. To calculate the collective DBH, the square root of the sum of all the squared values of the actual stems was taken (Forest inventory and, 2007).

Combined DBH equals: $\sqrt{\sum_{i=1}^{n} D_i^2}$ where D is the diameter of each stem

The coordinates of each tree were obtained using etrex 20 GPS units by GARMIN. To aid in tree species identification pictures of the tree, tree leaf, bark and any fruit or flower were taken and recorded. The waypoint number obtained from the GPS, the latitude and longitude coordinates, the circumference and the tree species were recorded in field notebooks. All data and maps are stored in the Office for Sustainability.

The Tree Carbon Calculator (TCC) program, obtained from the USDA Forest Service website was used to calculate the annual sequestration of CO2, the total amount of CO2 stored within the tree, and the tree's aboveground biomass using the climate zone, tree species identification and DBH as inputs. The tree size data used in TCC were based on growth curves developed from samples of 650-1000 street trees per city from a total of six reference cities. Each of the climate zones had one reference city. The measurements recorded at the reference cities were the following; DBH, tree crown, crown base, crown diameter in two direction, tree condition and location. CTCC lists 20-30 species in each climate zone. If the carbon and energy results for a species not included in the list are to be calculated then, a species from the same climate zone with the most similar mature size and growth rate must be chosen. (Table 1)

The City of Fayetteville is located in the Lower Midwest climate zone according to the CTCC program. Not all of the tree species encountered on the study area were present in the CTCC defined climate zone list; thus, substitutions based on species similarity, tree growth and wood density and other characteristics were made. (Table 1) Also, CTCC help file mentions that regional boundaries for climate zones are approximate, and the climate of cities within each region can differ considerably. Since Fayetteville was reasonable close to South climate zone and a majority of tree species listed in the South climate zone were native to Fayetteville, the tree species listed in South zone were also used for the carbon calculations.

Results

1212 trees from 79 different species were measured and recorded in our study area. 24% of the total trees surveyed were oaks, and 18% were maples. (Figure 2) The most common species were sugar maples, (12%) American Sycamores, (7%) White Oaks, (6%) and Nuttall Oaks. (5%) (Figure 3) The study found that this collective tree population stores 2588471.3 kilograms of CO_2,(2588.5 tons) and has a total aboveground biomass, or dry weight, of 1100274.962 kilograms (1100.3 tons) and a CO_2 sequestration rate of 178194.92 kilograms (178.2 tons) a year. If we project this data to the whole 425 acres of campus, then the entire urban forest stores 5237.42 tons of CO_2, has an aboveground biomass of 2226.19 tons, and sequesters 360.44 tons of CO_2 annually. Unfortunately, this shaves very little off each year's CO_2 emissions; this projected sequestration rate would have sequestered only .0002% of 2012's emissions. (Figure 7)

Observation of the data from individual species showed that while white oaks made up only 6% of the total surveyed trees, they stored 19% of the total CO_2 stored in the survey area, (Figure 4) and made up 29% of all surveyed aboveground biomass. (Figure 5) White Oaks had an average carbon sequestration rate of 487.28 metric tons a year, and an average DBH of 27.20 inches.(Figure 6) Nuttall Oaks stored 9% of the total CO_2 (Figure 4) and made up 8% of the total biomass, (Figure 5) having an average sequestration rate of 169.22 kg/yr, and an average DBH of 19.4 inches. (Figure 6) Sugar maples also stored 9% of total CO_2 (Figure 4) and made up 8% of the total biomass, (Figure 5) though with an average sequestration rate of 112.6 kg/yr, and an average DBH of 11.6 in. (Figure 6)

English Oaks as a species had the highest average sequestration rate at 21360.6 kg/yr, and the most average CO_2 stored at 1103.6 kg and the highest average biomass at 9079.7 kg. (Figure 6) However, it is important to note that there was only one English Oak surveyed in the entire study, and that the previously listed figures may not be indicative of the whole species. White Swamp Oaks had the second highest average sequestration rate at 978.12 kg/yr, second most average CO_2 stored at 17657.39 kg, and second highest aboveground biomass at 7505.59 kg. (Figure 6)But once again, we must note that there was only one White Swamp Oak surveyed in the study. All next highest figures also belonged to oak variants, with exception to several kinds of elms, Mulberries, Waterlocusts and River Birches. (Figure 6)

Discussion

Once again, it is important to note that the data produced for many of these species came from the CTCC model of a different tree species, and may not be indicative of the original species' true growth patterns. The study area encompassed 79 species and only 36 CTCC coded species were used; inconsistencies and inaccuracies in making substitutions may nullify the validity of our results. If a more extensive survey is to take place at a later date, the surveyors may want to consider finding a different program with more specific models corresponding to our area's common species.

The results indicate that the observed oak species stored the most biomass and CO_2 and had the highest sequestration rates. Oaks were also found to be the most common family of tree on the campus. The difficulty with utilizing oaks for forestry management is that they have very slow growth rates, and tend to interfere with surrounding structures. Most of the oaks on campus were not planted by facilities management, and many are older than the university itself. However, oaks present the advantage of living for much longer, thus being able to sequester more CO_2 in its lifetime than other species. In terms of forest management with respect to oaks, if planting more oaks is not a feasible option, specific care and attention should be given to the health of the large oaks that are already on campus, as they are sequestering the majority of CO_2 emissions.

