Report on the Ecological Characteristics of the Old-Growth Forest Near Lane Stadium

Report Prepared by
A. Grace Steger
William C. Parrott

Data Collected By
A. Grace Steger
William C. Parrott
Moriah Moss
Jackson Helling
Guinevere Unterbrink

Virginia Tech Campus Planning, Infrastructure, and Facilities

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Executive Summary

Purpose

To establish a comprehensive inventory of all trees over 4 inches DBH and assess understory composition in the Old-Growth Forest near Lane Stadium, allowing comprehensive management of this forest as part of campus urban forest stewardship.

Results

View of the "Colbert Oak" and the northern edge of the forest.

- *Composition:* There are 1,711 trees over 4 inches DBH. 52 different species compose the overstory, and 70 unique woody species are present throughout all canopy layers. Sweet cherry, white oak, black locust, black oak, and black cherry are the most numerous species in the overstory. Sweet cherry constitutes the highest proportion of the overstory population by stem count (23.5%), while white oak constitutes the highest proportion of the population by basal area (49.9%). Black cherry, chokecherry, blackhaw, and ash are the most numerous native understory species, constituting 72% of the total population. The most commonly occurring invasive species in the understory are English ivy and Oriental bittersweet, both of which are present in 90% of the sample plots.

- *Ecosystem Services:* Carbon storage for the inventory totaled 1,016.51 tons at a value of $173,360.06, while annual carbon sequestration totaled 15.7 tons and $2,680 in value. The forest is also capable of attenuating 43,130 ft^3 of stormwater runoff per year for a total of $2,883.03 per year in runoff intercepted.

- *Replacement Value:* The trees in the Old-Growth Forest near Lane Stadium have a replacement value of $6.23 million.

Abstract

The Old-Growth Forest near Lane Stadium is an 11.3 acre fragment of a white oak late successional forest on Virginia Tech's campus. The forest contains dozens of trees that predate the university and thus carries significant historical, cultural, and ecological value. This project sought to provide a thorough description of the forest's characteristics and introduce a baseline by which it can effectively be managed. This was accomplished through a forest inventory and an ecological sampling assessment. The forest inventory involved manual collection of metrics related to tree health, structure, and dimensions on trees greater than or equal to 4 inches DBH, and this data was exported to *i-Tree Eco* to evaluate forest composition and ecosystem services. The ecological sampling assessment was performed through the establishment of 1/20th acre radial plots and observation of saplings, seedlings, overstory trees, standing and fallen dead stems, and invasive species presence. It was found that there are 1,711 living woody stems over 4 inches DBH and 70 different species of woody plants in the over- and understory, with white oak (*Quercus alba* L.), sweet cherry (*Prunus avium* L.), and black oak (*Quercus velutina* Lam.) being the most significant species regarding population density and service provision across the board. The replacement value of all overstory species in the forest amounted to $6.23 million. Additionally, the understory is primarily composed of ash (*Fraxinus spp.* L.), blackhaw (*Viburnum prunifolium* L.), and black cherry (*Prunus serotina* Ehrh.) saplings and seedlings. Several non-native species were commonly found in the overstory, including sweet cherry, Norway maple (*Acer platanoides* L.), and littleleaf linden (*Tilia cordata Mill.*), and Oriental bittersweet (*Celastrus orbiculatus* Thunb.) and English ivy (*Hedera helix* L.) were present in most of the understory.

Introduction

The Old-Growth Forest near Lane Stadium, colloquially referred to as "Stadium Woods," is a unique urban greenspace on Virginia Tech's campus. Located to the east of Lane Stadium and the Beamer-Lawson Indoor Practice Facility and to the west of a residential zone in the Town of Blacksburg (**Figure 1**), the forest is an 11.3 acre fragment of a white oak late successional forest that contains numerous trees well over 300 years old (Seiler, 2012). The forest provides ecological services including carbon sequestration, stormwater management, and soil stabilization, as well as cultural services, like opportunities for outdoor recreation and experiential education.

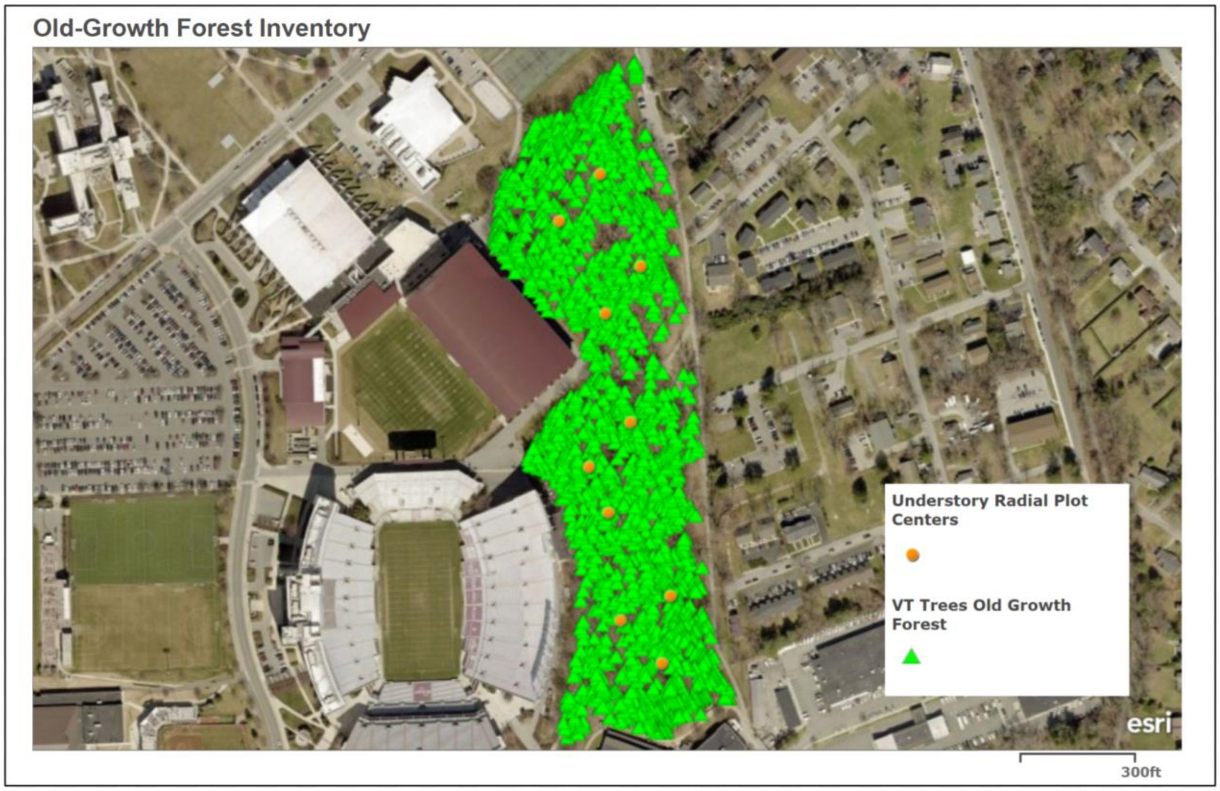


Figure 1. Map of the complete inventory of the Old-Growth Forest near Lane Stadium. Available to the public in Virginia Tech's *Campus Tree Inventory*.

