GIS APPLICATIONS IN URBAN TREE INVENTORY

by

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PROJECT PAPER submitted to the Faculty of the

Virginia Polytechnic Institute and State University

in partial fulfillment of the requirements for the degree of

MASTER OF FORESTRY

in

Forestry

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August 9, 2007
Blacksburg, Virginia

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Keywords: Urban tree inventory, GIS, CITYgreen, i-Tree

GIS Applications in Urban Tree Inventory

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(Abstract)

This project evaluates and demonstrates some applications of a GIS-based urban tree inventory. This was done by (1) collecting and analyzing data for Tinker Air Force Base (AFB), and (2) collecting and evaluating data for the Virginia Tech campus tree inventory. The urban tree inventory at Tinker AFB was estimated using remote sensing techniques that included the use of the eCognition 3.0 software. Inventory data was collected using a handheld computer and transferred to a desktop for data backup and analysis. Data was evaluated for urban forest structure and composition. The data collected for Tinker AFB was additionally analyzed for potential runway obstacles. CITYgreen software was used to determine tree canopy coverage and i-Tree STRATUM was used to compare against CITYgreen. Both CITYgreen and i-Tree are very useful tools for urban foresters, the purpose of the inventory should direct which software is utilized. An urban tree inventory provides a baseline to work from, facilitates management decisions, and provides a basis for future evaluation.

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Acknowledgements

This project would not have been possible without the help of many people. Thank you all for your helpful hands/minds and lending me your time. I would like to thank the following people:

Virginia Tech Department of Forestry
Steve Prisley
Eric Wiseman
Randy Wynne

Conservation Management Institute at Virginia Tech
Jessica Dorr
Laura Hendrick
Beth Pokorski
Pamela Swint

Tinker Air Force Base and Outside Contractors
Brian Gilliam
Emily Haney
John Krupovage
Jennifer McCanne
Raymond Moody
Brett Weigel

1. Introduction

An urban forest may be defined as the sum of all woody and associated vegetation in and around dense human settlements. More specifically this includes all street trees, park trees, residential trees, and greenbelt trees (Miller 1997). The people living in and around urban forests receive many direct and indirect benefits, such as the cooling effect of strategically placed trees around a house or the reduced costs of stormwater management (Konijnendijk et al. 2005). An inventory is an important and often overlooked step, in effectively managing urban forests, or any resource for that matter (Grey et al. 1992; Miller 1997). Inventories provide a baseline to work from, facilitate management decisions, and provide a basis for future evaluation of management efforts.

There are several considerations to be made before an urban tree inventory is conducted. First, the goal or purpose must be decided upon. This should clearly identify the trees of interest and why. The purpose of the inventory will direct what type of information is collected (Wood 1999). Second, the inventory type must be chosen. Inventories can be sample, partial, or complete. A sample inventory usually only looks at 5 to 25% of the entire urban forest and provides general forest information but not specifics on individual trees. Partial inventories can be spatial or temporal. If only trees in a certain area or a particular kind of tree are of interest then a spatial inventory can be used. If a complete inventory is done, but over a period years then the inventory is temporal. A complete inventory is done when every tree, area or management unit is inspected (Coder 1996). Third, the data collection method must be chosen. Will staff be performing direct measurements on the tree or will they collect their information from the vehicle (windshield survey)? Will they be recording information on paper or digitally? Information can also be gathered using ground or aerial photography. Will the inventory be continuously or periodically updated?

Geographic information systems (GIS) can assist urban forest professionals in the management of urban forests (Wood 1999) by allowing rapid and accurate mapping as well as easy access to tree data to keep it up to date (Kane et al. 1998; Widdicombe et al. 1999). Wood (1999) mentions CITYgreen, a GIS-based software program, as a potential management tool for the entire urban forest. CITYgreen can estimate stormwater reduction costs and energy savings for a locality. This is further emphasized in the urban ecosystem analysis done for Roanoke, Virginia by American Forests, which found that the urban forest annually removes 5.9 million pounds of air pollutants for an annual benefit of $14, 579, 297 (American Forests 2002). Using the information provided by CITYgreen, city managers can set appropriate canopy cover goals and justify spending for urban forestry programs.

The goal of this project was to evaluate and demonstrate some applications of a GIS-based urban tree inventory. This was accomplished by (1) collecting and analyzing data for Tinker Air Force Base (AFB), and (2) collecting and evaluating data for the Virginia Tech campus tree inventory.

1.1. Project Background

1.1.1. CMI and Tinker Air Force Base

Established in 2000, the Conservation Management Institute (CMI) is a research center within the College of Natural Resources at Virginia Tech. It was established to help address multi-disciplinary research questions that affect conservation management effectiveness within Virginia as well as around the United States. CMI allows faculty from Virginia Tech and other research institutions to collaborate on projects ranging from endangered species propagation to natural resource-based satellite imagery interpretation (CMI 2007).

Tinker AFB is located 8 kilometers southeast of downtown Oklahoma City, in central Oklahoma, Oklahoma County. Tinker AFB land area is approximately 4398 acres, oriented 6 (north-south) by 5 (east-west) kilometers. The major land area is a 4 (north-south) by 2.5 (east-west) kilometer airfield with two runways running north-south and northwest-southeast (Figure 1).

Land managers at Tinker AFB had a basic knowledge of their urban trees, but desired more thorough data on the structure, function, and management needs of urban trees within their boundaries. The urban forest structure is the extent, location, and composition of the tree population, while function refers to the environmental, social, and economic benefits of urban trees. This information will allow land managers to make knowledgeable decisions regarding the management of individual trees as well as the overall urban environment at Tinker AFB.