The abundance of Sugar Maples and Red Maples can likely be attributed to the University's tree planting pattern that emphasizes decorative and visually appealing trees. While it is important to value the campus's urban forest for its aesthetic utility, it is also important to recognize that decorative trees may not be the most useful trees. Our results indicate that maples do not have very large CO_2 storage and sequestration capacities, despite their enormous quantity on the campus. Cedar Elms, Slippery Elms, American Elms, Southern Magnolias, River Birches, Mulberries and Water Locusts are all possible species that grow faster than most oaks but store more carbon than most maples.

It should also be noted that during the survey, we noticed many trees that were too small to include that the university had planted, like several sky rocket oaks surrounding the Greek amphitheater, many lacebark elms along the senior walkway, and many young trees elsewhere. In this way, the university has already taken some action to increasing the population of the campus's urban forest; the effects simply won't be apparent for some time.

Conclusions

To summarize the findings, the study's results covered 1212 trees, 210 acres, and 79 species, which collectively store 2588.5 tons of CO_2, sequester 178.2 tons of CO_2 annually, and have an aboveground biomass of 1100.2 tons. Maples and oaks were the most common families, and oaks stored and sequestered the most CO_2. The predicted campus-wide levels of CO_2 storage and sequestration projected from this study still offsets very little of the university's emissions. Maintenance of older oaks of campus should become a priority of the university's, as well as utilizing more of the previously indicated species in further tree planting plans.

Tables and Figures

Table 1. All observed species and their scientific names, number of surveyed individuals, CTCC Codes, Regions, (LMW being Lower Midwest, S being South, BOTH being the species can be found in both the Lower Midwest and the South), and replacement species when needed.

Common Name	*Scientific Name*	#of Individuals	CTCC Code& Region	Substitute Species	Substitute code & region
American Elm	*Ulmus americana*	8		Siberian Elm	ULPU (LMW)
American Holly	*Ilex opaca*	14	ILOP (BOTH)		
American Sycamore	*Platanus occidentalis*	88		Sugar Maple	ASCA2 (BOTH)
Baldcypress	*Taxodium distichum*	20		Eastern Red Cedar	JUVI (S)
Bitternut Hickory	*Carya cordiformis*	2		White Oak	QUAL (S)
Black Cherry	*Prunus serotina*	1		Ginkgo	GIBI (MW)
Black Hickory	*Carya texana*	3		Black Walnut	JUNI (LMW)
Black Locust	*Robinia pseudoacacia*	4		Honeylocust	GLTR (LMW)
Black Oak	*Quercus velutina*	22		Northern Red Oak	QURU (BOTH)
Black Walnut	*Juglans nigra*	3	JUNI (LMW)		
Blackjack Oak	*Quercus marilandica*	5		Northern Red Oak	QURU (BOTH)
Boxelder	*Acer negundo*	1		Norway Maple	ACPL (LMW)
Burr Oak	*Quercus macrocarpa*	4		White Oak	QUAL (S)
Callery Pear	*Pyrus calleryana*	11	PYCA (S)		
Cedar Elm	*Ulmus crassifolia*	1		Winged Elm	ULAL (S)
Common Pawpaw	*Asimina triloba*	24		Southern Magnolia	MAGR (BOTH)
Common Persimmon	*Diospyros virginiana*	5		Flowering Dogwood	COFL (S)
Crape Mrytle	*Lagerstroemia indica*	2	LA6 (S)		
Cucumbertree	*Magnolia acuminata*	6		Southern Magnolia	MAGR (BOTH)
Dogwood	*Cornus florida*	18	COFL (S)		
Downy Serviceberry	*Amerlanchier laevis*	3		Plum	PR (S)

Eastern Cottonwood	*Populus deltoides*	2	PODE (LMW)		
Eastern Hemlock	*Tsuga canadensis*	1		Blue Spruce	PIPU (LMW)
Eastern Red Cedar	*Juniperus virginiana*	36	JUVI (S)		
Eastern Redbud	*Cercis canadensis*	55	CECA (LMW)		
Eastern White Pine	*Pinus strobus*	18	PIST (LMW)		
English Oak	*Quercus robur*	1		White Oak	QUAL (S)
Ginkgo	*Ginkgo biloba*	7	GIBI (MW)		
Goldenrain Tree	*Koelteuteria paniculata*	24		Norway Maple	ACPL (LMW)
Green Ash	*Fraxinus pennsylvanica*	1	FRPE (LMW)		
Hawthorn	*Crataegus phaenopyrum*	1		Yoshino Cherry	PRYE (S)
Hedge Maple	*Acer campestre*	5		Norway Maple	ACPL (LMW)
Honey Locust	*Gleditsa triacanthos*	9	GLTR (LMW)		
Japanese Maple	*Acer palmatum*	9		Red Maple	ACRU (BOTH)
Katsura Tree	*Cercidi phyllum*	1		Flowering Dogwood	COFL (S)
Kwansan Cherry	*Prunus serrulata 'Kwanzan'*	6		Yoshino Cherry	PRYE (S)
Lacebark Elm	*Ulmus parvifolia*	20		Winged Elm	ULAL (S)
Littleleaf Linden	*Tilia cordata*	21	TICO (LMW)		
Live Oak	*Quercus virginiana*	1		Water Oak	QUNI (S)
Mockernut Hickory	*Carya tomentosa*	37		Black Walnut	JUNI (LMW)
Mulberry	*Morus rubra*	8	MO (LMW)		
Norway Maple	*Acer platanoides*	1	ACPL (LMW)		
Nuttall Oak	*Quercus nutalli*	59		Roble Negro	QUIL (LMW)
Osage Orange	*Maclura pomifera*	27		Mulberry	MO (LMW)
Pagoda Tree	*Styphnolobium japonicum*	1		Honeylocust	GLTR (LMW)
Paper Birch	*Betula papyrifera*	15		River Birch	BENI (S)