Attention was called to the forest in 2012 when Virginia Tech Athletics proposed the construction of an indoor practice facility that would require significant degradation of the northern end of the Old-Growth Forest. Consequently, in 2012 an inventory of all trees greater than 12 inches diameter at breast height (DBH) was created in an initial effort to understand the quantity and quality of forest resources. It was found that the majority of the biomass consisted of white oaks that fell between the range of 289 to 464 years old at the time of measurement (Seiler, 2012). The inventory's efficacy was restricted by the technical limitations of the GPS used and the limited scope of the 12 inch DBH minimum. Despite this limitation, the 2012 inventory was important in establishing the forest as a place of historic, cultural, and ecological importance and opened the doors for efforts to conserve the forest, such as the development of a Stewardship Plan in 2016 and the hire of Urban Forest Manager and University Arborist Jamie King in 2019.

In 2021, under the supervision of Jamie King, a trial study was conducted to evaluate the scope and methods involved in the execution of a complete inventory of the Old-Growth Forest. Interns Jackson Helling, Grace Steger, and Ethan Apisa established 15 randomly-generated plots equal to 10% of the forest area. It was found that the forest consisted largely of white oak, black oak, and sweet cherry of varying sizes. Following this trial study, plans were set to conduct a complete inventory.

This project aims to develop a thorough profile of the forest's characteristics and values and introduce a baseline understanding by which it can effectively be managed. This was done through the creation of a complete inventory of all living trees over 4 inches DBH and the establishment of permanent radial plots to evaluate understory composition, standing and fallen woody debris, and invasive species presence. Once inventory data was collected, it was analyzed through the software *i-Tree Eco* in order to evaluate the composition of the forest as well as the services and value of the trees.

The following report provides a summary of the data collected in the Old-Growth Forest near Lane Stadium. The data is presented according to the method by which it was collected, starting first with the Complete Inventory and *i-Tree Eco* Report and continuing to the Ecological Sample Assessment.

Complete Inventory and *i-Tree Eco* Report

Methods

Criteria For Measurement

For a tree to be included in the inventory, it had to attain two criteria:

- Diameter at Breast Height (DBH): At a minimum, the DBH of at least one stem on a tree must be 4.0 inches or greater without rounding.

- Living Status: The inventory was to only include trees that were conclusively alive. "Alive" within this context indicated trees with full canopies to those with 95-99% dieback or missing—to the extent where regrowth was plausible. If a tree was completely dead or otherwise impaired to the point where rehabilitation was unrealistic, it was not included in the inventory.

A damaged sweet cherry deemed past plausible rehabilitation.

Data Collection

Data was collected in ESRI's mobile collection mapping application *ArcGIS Field Maps*. A GPS point was collected at each tree using a survey-grade, sub-meter GNSS receiver—the *Geode GNS2* developed by Juniper Systems—and stored in *Field Maps*. Residence time averaged approximately 5 minutes, consistently generating an accuracy between 0.5 to 3 feet. If accuracy was limited due to dense canopy cover or topographic challenges, positions of trees were manually entered relative to other points. For each tree, nineteen metrics were collected and stored for later integration into the complete campus tree inventory. These metrics include species identification, Tree ID, landscape status, native status, DBH, Total Height, Live Top Height, Base Height, North-South Crown Dimension, East-West Crown Dimension, Percent Crown Dieback, Percent Crown Missing, Health, Structure, Age Class, Percent Shrub Under Crown, Percent Impervious Under Crown, and Crown Light Exposure. They are defined as follows:

- Tree Identification: Trees were identified to the species-level when possible and to the genus-level when practical. Each tree was also assigned a Tree ID with the format OGF-X, where "OGF" stands for Old-Growth Forest and "X" is the number of the tree inventoried (e.g. the fiftieth tree logged will have an ID of OGF-50). Trees that were tagged for the 2012 inventory or for previously established permanent radial plots were marked with "Tagged: Y" or "Circle Tagged: Y" respectively in the comments, where "Y" is the number on the tag.

- Status: The tree was determined to be either a landscape (volunteer) or planted tree. Landscape trees are trees that are self-seeded and planted trees are those that were planted for aesthetics or other purposes. Trees were categorized according to their native status, indicated by the following labels: Native to VA, Native to US, Naturalized to US, and Non-native, non-naturalized. Species that are native to VA have ranges that fall within the borders of Virginia. Species that are Native to US do not have native ranges in Virginia but have ranges elsewhere in the United States. Naturalized species are non-native to the US but routinely establish within the ecosystem. Non-native, non-naturalized species are those that have yet to fully integrate into the ecosystem and originate from a point outside the United States.

- Diameter at Breast Height (DBH): The diameter of each stem was measured to the nearest inch with a diameter tape. DBH was measured at 4.5 feet from the base of the tree on the uphill side and measured adjacent to any irregularities, such as wounds or branches. Stems that split below 4.5 feet on the same tree were recorded as one tree with multiple stems, and up to 6 values of DBH were measured individually rather than summatively for any tree with multiple stems. In the cases of conditions that would put field technicians at risk of harm (e.g. poison-ivy, hanging limbs overhead), DBH was estimated ocularly and discussed until agreement, with "DBH Estimated" notated in the comments.

Field Technicians Grace Steger (right) and Moriah Moss (left) take measurements on a black locust.