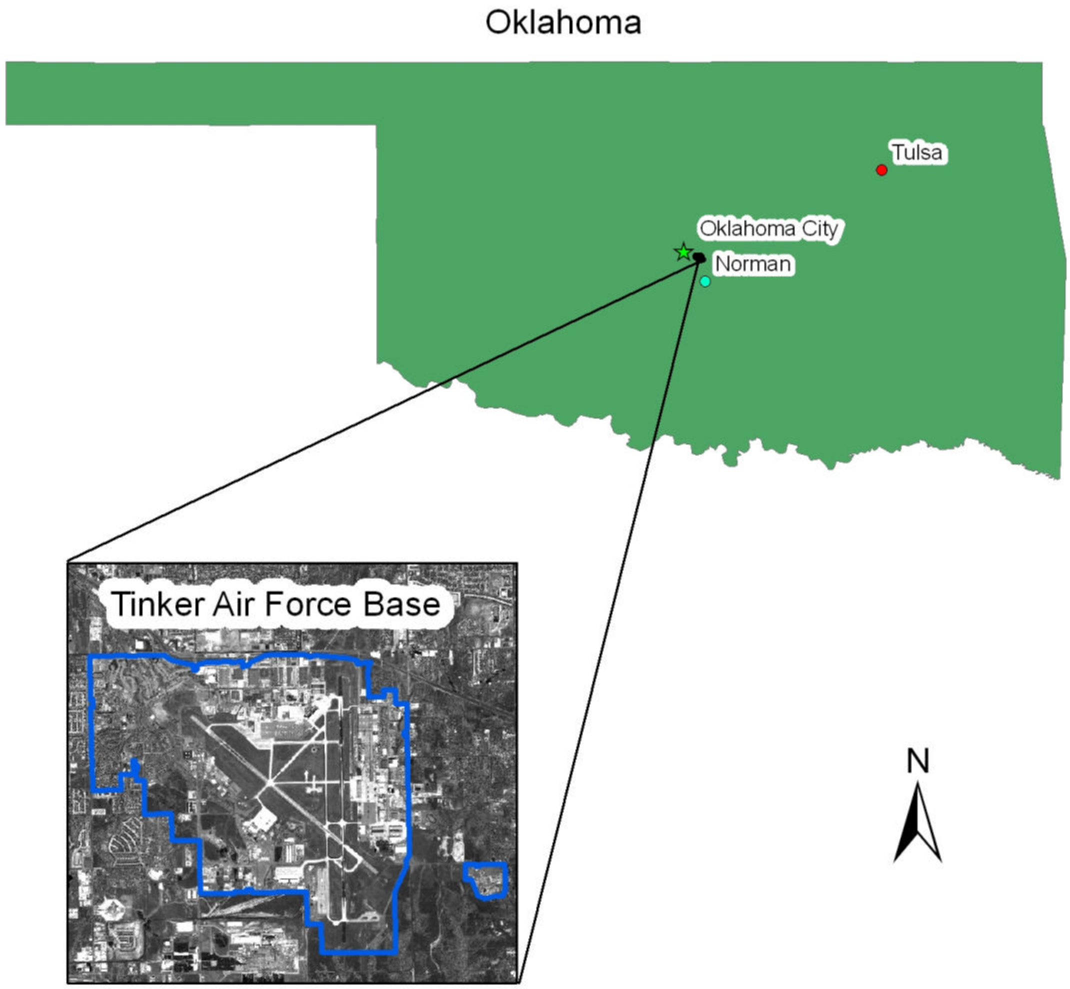

Figure 1: Tinker Air Force Base is located east of Oklahoma City, in central Oklahoma.

The overall objective of this component of the project was to support the revision of the Integrated Natural Resource Management Plan (INRMP) at Tinker AFB using fieldwork and GIS/GPS technologies. This overall objective was partially fulfilled through a complete, base-wide urban tree inventory. This inventory identified and characterized all trees in order to manage the urban forest at Tinker AFB more effectively and efficiently, with an aim towards improving overall forest condition. This in turn should improve environmental quality and ultimately contribute to a higher quality of life for Tinker's personnel.

For purposes of a base-wide urban tree inventory, the urban forest at Tinker AFB is defined as primarily street and park trees that are located on improved and semi-improved grounds, not including small volunteer saplings. Trees located in unimproved grounds or that occur as groupings with dense understory vegetation are considered "tree stands" for identification purposes and individual tree measurements were not required in these areas.

Once the data were collected, they were analyzed for flight path encroachment, used in a CITYgreen analysis (American Forests, Washington, DC), and used as input into i-Tree STRATUM (i-Tree, Kent, OH). The air force has restrictions on the allowable heights of objects near runways. Using the guidelines provided by Tinker AFB personnel, the trees within predetermined zones around the runways at Tinker AFB were analyzed for their allowable heights. It was determined whether they were exceeding their allowable height and by how much or the amount they could grow before they reached their allowable height.

The data were analyzed with CITYgreen to compute the amount of tree canopy cover for the base. The CITYgreen software allows users to perform an urban ecosystem analysis (UEA). A UEA, based on the assessment of ecological structures (land use and land cover) of a selected area, measures a localities' tree canopy cover and calculates the urban forest's ecological benefits (American Forests 2002). The study area usually corresponds to a municipality or community boundary. The CITYgreen software runs as an extension on ArcView (ESRI Inc., Redlands, CA). Using CITYgreen as a planning tool can help communities make smarter planning decisions.

Lastly, a portion of the data was input into the i-Tree STRATUM program to perform a comparison with CITYgreen. i-Tree is a computer software package that provides urban forest inventory and analysis tools. The Street Tree Resource Analysis Tool for Urban-Forest Managers (STRATUM) component within i-Tree was selected for this project. This allows managers to describe tree management needs as well as quantify the dollar value of annual environmental and aesthetic benefits such as energy conservation, air quality improvement, CO_2 reduction, stormwater control, and property value increases. i-Tree is in the public domain and therefore is a free product available by request through the i-Tree website. Through a cooperative partnership between the USDA Forest Service, the Davey Tree Expert Company, the Society of Municipal Arborists and the National Arbor Day Foundation, i-Tree is being disseminated and training and technical support are being offered (i-Tree 2006).