Pecan	*Carya illnoinensis*	7		Black Walnut	JUNI (LMW)
Pin Oak	*Quercus palustris*	19		Northern Red Oak	QURU (BOTH)
Post Oak	*Quercus stellata*	52		White Oak	QUAL (S)
Red Maple	*Acer rubrum*	58	ACRU (BOTH)		
Red Pine	*Pinus resinosa*	37		Shortleaf Pine	PIEC (S)
River Birch	*Betula nigra*	2	BENI (S)		
Sawtooth Oak	*Quercus acutissima*	6		Water Oak	QUNI (S)
Shagbark Hickory	*Carya laciniosa*	1		Black Walnut	JUNI (LMW)
Shantung Maple	*Acer truncatum*	1		Norway Maple	ACPL (LMW)
Shingle Oak	*Quercus imbricaria*	1		Northern Red Oak	QURU (BOTH)
Shortleaf Pine	*Pinus echinata*	16	PIEC (S)		
Shumard Oak	*Quercus shumardii*	19		Northern Red Oak	QURU (BOTH)
Siberian Elm	*Ulmus pumila*	3	ULPU (LMW)		
Silver Maple	*Acer saccharinum*	3	ASCA1 (BOTH)		
Slippery Elm	*Ulmus rubra*	2		*Siberian Elm*	ULUP (LMW)
Southern Hackberry	*Cetlus laevigata*	12		Northern Hackberry	CEOC (LMW)
Southern Magnolia	*Magnolia grandiflora*	2	MAGR (BOTH)		
Sugar Maple	*Acer saccharum*	147	ACSA2 (BOTH)		
Sweetgum	*Liriodendron tulipifera*	41	LIST (S)		
Topel Holly	*Ilex 'X attenuata'*	14		American Holly	ILOP (BOTH)
Trident Maple	*Acer buergerianum*	1		Sugar Maple	ASCA2 (BOTH)
Tuliptree	*Liriodendron tulipifera*	12		Eastern Cottonwood	PODE (LMW)
Tupelo	*Nyssa sylvatica*	1		Flowering Dogwood	COFL (S)
Water Oak	*Quercus nigra*	13	QUNI (S)		
Waterlocust	*Gleditsa aquatica*	7		Honeylocust	GLTR (LMW)
Weeping Yaupon	*Ilex vomitoria 'Pendula'*	1		American Holly	ILOP (BOTH)

Holly					
Western Soapberry	*Sapindus drummondii*	11		Norway Maple	ACPL (LMW)
White Ash	*Fraxinus americana*	11	FRAM (LMW)		
White Oak	*Quercus alba*	72	QUAL (S)		
White Swamp Oak	*Quercus bicolor*	1		White Oak	QUAL (S)
Willow Oak	*Quercus phellos*	22	QUPH (S)		
Winged Elm	*Ulmus alata*	5	ULAL (S)		
Witch Hazel	*Hamamelis virginiana*	1		Flowering Dogwood	COFL (S)