- Crown Dimensions: A Nikon Forestry Pro II Laser Hypsometer, Bosch Professional GLM 50C Laser Rangefinder, and diameter tape were utilized to collect the dimensions of each tree's crown. Total Height was measured from the base to the highest point of the crown, *living or dead*, while Live Top Height was measured to the highest *living* point in the crown. Base Height was collected by either measuring to or ocularly estimating the height of the lowest *living* point, not including epicormic sprouts. Crown dimensions were recorded as lateral distances from North to South and East to West from the ground at the farthest points of the crown in each respective direction. If these dimensions were inaccessible from the ground (e.g. gates, private property), they were estimated and notated as such in the comments.

- Crown Condition: Crown condition was assessed based on the amount of dieback and missing present. Percent Crown Dieback is an estimate of the percent of the crown composed of dead branches. Only health-caused dieback was included in this assessment, which typically originates from the tips of branches and progresses inwards through the canopy. Shade-caused dieback from self-pruning or competition, which originates from the interior and lower branches, was excluded. Percent Crown Missing is an estimate of the percent of the crown that is not occupied by branches. For example, branches that have been torn off by a storm constitute a portion of crown missing. Both Percent Dieback and Missing were recorded as percentages on intervals of 5% (e.g. 0%, 1-5%, … 95-99%).

- Tree Condition: Specimens were assessed for the quality of their Health and Structure as well as their Age Class. Health and Structure were recorded on a 4-point scale of Poor, Fair, Good, or Excellent. Health was evaluated based on indicators such as crown dieback and disease, and structure was evaluated based on evidence of decay, extensive lean or uprooting, and portion of the crown missing. Age Class was guided by metrics of DBH, height, and species growth characteristics and recorded as Young, Immature, Mature, or Overmature.

- Ground Conditions: The percentage of woody understory cover that fell within the zone created by the drip line of a tree was marked as Percent Shrub Under Crown. Shrubs are defined here as woody plants including those that exclusively reach understory size (e.g. arching canes, spicebush [*Lindera benzoin* L.], blackhaw, etc.) as well as those that do reach overstory size (e.g. oak, ash, etc.) but are still Young, generally less than 8 feet tall and 2 inches diameter. Similarly, the percentage of impervious surfaces that fell within this area was recorded as Percent Impervious Under Crown. Impervious surfaces are ground cover types through which water cannot penetrate, including asphalt and heavily compacted gravel roads. These metrics were recorded as percentages by 5% intervals.

- Crown Light Exposure: The amount of direct light the crown received was measured using Crown Light Exposure using USFS methodology (Bechtold, 2003) and recorded as an integer value from 0-5. The value indicates the number of sides that a tree’s canopy is receiving direct light from; 0 indicates no direct overhead light, while 5 indicates it is receiving direct light from the top and all 4 sides.

Data Processing

To process the data, the program *i-Tree Eco* was utilized. *i-Tree Eco* is a peer-reviewed data-processing software used to conduct urban and rural forestry analysis and benefits assessment. *i-Tree* products were developed in a cooperative between the USDA Forest Service, Davey Tree Expert Co., National Arbor Day Foundation, Society of Municipal Arborists, International Society of Arboriculture and Casey Trees. The data collected in this study was input into *i-Tree Eco* as a complete inventory, and the software generated reports on forest structure, ecosystem services, and monetary values of those services. The stratum area was input as 14 acres due to the recording of trees on the periphery of the forest. The metrics used by *i-Tree* were User Tree ID (OGF-X), Survey Date, Status (Landscape/Planted), Species, DBH, Total Height, Crown Top and Base Heights, Crown Dimensions, Percent Crown Dieback, Percent Crown Missing, Latitude, Longitude, and Crown Light Exposure. After inputting the data and submitting for processing, the reports were generated.

Results

Forest Composition

A total of 1,711 trees of 52 unique species are inventoried in the Old-Growth Forest. Sweet cherry, white oak, and black oak make up 48% of the total species count, with the remaining majority being constituted of black locust (*Robinia pseudoacacia* L.), black cherry, red maple (*Acer rubrum* L.), flowering dogwood (*Cornus florida* L.), Norway maple, littleleaf linden, sassafras (*Sassafras albidum* (Nutt.) Ness), and black walnut (*Juglans nigra* L.). Forty-one other species are present in limited numbers, accounting for 3% or less of the total population per species, for a sum of approximately 13% of the inventory (**Figure 2**). The forest exhibits the diameter distribution of an uneven-aged stand. The size classes of the measured stems trend heavily towards 3-6 inches and 6-12 inches, and fewer stems up to 57 inches are present (See **Figure 3**).

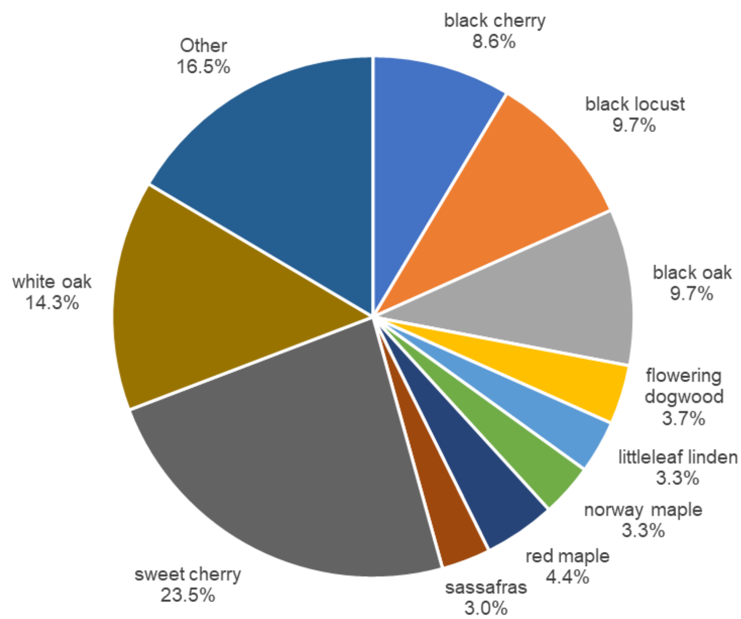
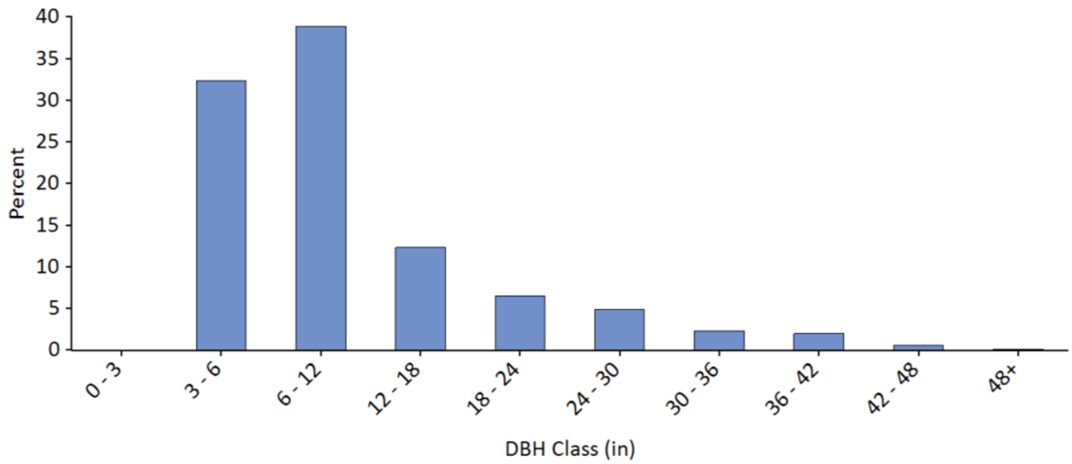