1.1.2. Virginia Tech Campus Tree Inventory

Virginia Tech is located in Blacksburg, VA (Figure 2) and has 2600 acres with more than 100 buildings. Over 32,000 faculty, staff, and students work, live, and study on the campus. The goal of this component of the project was to develop a GIS database for Virginia Tech's urban forest to better understand the extent and composition of this resource. This data will be used as a teaching tool for students learning tree biology as well as arboriculture. It will also be a resource for the biology, forestry, and horticulture programs at Virginia Tech as well as a database for the maintenance and management of the urban forest. This has provided urban forestry students with hands-on experience in conducting a tree inventory. This component has not yet been completed; existing data will be presented.

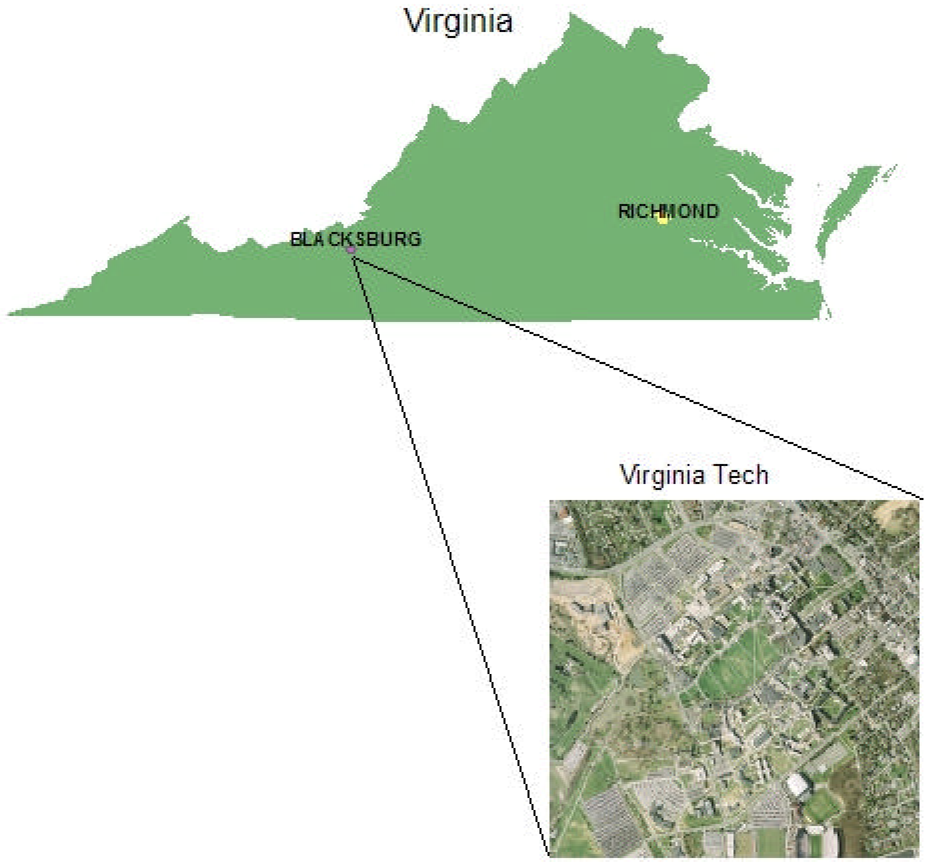

Figure 2: Virginia Tech is located in the town of Blacksburg in western Virginia.

2. Methods

2.1. Tinker AFB – Methods and Data collection

The Tinker AFB inventory was performed under contract, so many attributes were pre-determined. An estimate of the number of urban trees at Tinker AFB was made using high resolution multispectral imagery (DigitalGlobe 2005). We analyzed this imagery to provide a baseline of the number of urban trees for the planning of fieldwork and to examine novel techniques in the remote sensing of urban trees (Cooke III et al. 2004). There were 4,432 urban tree segments identified using eCognition (Definiens Inc., Munich, Germany) with a total area of 295,396 square meters. We created a point layer from the middle of the segments, which was used to plan and prioritize for the subsequent tree inventory.

Several data collection, storage, and analysis systems were analyzed for possible use with this project. A perfect prepackaged system was not available at the time of inventory, so we created an ArcPad form to streamline data collection. Where appropriate, pick-lists were used. A potential list of tree attributes was compiled based on literature review (Bond et al. 2006) and consultation with urban forestry professionals. The final list of attributes was selected based on informational needs for urban forest management and technical/logistical constraints of the inventory. The following attribute data were collected for each urban tree at Tinker AFB:

1) Geographic location from high resolution digital orthophotography (Tobin International 2004) and/or field computer with ±15 meter GPS unit
2) Scientific and common names
3) Diameter at breast height (DBH)
4) Tree height
5) Crown radius
6) Age Class
7) Condition
8) Soil/root problems (could pick up to 3 most applicable)
9) Trunk problem (could pick up to 3 most applicable)
10) Crown problem (could pick up to 3 most applicable)
11) Conflict – The tree is in direct conflict with one of the following or breached the required clearance (could pick up to 3 most applicable), clearances were provided by Tinker AFB personnel
12) Pruning Priority
13) Pruning Type
14) Hazard rating
15) Notes – additional information deemed important: tree guard, poison ivy, staking, etc.