Figure 2. Condensed Tree Species Composition of Surveyed Area

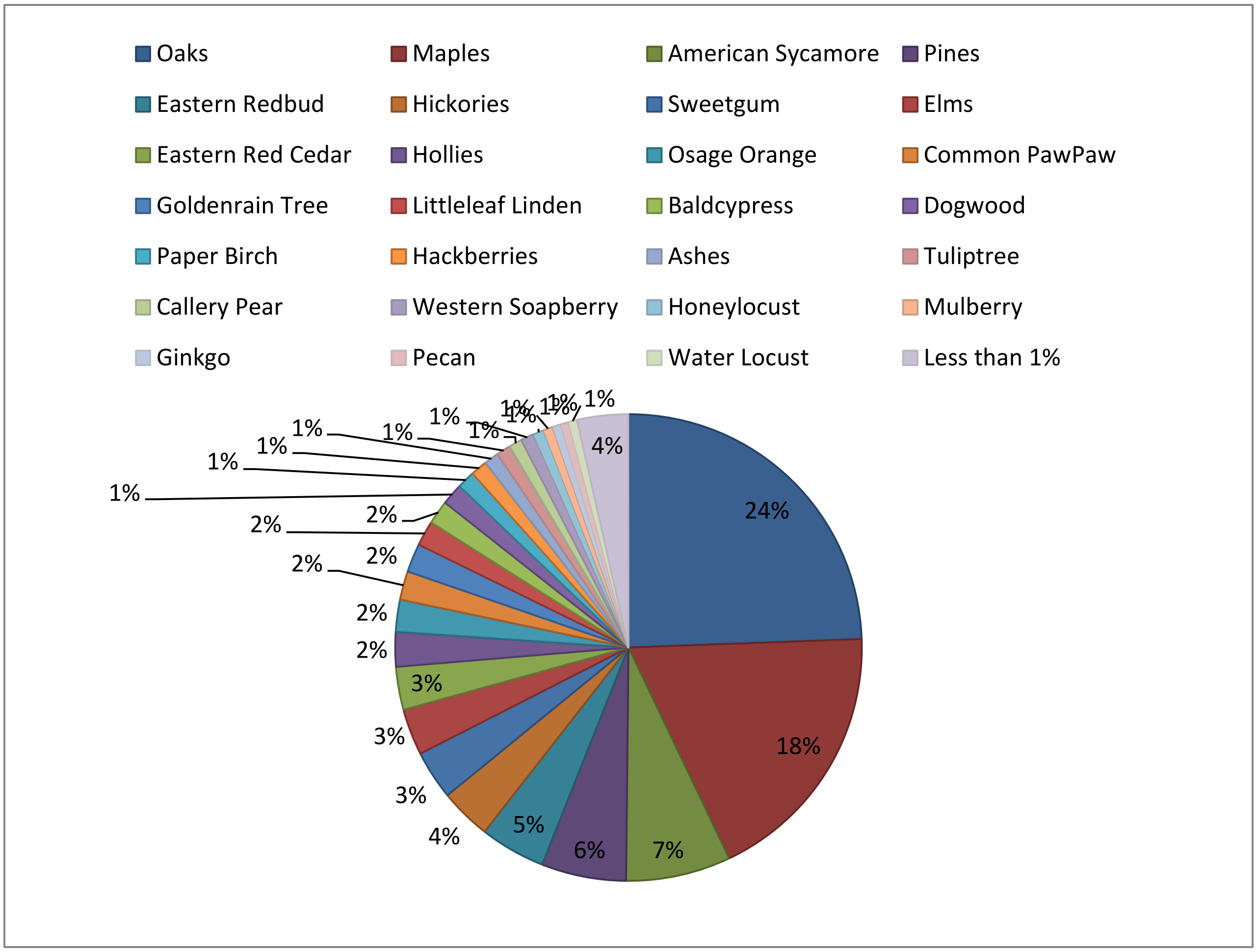


Figure 3. Complete Tree Species Composition of Surveyed Areas

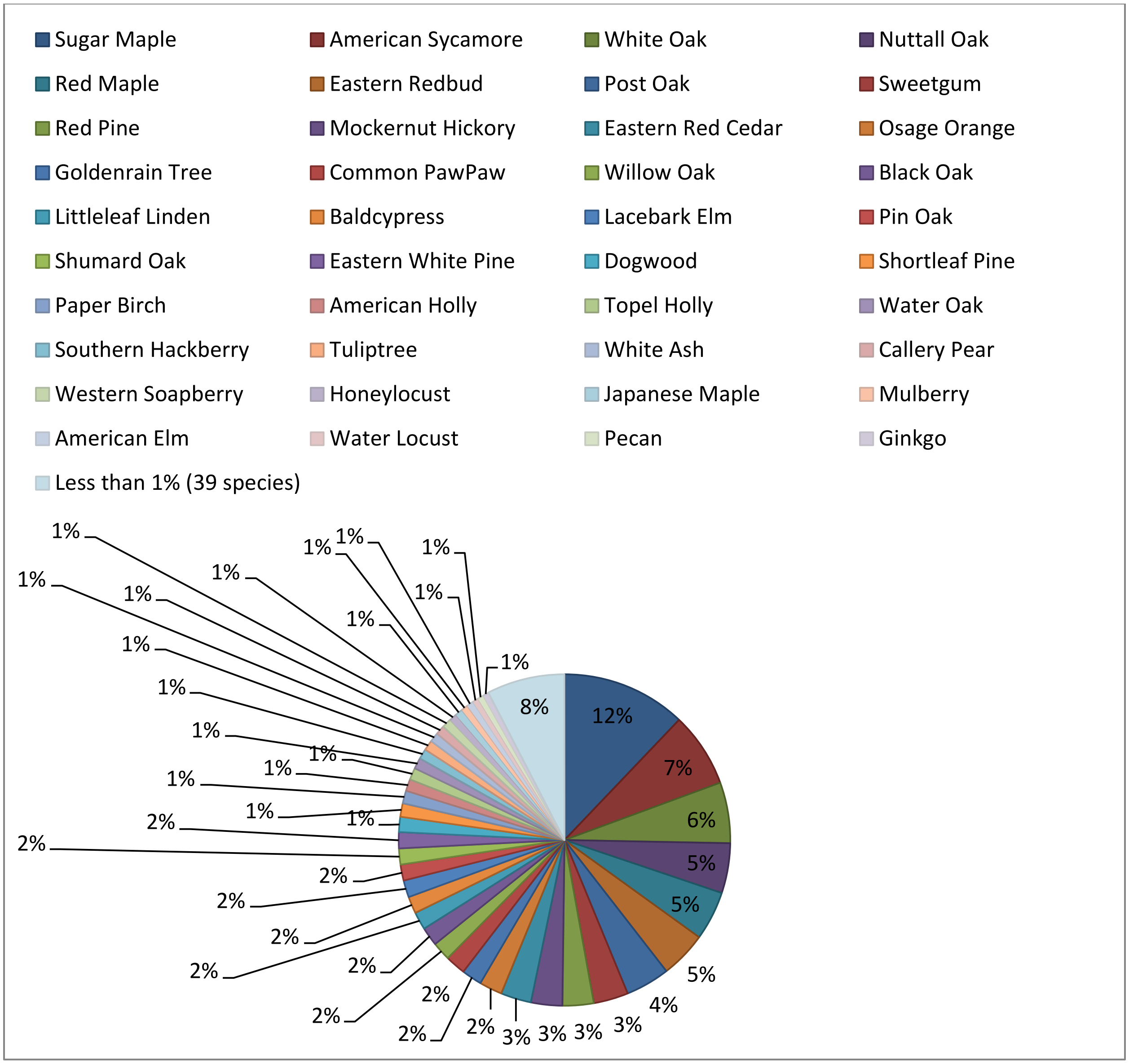


Figure 4. Species Composition of Total CO2 Stored in Surveyed Area