Figure 2. Species composition by stem count of trees greater than or equal to 4 inches DBH in the Old-Growth Forest near Lane Stadium.

By number, sweet cherry is the most common species in the forest, constituting 23.5% of the total population. It is followed by white oak and black oak, which make up 14.3% and 9.7% of the population respectively.

Figure 3. Diameter distribution of trees over 4 inches DBH in the Old-Growth Forest near Lane Stadium. Figure generated by i-Tree Eco.



White oak, black oak, and sweet cherry make up the greatest proportion of the leaf area and basal area (**Figure 4**), with summative percentages of 66.7% and 74.4% respectively. While sweet cherry is the most abundant species in the forest by number, white oak has the greatest total leaf area (39.8% of total) and basal area (49.9% of total) of all species.

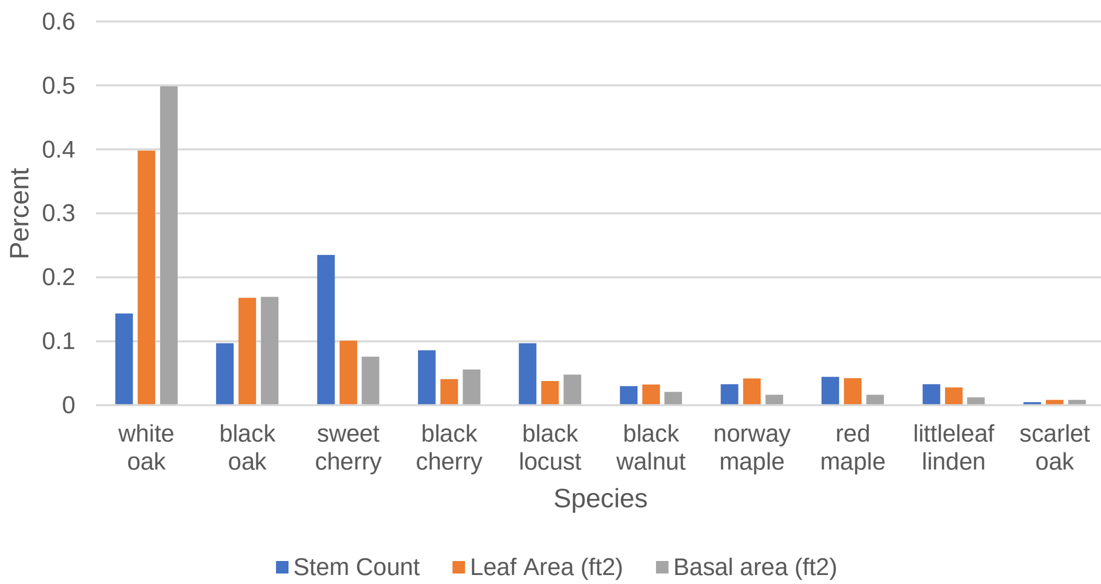


Figure 4. Forest composition in the Old-Growth Forest near Lane Stadium represented by proportion of total stem count, leaf area, and basal area and sorted by the ten species with the highest proportion of total basal area.

Within the forest, there are 532 non-native trees, or 31% of the total forest inventory. The majority of these trees are sweet cherry, followed by Norway maple, littleleaf linden, and Amur corktree as seen in **Figure 5**. Other non-native species include Chinese chestnut (*Castanea mollissima* Blume), atlas cedar (*Cedrus atlantica* Endl.), ginkgo (*Ginkgo biloba* L.), goldenrain tree (*Kelreuteria paniculata* Laxm.), callery pear (*Pyrus calleryana* Decne.), sawtooth oak (*Quercus acutissima* Carruth.), and chinese elm (*Ulmus parvifolia* Jacq.). Multiple non-native, non-naturalized trees are planted in a garden space on the north-west corner of the forest.

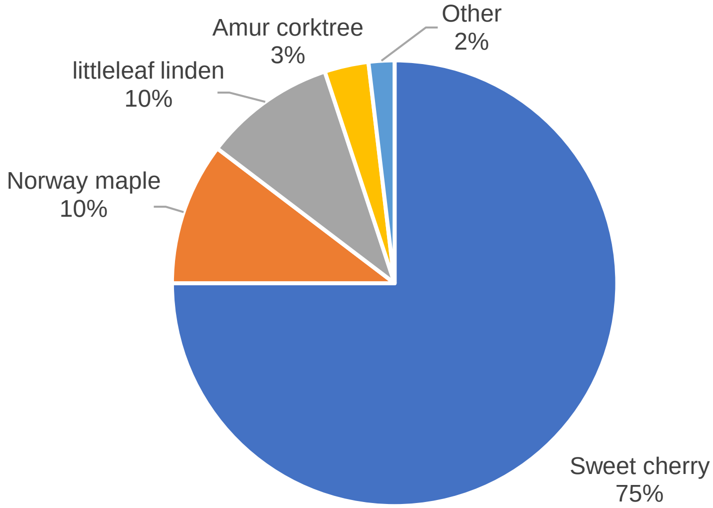


Figure 5. Composition of the population of non-native species in the Old-Growth Forest near Lane Stadium.