The majority of field measurements were performed in summer 2006. Field data collection was completed in December 2006. The urban forestry point data were exported to Microsoft Excel (Microsoft Corporation, Redmond, WA) to produce summarization tables and figures. To more easily manage the urban forest, Tinker AFB was divided into 27 Urban Forest Management Units (UFMU) (Figure 3). Data are presented for both the entire base and for individual UFMUs.

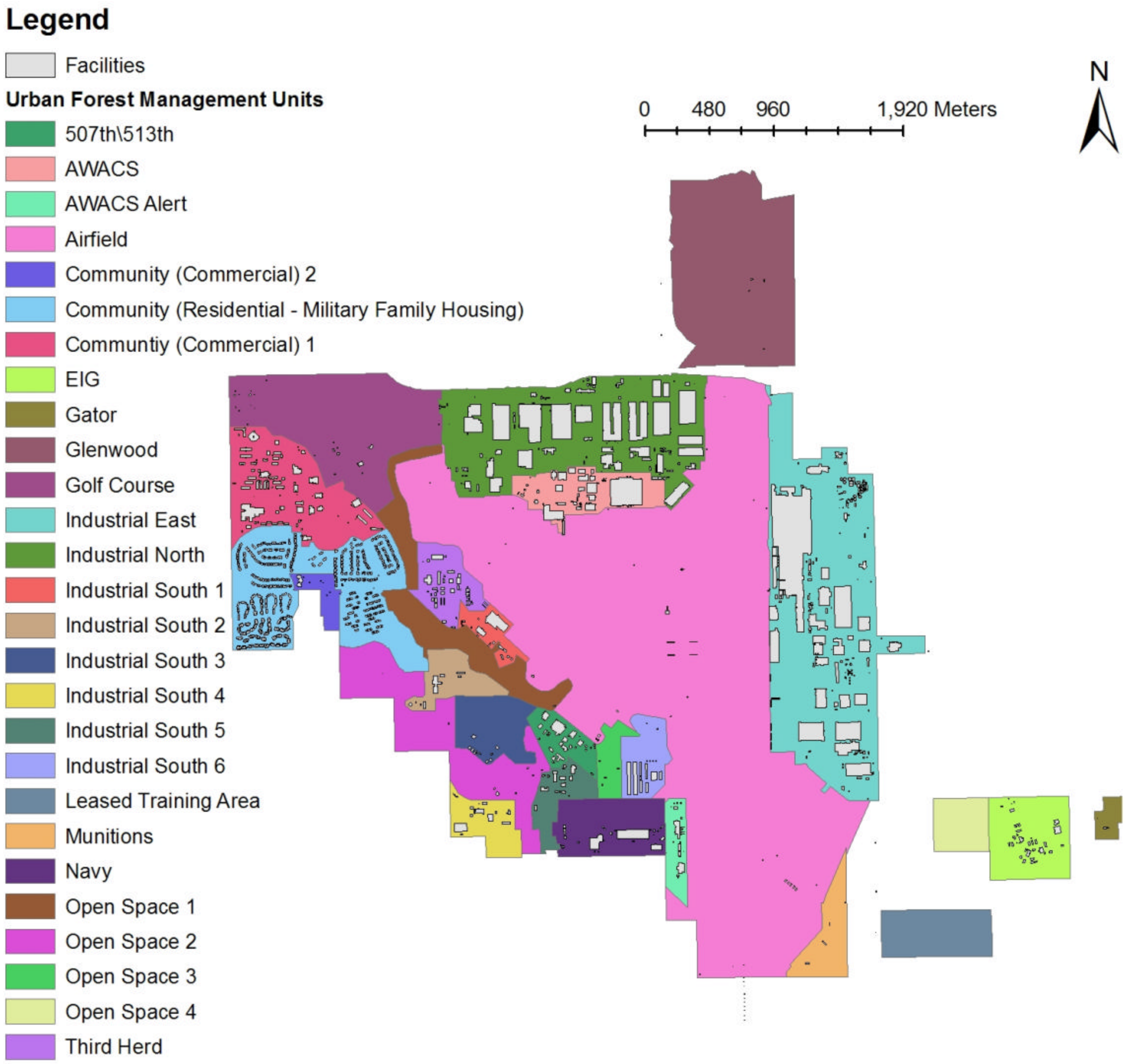

Figure 3: Tinker Air Force Base is divided into 27 Urban Forest Management Units.

2.1.1. Remote Sensing

An estimate of the number of urban trees at Tinker AFB was obtained using high resolution multispectral imagery (DigitalGlobe 2005). We explored this to provide a baseline of the number of urban trees for the planning of fieldwork and to examine novel techniques in the remote sensing of urban trees (Cooke III et al. 2004).

Traditionally, classification is performed with the pixel as the sampling unit. Unfortunately, pixels may not actually represent real objects on the ground and can make it difficult to identify where the edges of the pixel exist on the ground. A new technique, object-based classification, allows the analyst to create objects that represent real ground objects. Object-based classification was used to identify individual tree crowns in Scotland (Suárez et al. 2005). They used the software program eCognition to segment homogenous areas within the forest. The program has also been used to delineate individual tree crowns in Queensland, Australia (Bunting et al. 2006). van Aardt (van Aardt et al. 2006) used eCognition for the segmentation of structurally homogeneous groups of trees as opposed to individual trees.

We used eCognition 3.0 to identify urban trees at Tinker AFB. Using the LiDAR (light detection and ranging) digital terrain model (DTM) and digital elevation model (DEM), a digital surface model (DSM) was created by subtracting the DEM from the DTM. Figure 4 shows the DSM, which supplies the heights for all structures on the ground, including tree heights as well as building heights. We also created a vegetation index (VI), (Figure 5) for the area using ERDAS Imagine software (Leica Geosystems Geospatial Imaging, Norcross, GA) and the multispectral imagery (DigitalGlobe 2005). A vegetation index quantitatively measures biomass or vegetative vigor (University of Arizona 2004), in this case using the simple ratio, near infrared band / red band.