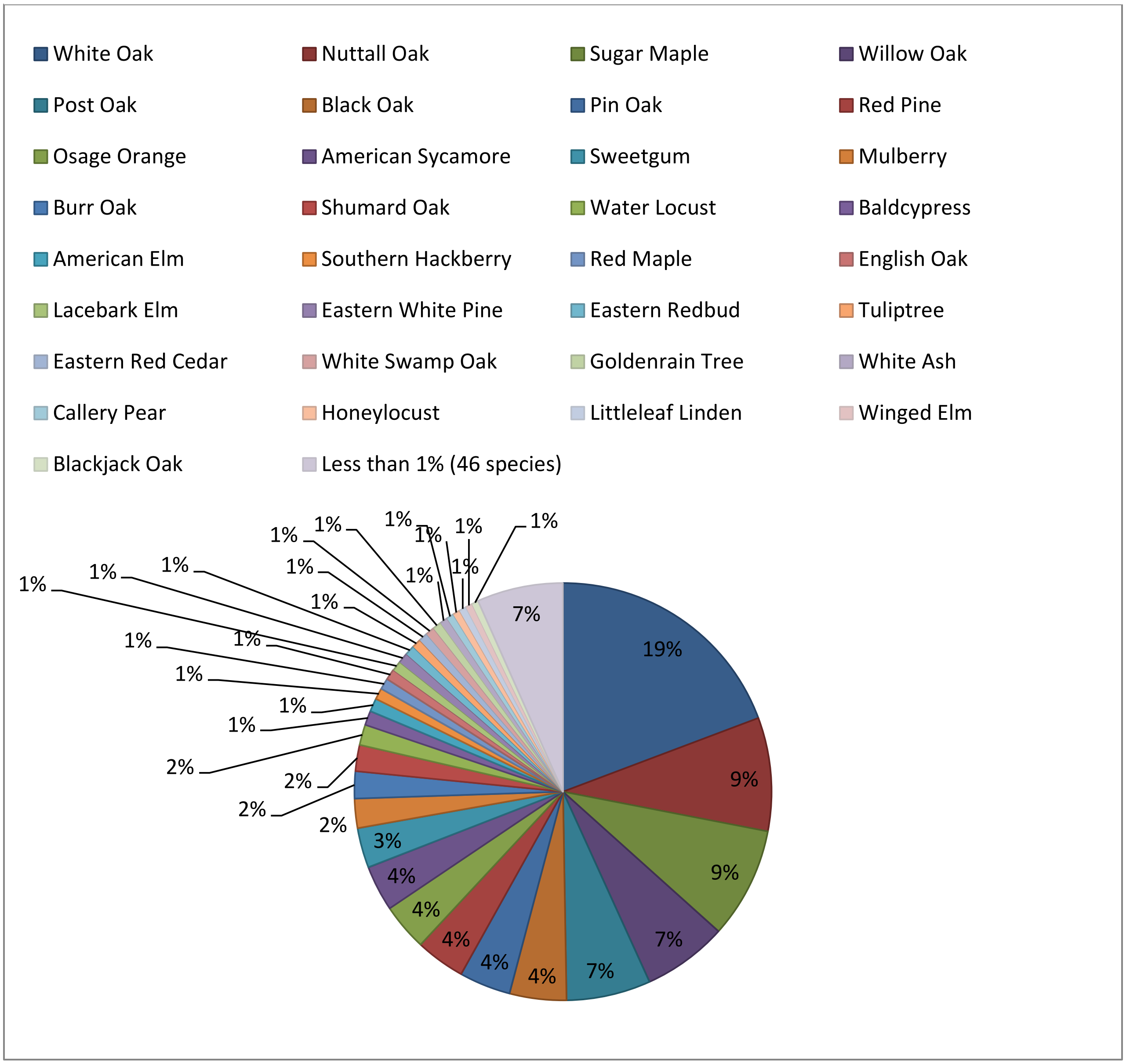


Figure 5. Species Composition of Total Aboveground Biomass in Surveyed Area

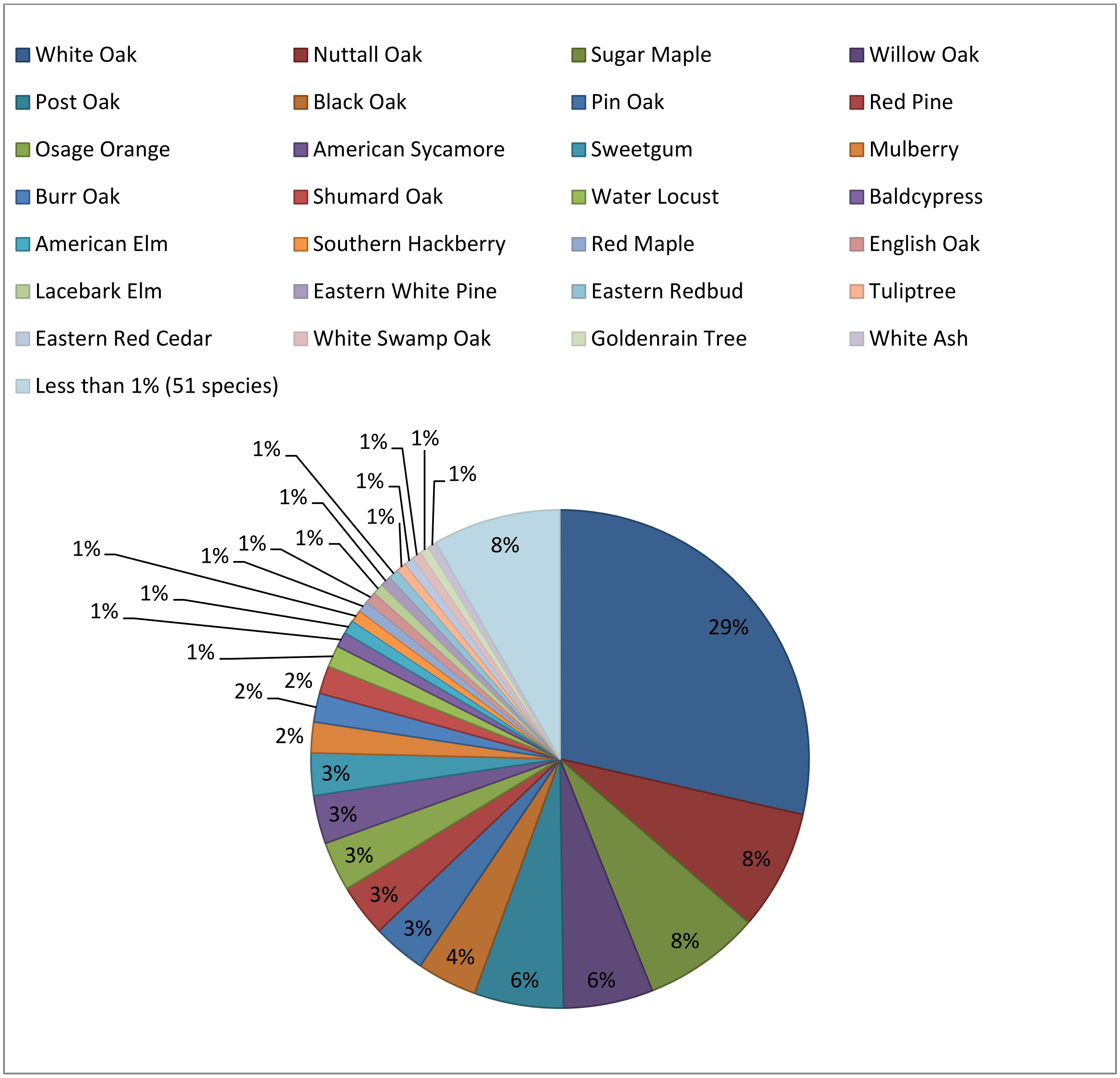


Figure 6. Average Aboveground Biomass, CO2 Storage, and Sequestration Rate of Individual Species