Wildlife Services

The Old-Growth Forest is a unique asset to wildlife compared to other areas on campus. Contrasted to most developed areas with hygienic landscapes which have sparse brush, few edible plants, and little attention to native flora for fauna's benefit, the forest boasts of a functional understory, tree species that provide a food resource, and regular invasive species removal. The i-Tree Eco assessment revealed that honeylocust (Gleditsia triacanthos L.), black walnut, red mulberry (Morus rubra L.), black locust, american basswood (Tilia americana L.), and littleleaf linden provide a resource to local fauna.

Eastern Towhee perched on an American elderberry.

Atmospheric Services

The Old-Growth Forest provides many atmospheric services including carbon storage and sequestration, oxygen production, and air pollutant filtration. i-Tree Eco categorizes the values of ecosystem services by replacement values and functional values. A replacement value is based on the tree itself, and a functional value is based on the functions the tree performs. Carbon storage is categorized as a replacement value, and is defined as the amount of carbon that has been stored in the tissues of a stem at a given moment. Carbon sequestration is a functional value and is defined as the annual rate at which carbon is stored. The *i-Tree Eco* analysis generated monetary values for both of these factors, as shown in **Table 1**. Both the carbon storage value and the carbon sequestration value are based on the economic damages associated with increases in carbon or carbon dioxide (CO_2) emissions. These values were calculated based on the rate of $170.55 per ton of carbon.

Table 1. Carbon and CO_2 Equivalent Storage and Sequestration for the highest storing species in the Old-Growth Forest near Lane Stadium.

Species	**Basal Area (ft^2)**	**Carbon Storage (tons)**	**CO2 Equivalent Storage (tons)**	**Carbon Storage Value ($)**	**Gross Carbon Sequestration (ton/yr)**	**CO2 Equivalent Sequestration (ton/yr)**	**Carbon Sequestration Value ($)**
white oak	964.7	567.19	2,079.9	96,734.25	4.5	16.5	767.48
black oak	328.3	211.11	774.1	36,004.81	3.35	12.29	571.34
sweet cherry	147.1	60.32	221.2	10,287.58	1.9	6.98	324.05
black cherry	107.9	48.65	178.4	8,297.26	1.56	5.72	266.06
black locust	92.4	27.95	102.5	4,766.87	1.12	4.1	191.02
black walnut	39.9	9.3	34.1	1,586.12	0.34	1.25	57.99
norway maple	31.8	13.71	50.3	2,338.24	0.45	1.65	76.75
red maple	31.6	11.7	42.9	1,995.44	0.54	2	92.10
littleleaf linden	23.4	6.34	23.3	1,081.29	0.22	0.81	37.52
scarlet oak	16.1	8.61	31.6	1,468.44	0.19	0.7	32.40

For the forest, carbon storage for the inventory totaled 1,016.51 tons at a value of $173,360.06, while annual carbon sequestration totaled 15.7 tons and $2,680 in value. White oak constitutes the highest portion of carbon storage at 53.4%, followed by black oak and sweet cherry. White oak is also responsible for 28.7% of the carbon sequestration in the forest, taking in 4.5 tons of carbon per annum, equivalent to 16.5 tons of CO_2.

The forest population produces 41.9 tons/yr, or 2.99 ton/acre/yr, of oxygen. On average, 16.41 lbs of carbon monoxide (CO), 55.99 lbs of nitrogen dioxide (NO_2), 927.04 lbs of ozone (O_3), 170.98 lbs of particulate matter between 2.5 and 10 microns in diameter (PM10), 26.51 lbs of particulate matter less than 2.5 microns in diameter (PM2.5), and 85.53 lbs of sulfur dioxide (SO_2) are removed per annum. In total, this comes out to a yearly average of $1,839.75 saved in mitigation costs. As seen in **Figure 6**, the removal of ozone is the most significant of the pollutants removed.

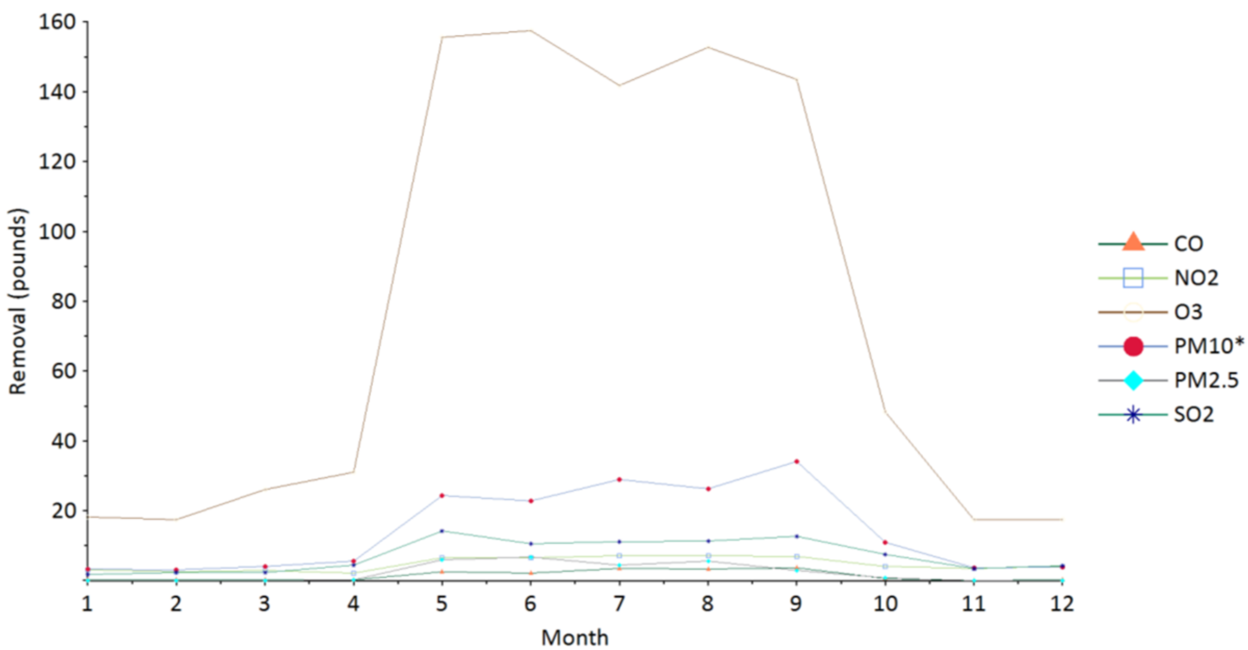


Figure 6. Removal of air pollutants by month in the Old-Growth Forest near Lane Stadium. Figure generated by i-Tree Eco.