We located individual trees from a segmentation performed in eCognition. The segmentation was a combination of the original multispectral image, the DSM, and the VI. After the trees were segmented and classified they were exported to ArcGIS 9.1 (ESRI Inc., Redlands, CA) shapefile format, resulting in a layer with trees represented as polygons. We referenced the polygons against the 0.25-meter resolution digital orthophotography (Tobin International 2004). Individual polygons that were not trees were removed and if they had multiple features for a single tree they were merged. Only trees that were in the appropriate vegetation areas were included. The areas of interest were identified as improved turf, paved/built areas, and urban woodland from the 2005 vegetative communities map (Dorr et al. 2005). We created a point shapefile to represent each feature and found coordinates by referencing the points with the high-resolution orthoimagery (Figure 6).

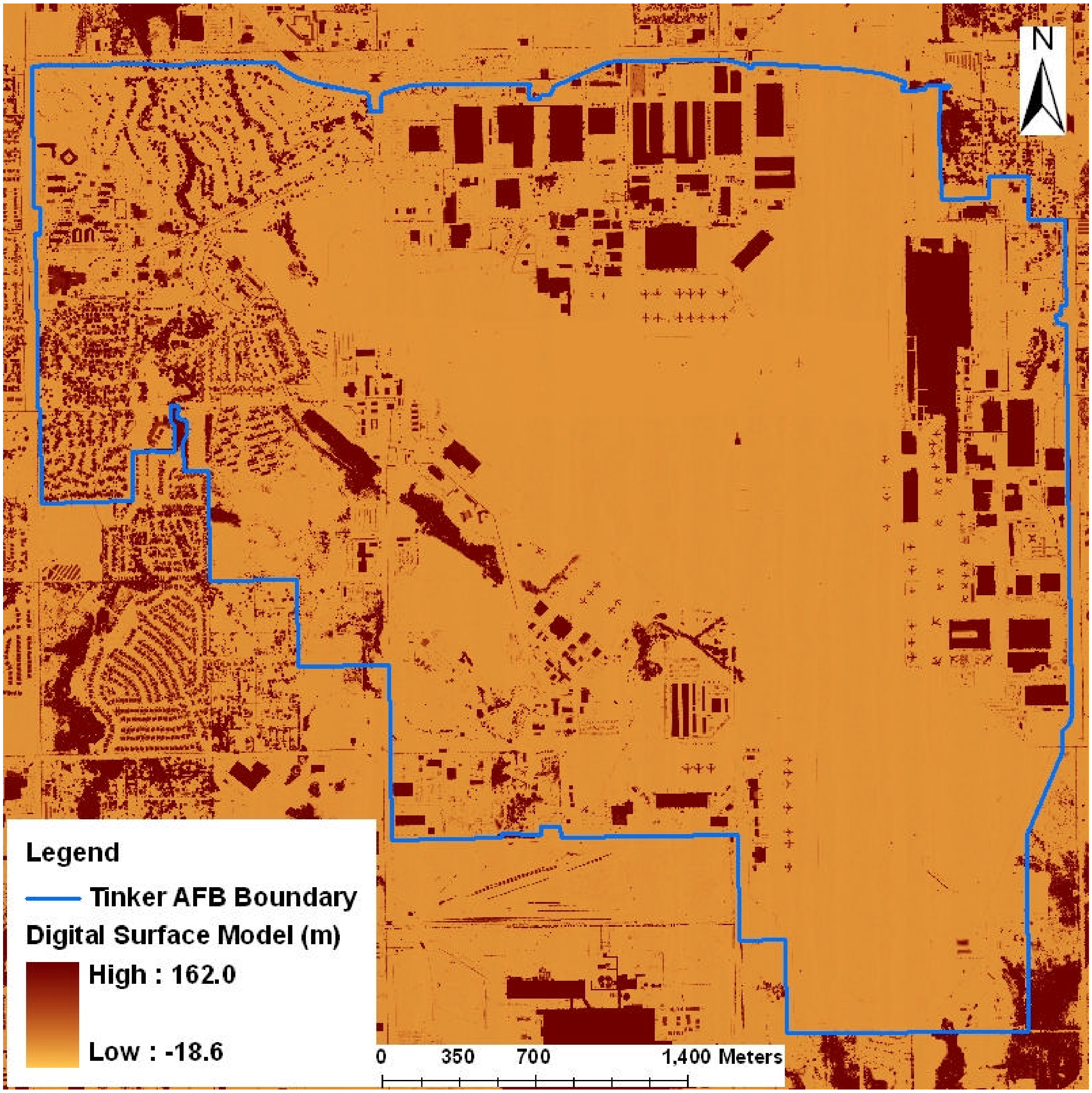

Figure 4: A digital surface model (DSM) was created for Tinker Air Force Base and the surrounding area by subtracting the digital elevation model (DEM) from the digital terrain model (DTM).