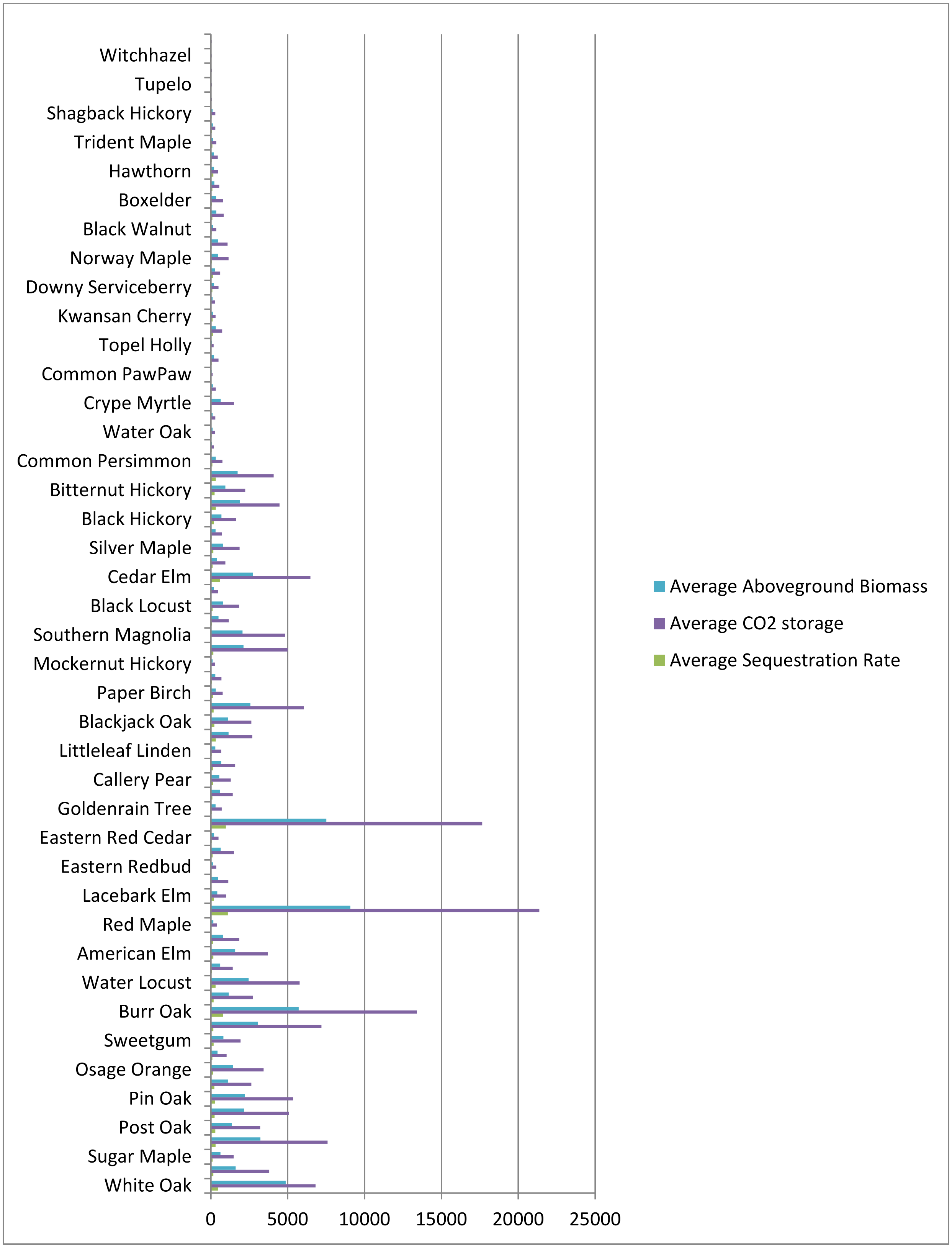


Figure 7. Urban Forest's Effects of the University's