Stormwater Benefits

The Old-Growth Forest provides several benefits for stormwater management, most notable of which is stormwater runoff avoidance. At present, the forest is capable of attenuating 43,130 ft^3 of stormwater runoff per year. This totals $2,883 per year in runoff intercepted which would otherwise need to be managed by gray infrastructure. As seen in **Table 2**, 66.7% of the runoff avoided and related value consists of three species: white oak, black oak, and sweet cherry.

Table 2. Tree species with the most significant impact on avoided runoff in the Old-Growth Forest.

Species	Avoided Runoff (ft^3/yr)	Avoided Runoff Value ($/yr)
White oak	17,177.62	1,148.25
Black oak	7,246.53	484.40
Sweet cherry	4,341.37	290.20
Total	43,129.57	2,883.03

Susceptibility to Pests and Disease

i-Tree Eco calculates the ecological and economic damage that a potential outbreak of a pest or disease may inflict, based on species diversity in a population. Of the ailments present or plausible to be introduced in Virginia in the near future, those which have the highest potential impact on total leaf area in the Old-Growth Forest are included in **Table 3.** These threats are all categorized as primary pests or diseases, meaning that the threat is not caused by a previous disease or injury but could be exacerbated by abiotic stressors. Primary stressors each have individual characteristics, means of spread, and impact on host populations, therefore demanding individual mitigation strategies.

Table 3. The plausible impacts of diseases and pests on the Old-Growth Forest Near Lane Stadium

Pest Species	Leaf Area (%)	Most Susceptible within Old-Growth Forest	Category of Pest/Disease	Replacement Value ($)
Spongy Moth	61.9	Oak	Defoliating Insect	4,686,308.00
Oak Wilt	58	Oak	Vascular Disease	4,557,076.00
Asian Longhorned Beetle	11.5	Ash, Elm, Maple	Bark Beetle / Wood Borer	302,629.00
Laurel Wilt	0.8	Sassafras	Vascular Disease	36,633.00
Sudden Oak Death	0.5	Oak, Blackhaw	Fungal Disease	18,379.00
Emerald Ash Borer	1.1	Ash	Bark Beetle / Wood Borer	33,231.00

Not listed in this table are secondary stressors, which follow and are exacerbated by other stressors. Hypoxylon is a fungal disease that attacks vulnerable trees, often in decline due to abiotic stress. It was identified in the field by the University Arborist and field technicians on snags, fallen dead stems, and living trees. The infection of dominant old-growth white oaks indicates the presence of external stressors, which may include soil compaction from mechanical and foot traffic; an increase in runoff and associated damages from adjacent development; and the presence of primary pests and disease.

For both primary and secondary pests and disease, limiting abiotic stress will reduce vulnerability to biotic disease. The more immediately management actions are executed to reduce abiotic stressors, the greater the likelihood of successful preservation.

Replacement Value

Replacement value calculated by *i-Tree Eco* is the compensatory cost of replacing a tree with a similar tree. This calculation is based on the size of the tree, thus the replacement value of a healthy tree increases over time as the tree grows. This metric is useful for communicating the economic implications of the loss of a tree, however this sum does not include or account for carbon storage value, functional values, or intrinsic values of a tree.

Collectively, the trees in the Old-Growth Forest near Lane Stadium have a replacement value of $6.23 million.

Limitations

As previously stated, estimations were necessary to protect field technician safety and comply with access limitations across gated property. As such, 3.7% (65) of the DBH values and 0.005% (8) of other values such as Crown Dimensions were estimated ocularly and then discussed until agreement by three field technicians. Due to the subjective nature of estimations such as Percent Missing, Dieback, or Shrub, it is possible that there are minute variations in collected values. The frequency of these errors likely decreased as the collection continued due to the improving assessment and collaboration skills of field technicians. Finally, there are GPS points within the inventory map that are less accurate due to terrain and canopy density restricting the accuracy of the *Geode*.

Ecological Sample Assessment

Methods

Plot Establishment

Ten permanent radial plots, each with an area of 1/20th acre (26.2 foot radius), were established to estimate the ecological characteristics of the forest. The general locations of the sample plots were scattered uniformly throughout the old-growth forest and the specific plot centers were determined randomly, without the use of a grid system or any set procedure, to ensure an even representation of the population. No plots were established within one chain (66 ft) of the forest edge, a structure, or another plot.

Field technician William Parrott placing a tag on a plot center.

A steel rebar stake and a PVC sleeve were driven at each plot center and tagged with a numbered aluminum label corresponding with the number of the sample plot, numbered sequentially from 101 to 110. A GPS point was collected at each plot center using the *Geode GNS2* and stored in *ArcGIS Field Maps*, and the coordinates of each plot center area listed in the Appendix.

Data Collection

Six metrics were collected within each 1/20th acre sample plot: overstory trees, saplings, seedlings, presence of invasive species, standing dead stems, and fallen dead stems.

- Overstory Trees: Every tree over 3.5 inches DBH within 26.2 feet of the plot center, measured from the pith, was recorded as an overstory tree. On trees with multiple stems, stems over the diameter minimum that originated below 4.5 feet were recorded as separate trees. DBH to the nearest 1/10th inch and total height to the nearest foot were measured for all trees. If the tree was included in the complete inventory, Tree ID and total height were extrapolated from the inventory data.

- Saplings: Stems above 1 inch and less than 3.5 inches DBH were categorized as saplings and tallied by species. Measured at the base from the pith, all saplings originating within 26.2 feet of the plot center were recorded. Stems over the diameter minimum that originated below 4.5 feet were recorded as separate saplings. Invasive species were accounted for separately and thus were excluded from this category, as were arching canes (*Morus* spp., etc.) and all non-woody species.

- Seedlings: Three 1/1000th acre sub-sample plots (3.72 foot radius) were temporarily established within each sample plot, and seedlings were counted within. Sub-sample plot centers were placed 6.6 feet from the center of the 1/20 acre sample plot, distributed around the center at 120 degree angles (N 0°, ESE 120°, WSW 240°). Seedlings were defined as woody plants above 10 inches tall and less than 1 inch in diameter measured at the base. Stems were tallied from the base by species, if the pith originated within 3.72 feet of the sub-sample plot center. Invasive species were excluded, except those that can reach overstory size, of which there were no occurrences. Also excluded were arching canes and non-woody species.