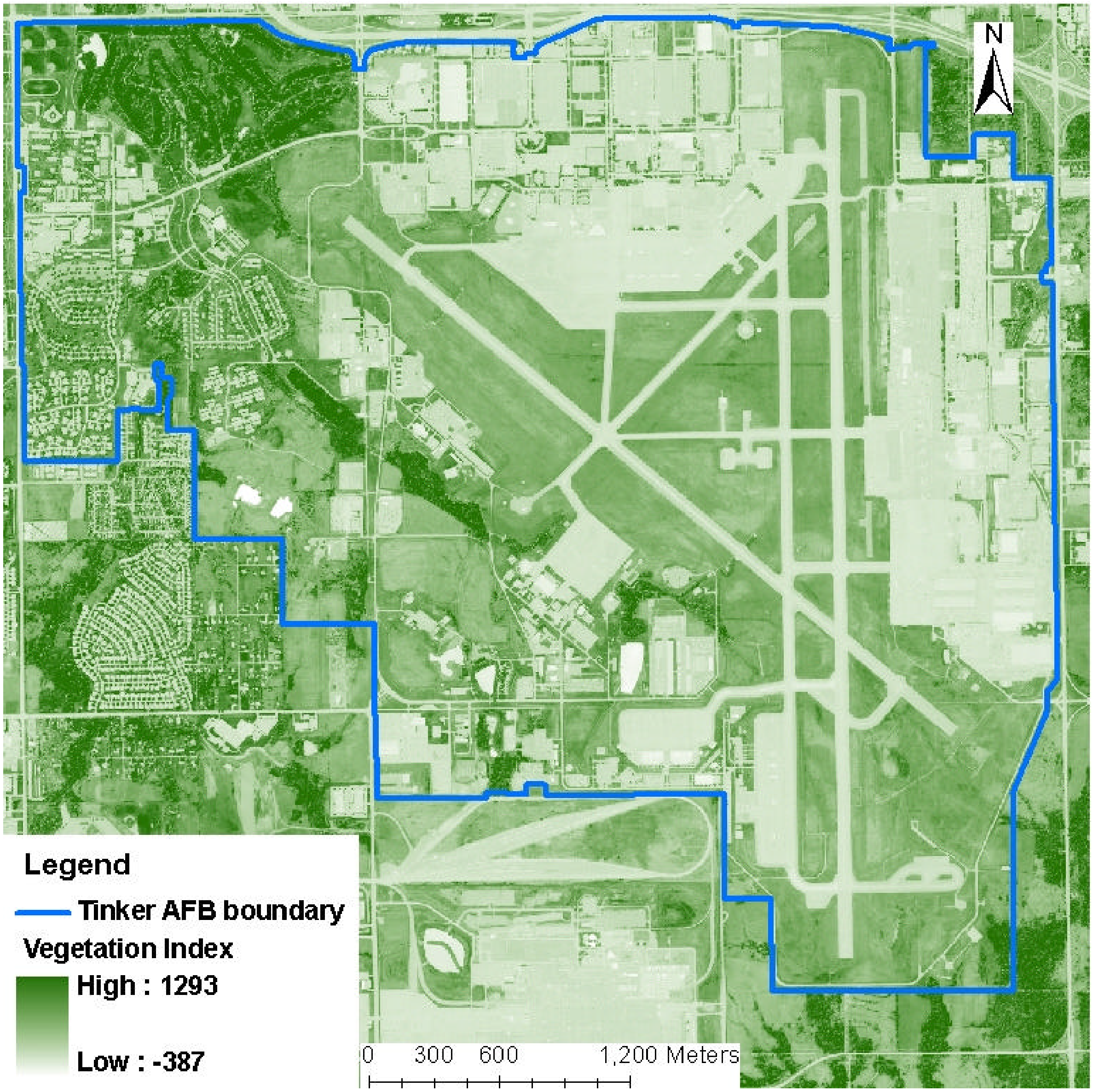

Figure 5: Vegetation index (VI) for Tinker AFB and the surrounding area was created using the simple ratio, near infrared band/ red band. The higher the VI, the denser the vegetation.