Carbon Emissions

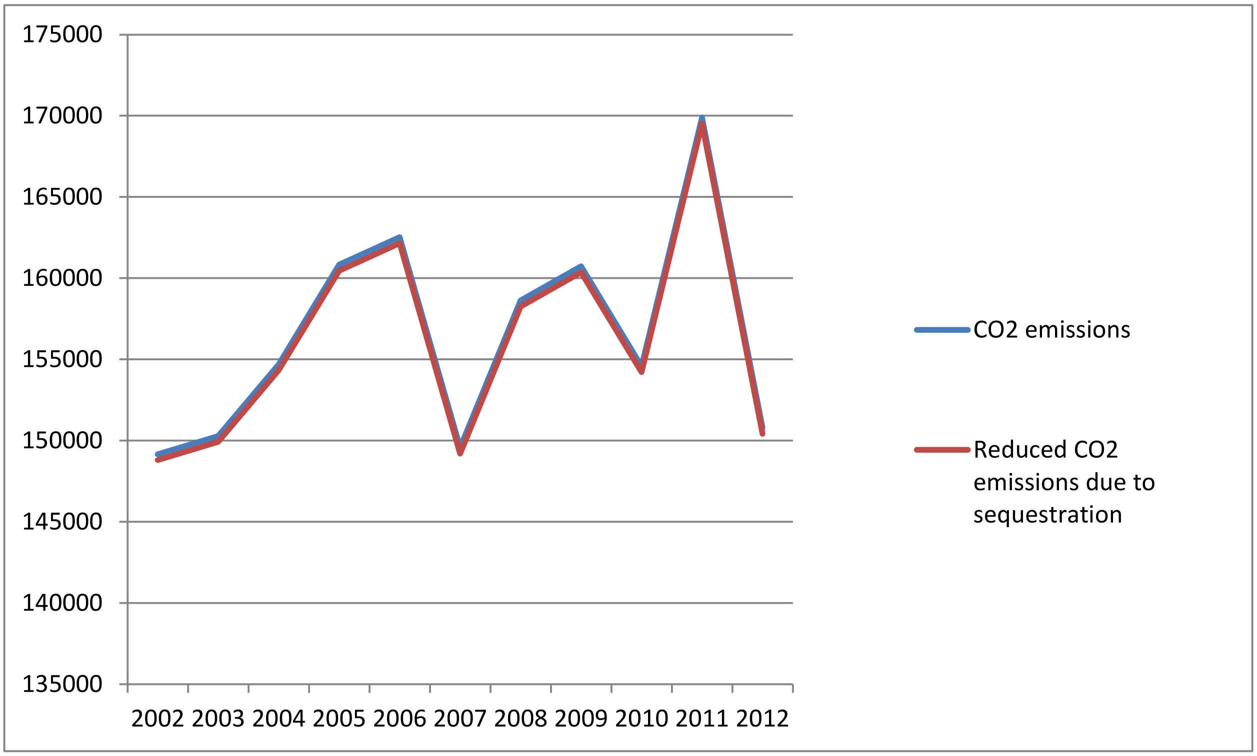
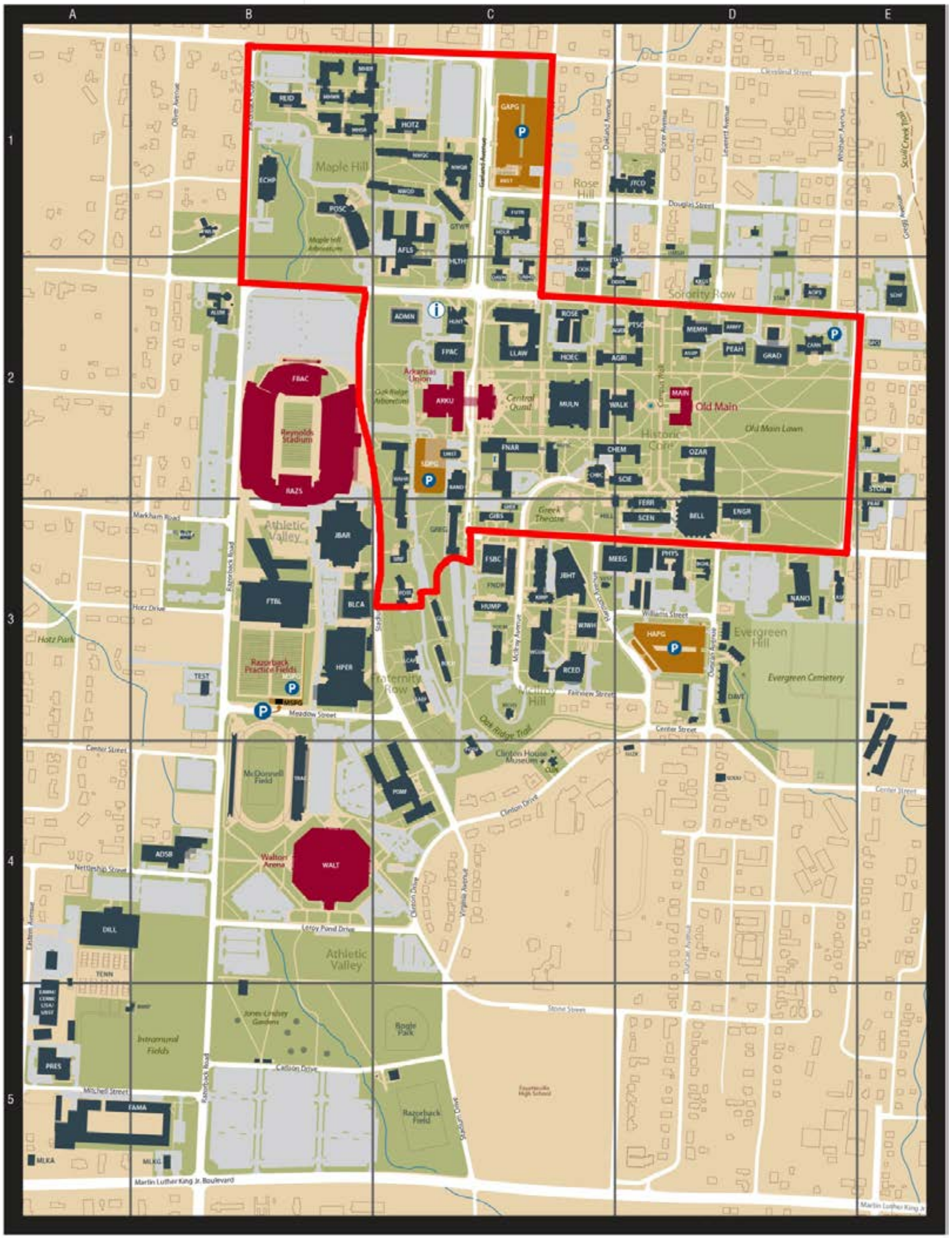