- Invasive Species: The presence of any woody invasive species was recorded in each sample plot. This list was developed initially to include the most common invasive understory species in the study's geographic area and was updated throughout data collection if another species was identified.

- Standing Dead Stems: Snags with a minimum height of 4.5 feet and a minimum DBH of 3.5 inches (4 inches rounded) were recorded as standing dead stems in each sample plot. For each dead stem originating below 4.5 feet, recordings were taken for DBH measured to the nearest inch, height measured to the nearest foot, and species if determinable. Dead stems of living trees were included in this metric.

- Fallen Dead Stems: Woody debris at least 4 inches in diameter laying on the ground within the sample plot was tallied as a fallen dead stem. DBH was ocularly estimated to the nearest inch and recorded for each stem. If a root collar was evident, diameter was estimated at 4.5 feet along the stem; otherwise, diameter was estimated at the largest point along the stem occurring in the plot. If the stem was not entirely within the sample plot, diameter was only estimated along the portion of the stem that fell within.

Results

Overstory Trees

Seventeen species constitute the overstory of the ecological sample of the Old-Growth Forest (**Table 4**). Relative composition of the overstory differs between total basal area per acre and total trees per acre by species (**Figure 7**). By trees per acre, the majority of the overstory population is constituted of sweet cherry, white oak, black oak, and black cherry, in order of abundance.

Table 4. Composition and characteristics of overstory trees from an ecological sample of the Old-Growth Forest near Lane Stadium.

Species	BA/Ac (ft^2)	Trees Per Acre	Average DBH (in)	Average Height (ft)
White Oak	62.8	16	26.6	89.1
Sweet Cherry	14.3	40	7.3	40.1
Black Oak	14	16	10.3	50.5
Black Walnut	10	6	16.6	71.7
Black Cherry	6.9	16	8.2	36.6
Red Maple	4	8	9.2	45.8
Flowering Dogwood	1.5	10	5.2	26.8
Norway Maple	1	4	6.8	41
Sassafras	1	8	4.7	33.8
Black Maple	0.8	2	8.4	53
Littleleaf Linden	0.7	4	5.5	25.5
Downy Serviceberry	0.5	4	4.8	41
Blackhaw	0.3	4	3.9	19
Ash	0.2	2	4.4	38
Black Gum	0.2	2	3.9	29
Total	118.1	142	8.4	42.7

However, white oaks functionally act as the dominant species of the overstory, constituting 53.2% of the total basal area per acre of all trees, followed by sweet cherry, black oak, and black walnut. Recorded values of DBH ranged from 3.5 inches to 34.6 inches, with an average of 8.4 inches. Recorded height ranged from 17 to 100 feet, with an average value of 42.7 feet.

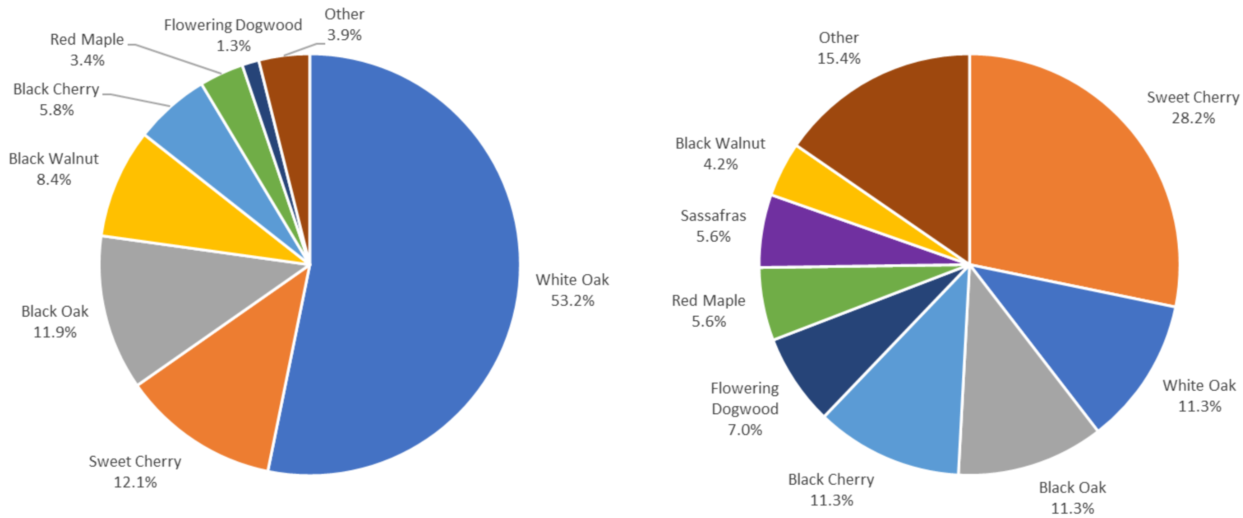


Figure 7. Proportion of total basal area per acre (left) and total trees per acre (right) by species in the overstory of the Old-Growth Forest near Lane Stadium averaged from ecological sampling.

Saplings and Seedlings

A total of 26 unique species are recorded in the ecological survey of the understory of the Old-Growth Forest. 25 species are found in the sapling size class with blackhaw and ash being the most numerous species respectively, constituting 54.9% of the total population. 16 species are found in the seedling size class; black cherry, blackhaw, and ash are the most numerous respectively, constituting 72% of the total population (**Table 5**).

Regeneration of hickory (*Carya spp.* (Poir.) Nutt) and American chestnut (*Castanea dentata* (Marsh.) Borkh.) were noticed during data collection but fell outside of the geographic bounds of the sample areas; these species are not included in the understory analysis. Oak regeneration is present but notably lesser than its relative abundance in the overstory. Black oak is found in the seedling size class, but white oak and northern red oak are absent. Ash constitutes a much higher proportion of the understory than the overstory population.

Table 5. Average population of saplings and seedlings per acre by species in the Old-Growth Forest.