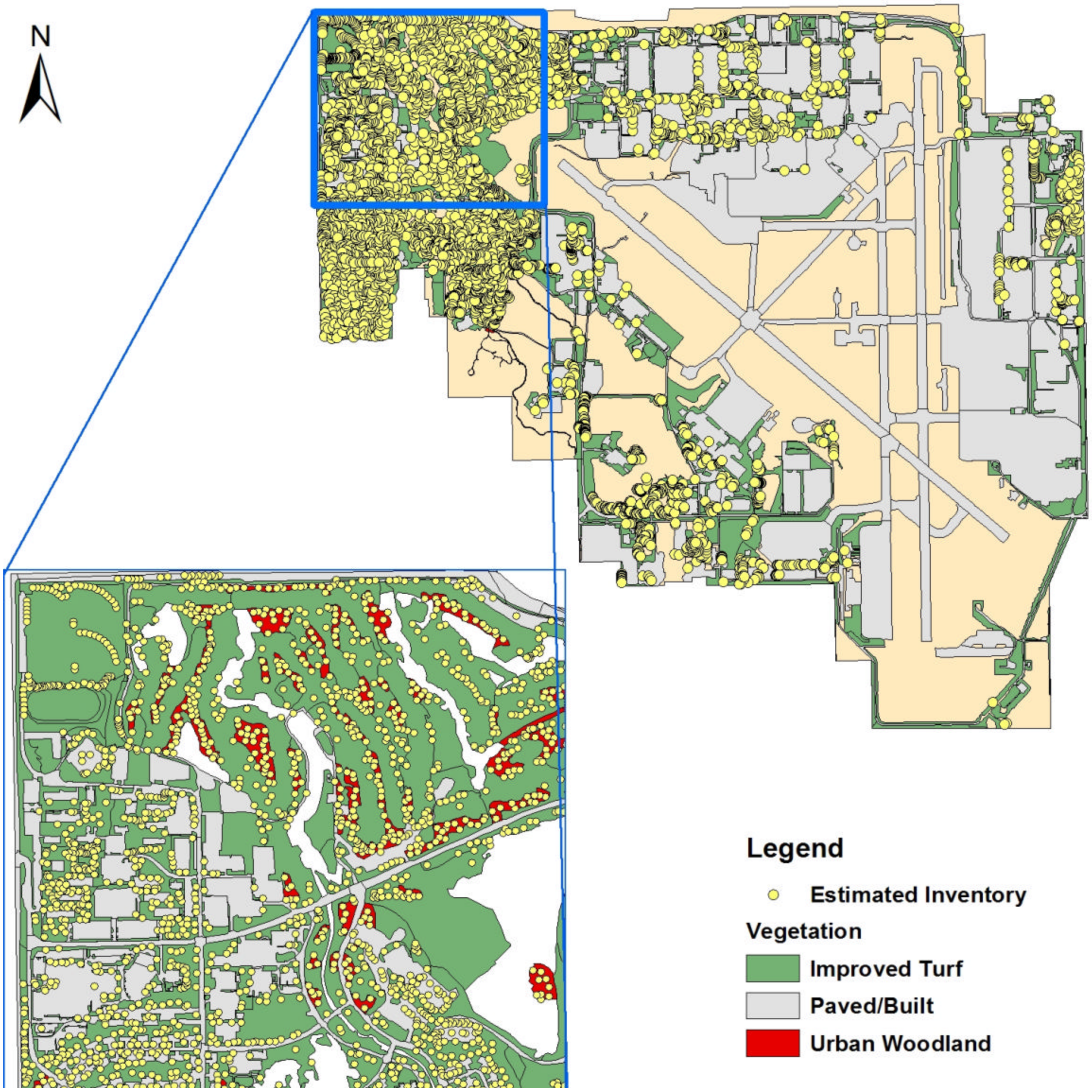

Figure 6: For the Tinker AFB urban tree inventory an estimated number of trees were found using remote sensing techniques. Only those trees within the areas of interest (Improved turf, Paved/built and Urban woodland) were kept.

2.1.2. Procedures for the Daily Collection of Inventory Data

We navigated to tree locations using known landmarks and the field computer with aerial photography and GPS. At each tree, species was first determined, and then DBH, tree height, and crown radius were measured. We measured DBH to the nearest inch using a logger's tape. If the tree was codominant the largest leader at breast height (4.5 feet) was measured and recorded. Tree height was measured to the nearest foot using a 100 LH Laser Rangefinder/Hypsometer (Opti-Logic, Tullahoma, TN). On windy days several measurements were taken and averaged. We measured crown radius with a logger's tape to the nearest foot from the center of the trunk to the dripline of the canopy by using a nail to secure the tape to the trunk. Two measurements were recorded to average at a later time.

Once the measurements were complete, we evaluated the tree's condition: soil, trunk, and crown problems; conflicts; pruning priority and needs; and hazard. Condition was evaluated on an integrated assessment of tree health and structural integrity. We determined the rating based on information provided in Appendix A: Tinker AFB Data Collection. Soil, trunk, and crown defects were noted using the attributes in Appendix A: Tinker AFB Data Collection.

Pruning priority was based on the pruning type needed. A pruning type associated with a clearance would be listed as a major pruning priority if it exceeded the clearance. A tree at or approaching the clearance was recorded as moderate pruning priority. We recorded trees as minor pruning priority that were not close to the clearance but could possibly grow into it. For example, if a tree canopy was 2 feet from a building which has 4 foot clearance, then we listed it as a major priority.

We determined tree hazard by the size of the defect and the exposure of a target. A target is defined as a person or a piece of property, such as a vehicle, that could be injured or damaged in the event of failure. For example, a tree with a large dead branch over a trail or sidewalk would have a high rating since people would be passing underneath it on the path. A tree in a field with a similar defect would be listed as a low hazard due to low target exposure. If a tree had a small dead branch hanging over a trail or sidewalk the hazard rating would only be moderate due to te smaller defect.

2.1.3. Data Preparation for CITYgreen

We used only the calculation of percent canopy cover from CITYgreen for this project. The percent canopy cover is used in several of the additional calculations that are performed. In addition, CITYgreen can estimate the magnitude and monetary value of stormwater runoff reduction, water quality, air quality, and carbon storage and sequestration. For this project the study areas were either the entire base or each UFMU.

The GIS layer inputs used for the CITYgreen analysis were the vegetative communities map (Dorr et al. 2005), urban tree inventory buffered with the trees' average crown radius, and the buildings layer. Once we loaded the inputs into ArcGIS, there were several steps that were taken before the analysis could be run. CITYgreen has a custom toolbar for ArcGIS that contains all the tools for the following steps. All vector data was converted to raster using the parameters automatically set by CITYgreen. The vegetation types in the vegetative communities map were labeled with their corresponding CITYgreen feature name. Tree stands that were not inventoried were labeled with their appropriate CITYgreen feature names. Areas inventoried were labeled as Grass/Turf understory instead of the classification given in the vegetative communities map. This was done to insure that percent canopy cover was calculated using the crown radii measured in the field. We labeled the buffered urban tree layer as the CITYgreen feature name, Trees: Grass/Turf understory. The buildings layer was labeled Impervious Surfaces: Buildings/ Structures. When combining the raster layers the order is very important, because the top layer will cover anything underneath it. With this knowledge, the layer order was (top to bottom) the urban tree inventory, the buildings, and the vegetative communities map.

We set several preferences so that the canopy cover calculations would be correct for the study area. The LiDAR DEM was referenced as the elevation data set. We set the default air quality area of interest (AOI) to Oklahoma City. The default land cover type was set to Open Space – Grass/Scattered trees with the replacement land cover type as Impervious Surfaces: Buildings/

Structures. The default hydrologic soil group was set to B – Somewhat Pervious. The defaults are only used if the program cannot compute the values dynamically. After we set the preferences and the data were converted to raster format, a land cover map was created and the analysis was performed.

To calculate the percent canopy cover within each urban forest management unit, we used the UFMU layer as the study area polygon (boundary polygon). The EIG and Gator management areas had to be calculated separately since they are not connected to the main base. To create their boundary polygons, the corresponding UFMU boundary was copied and used separately from the main base UFMU boundaries. Once the analysis was complete, we generated reports which contained the percent canopy cover for the selected study area.