Figure 8. University of Arkansas campus, red indicated the survey area



Works Cited

Arbor day foundation tree guide database. (n.d.). Retrieved from http://www.arborday.org/trees/treeguide/index.cfm

Avila, Iris, and Alex Hardison. "Carbon Sequestration by Urban Forests on the University of Arkansas' Campus." (2013): 2-7. Print

Brown, N. R. (2009). *University of arkansas climate action plan*. (Sustainability Council Report, University of Arkansas)Retrieved from http://sustainability.uark.edu/University_of_Arkansas_Climate_Action_Plan.pdf

Coombes, A. J., & Debreczy, Z. (2010). *The book of leaves: A leaf-by-leaf guide to six hundred of the world's great trees*. Chicago: The University of Chicago Press.

CUFR Tree Carbon Calculator. US Forestry Service, (n.d.).

Meier, E. (n.d.). *The wood database*. Retrieved from http://www.wood-database.com/.

McPherson, E. G. (1998). Atmospheric carbon dioxide reduction by sacramento's urban forest. *Journal of Arboriculture*, *24*(4), 215-223.

Moore, D. (1999). *Trees of arkansas*. (5th ed.). Little Rock: Arkansas Forestry Commission.

Nowak, D., & Crane, D. (2002). Carbon storage and sequestration by urban trees in the usa.*Environmental Pollution*, *116*, 381-389.

Nowak, D., Stevens, J., Sisinni, S., & Luley, C. (2002). Effects of urban tree management and species selection on atmospheric carbon dioxide. *Journal of Arboriculture*, *28*(3), 113-122.

Sibley, D. (2009). *The sibley guide to trees*. (1st ed.). New York: Knopf Doubleday Publishing Group.

Sightlines.com, "Campus Sustainability." *Sightlines*. (n.d.). Retrieved from http://www.sightlines.com/what-we-do/campus-sustainability/

(2007). *Forest inventory and analysis national core field guide*. (4 ed., Vol. 1, pp. 70-77). US Forest Service, Department of Agriculture. Retrieved from http://www.fia.fs.fed.us/library/field-guides-methods-proc/docs/core_ver_4-0_10_2007_p2.pdf