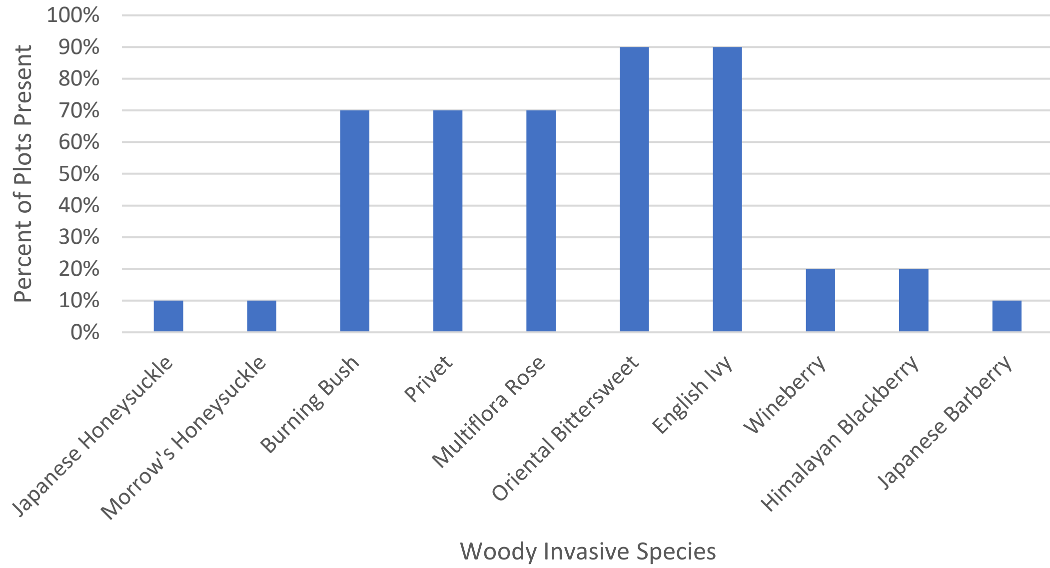
Species	Saplings Per Acre	Seedlings Per Acre
Boxelder	28	0
Norway Maple	24	200
Red Maple	28	33
Sugar Maple	6	67
Downy Serviceberry	16	33
Flowering Dogwood	10	67
Hawthorn	0	167
Ash	126	733
Honeylocust	4	0
Witch Hazel	4	33
American Holly	4	0
Spicebush	8	100
Black Gum	8	0

Species	Saplings Per Acre	Seedlings Per Acre
Amur Corktree	4	0
Sweet Cherry	28	300
Black Cherry	48	1967
Choke Cherry	50	233
White Oak	4	0
Northern Red Oak	2	0
Black Oak	8	67
Pink Azalea	2	0
Sassafras	26	200
American Elderberry	12	300
American Basswood	4	0
Littleleaf Linden	10	0
Blackhaw	286	1933

Invasive Species

Ten woody invasive species are present in the Old-Growth Forest (**Figure 8**). The most commonly occurring species are English ivy and Oriental bittersweet, both of which are present in 90% of the sample plots. Closely following are burning bush (*Euonymus alatus* (Thunb.) Siebold), privet (*Ligustrum spp.* L.), and multiflora rose (*Rosa multiflora* Thunb.), which occur in 70% of the plots. Other species present are Japanese honeysuckle (*Lonicera japonica* Thunb.), Morrow's honeysuckle (*Lonicera morrowii* A. Gray), wineberry (*Rubus phoenicolasius* Maxim), Himalayan blackberry (*Rubus armeniacus* Focke), and Japanese barberry (*Berberis thunbergii* DC.).

Figure 8. Percentage of sample plots with invasive species present in the Old-Growth Forest near Lane Stadium.



Standing and Fallen Dead Stems

As seen in **Table 6**, black locust is the most common species of standing dead stem, followed by sweet cherry. On average, the tallest standing dead stems are black oak snags. There is an average of 3.8 standing dead stems and 84 fallen dead stems per acre. The average diameter of a standing dead stem is 9.1 inches and the average height is 24.5 feet. The average diameter of a fallen dead stem is 8.7 inches.

Table 6. Characteristics of Standing Dead Stems from an ecological sample of the Old-Growth Forest

Species	Average Standing Dead Trees Per Acre	Average Height (ft)	Average DBH (in)
Black Locust	8	15.5	5.88
Sweet Cherry	6	30	7.07
Black Oak	4	45.5	9.5
Sassafras	4	31	7.35
Black Cherry	2	14	7.5
Ash	2	27	6.2
Boxelder	2	9	3.6
White oak	2	24	26
Total	3.8	24.5	9.1

Limitations

There are a few instances of potential variation in data as well as a few notes on the placement of the surveyed area. In Plot 104, a live littleleaf linden whose base was outside of the plot fell so that its crown was within the plot. The tree and its branches were not included in the plot data, but it influenced the ecology and structure of the understory, consuming light and space. In Plot 108, the WSW sub-sample area coincides with an informal trail, and a formal trail crosses through a portion of Plot 110. In both of these instances, recorded woody vegetation was reduced. The data collected on invasive species is not an estimate of the amount of vegetation present, but only a record of presence or absence of the species in each plot. Lastly, because the radial sample plots were placed one chain away from the edge of the forest, understory composition around the periphery of the forest is underrepresented in this analysis. From the observations of field technicians, the periphery and especially the eastern edge of the forest had a denser understory.

Conclusion

The population of the Old-Growth Forest near Lane Stadium is diverse, sporting 70 unique woody species and 1,711 individual trees over 4 inches DBH. The overstory is largely composed of white oak, sweet cherry, and black oak, and these three species are crucial actors in the services that the forest provides. Norway maple and littleleaf linden, two non-native, non-naturalized species, are present in the overstory. The understory is largely composed of blackhaw, black cherry, chokecherry, and ash, and regeneration of oak species is present but limited. Oriental bittersweet and English ivy, among other invasive woody understory species, have a large presence within the forest understory.

The forest holds a replacement value of $6.23 million and provides several services that benefit the surrounding area, including atmospheric services like carbon sequestration and storage, stormwater services like runoff attenuation, and wildlife services like habitat and food. The Old-Growth Forest is a unique site at Virginia Tech that will appreciate in value and services over time if managed properly, a trait that few other sites on campus can claim.

Appendix – Radial Plot Center Locations

Radial Plot Number	**Latitude**	**Longitude**
101	37.222988N	80.416457W
102	37.222017N	80.416406W
103	37.222345N	80.416102W
104	37.222662N	80.416817W
105	37.221257N	80.416195W
106	37.220945N	80.416551W
107	37.220623N	80.416381W
108	37.220035N	80.415840W
109	37.219564N	80.415916W
110	37.219864N	80.416820W

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