2.1.4. Data Preparation for i-Tree STRATUM

STRATUM was the most appropriate i-Tree tool for analysis of the Tinker AFB urban forest. STRATUM is spreadsheet based, so GIS data had to be formatted to comply with the program. This option also requires information that was not collected in the original inventory, which had to be interpreted from aerial imagery.

The following information was not collected in the original inventory:

1. The numeric code for the street segment within a city where the tree is located, obtained from TIGER/line files.
2. The management area or zone within a city.
3. If the trees were city owned and managed or privately owned and managed.
4. The land use of the area where the tree is located.
5. The site location of where the tree is planted.
6. The recommended maintenance for the tree (different qualifications than pruning needs).
7. The highest priority task to perform on a tree.
8. The amount of sidewalk damage.
9. The presence or absence of utility lines above or in a tree's canopy.
10. The health of the tree's wood or its structural health.
11. The health of the tree's leaves or its functional health.

To format the GIS inventory data to comply with the STRATUM format, fields had to be added and removed, new information was interpreted from aerial imagery, and other data was reinterpreted from the collected data. For all fields that were required, but for which information was either not available or not needed, a null value was entered.

The original tree ID numbers, species code, DBH, and tree height were all utilized. The species codes were manipulated to match the codes provided by STRATUM. Street segments were not required since a full inventory was completed. The only areas considered for the evaluation were located within the Industrial North or AWACS UFMUs; this insured that all trees were street trees. All trees on base are property of Tinker AFB, so this field was set to city owned. Land use was set to Industrial/large commercial. The site locations were interpreted from aerial imagery; possible options are listed in Appendix C: i-Tree STRATUM Appendix C: i-Tree STRATUM (median and other maintained locations definitions were more precisely defined by the author). Recommended maintenance was adapted from the hazard rating. If the tree had a high hazard rating it was assumed to be a critical concern for public safety. Moderate and low hazard ratings were given null values as they could not be adapted to the ratings for the classification. Task priority was determined by matching the pruning needs with the values defined for this field. Sidewalk damage and utility presence were not used as they were not required fields for the original inventory. Structural and functional health were not considered separately in the inventory so the same value was given for both fields.

Once the data were formatted properly, the Excel spreadsheet was imported into Microsoft Access (Microsoft Corporation, Redmond, WA) and then imported into the STRATUM program. Within STRATUM, several attributes had to be defined. Information about the city was needed, such as population, total land area, average sidewalk width, and total linear miles of street.

2.2. Virginia Tech Campus- Data collection

The campus inventory data collection was primarily performed by undergraduate students in the Department of Forestry. For data collection an Axim x51 handheld computer (Dell inc., Round Rock, TX) running ArborVue 2006 (The Laurus Group LLC., Seneca, SC). ArborVue 2006 is a commercial software system that runs on an ArcPad platform. The software system consists of a desktop and a field collection application, this allowed for backup of the field data as well as various management options that are integrated in the desktop version. To allow for accurate tree placement and campus navigation, high resolution aerial imagery was used as the background during inventory. For this project a tree was defined as a woody plant at least 10 feet tall or a woody plant with no branches originating within 1 foot of the ground line on the main stem. This prevented most shrubs from being inventoried.

Inventory attributes were selected based on their ability to effectively characterize the structure of the urban forest and the management needs of trees within the urban forest. The following attributes were collected:

1. Location
2. Tree species
3. DBH
4. Closest building
5. Condition
    a. Excellent – No apparent problems
    b. Good – Minor problems
    c. Fair – Major problems
    d. Poor – Extreme problems
6. Crown radius (in feet)
7. Mulch presence
    a. Absent – No apparent mulch
    b. Too deep – Mulch deeper than 4 inches
8. Codominant stems – A stem originating in the lower half of the canopy that extends into the upper third of the canopy
9. Weak branch attachment – A branch within 8 feet of the ground that is greater than half of the parent stem diameter
10. Trunk wound – A palm sized or larger wound within 4 feet of the ground

11. Date inventoried
12. Photograph number
13. Technician’s initials

Location was determined by zooming in to the area where the tree was located. Once the field technician could identify the tree’s location on the aerial imagery a point was digitized (Figure 7). The closest building was then identified and the DBH was measured at 4.5 feet from the ground using a logger’s tape. The tree species would then be identified as well as the overall condition of the tree. Condition was determined by evaluating the tree’s health as well as its structural integrity and was recorded as one of the previously listed ratings. Crown radius was measured from the center of the trunk to the edge of the dripline. Mulch presence, codominant stems, weak branch attachment, and trunk wounds, as defined previously, was noted. Lastly, the technician noted their initials, the current date, and the photograph number of the tree. After completing an inventory session, the data was uploaded to the desktop version of ArborVue.

Figure 7: High resolution aerial imagery was used so the field technician could visually reference the tree location on the handheld computer.

3. Results

3.1. Tinker AFB

The urban forest at Tinker AFB contains 6604 urban trees. Eastern redcedar (*Juniperus virginiana*) is the most abundant tree species in the urban forest at Tinker AFB. It accounts for approximately 14% of the total urban tree population on base with 908 specimens (Figure 8 & Table 1). It is also the most common species in Community (Residential – Military Family Housing), EIG, Industrial East, Industrial North, Industrial South 2, and Industrial South 3 urban forest management units. The second most abundant species is Austrian pine (*Pinus nigra*), comprising roughly 10% of the urban forest with 635 specimens (Figure 8 & Table 1).

According to Santamour's species diversity model (Santamour 1990), less than 30% of the total population should be comprised of a single family (Figure 9), less than 20% should be comprised of a single genus (Figure 10), and less than 10% should be comprised of a single species (Figure 8). This model can be used as a guideline in species selection for new trees. The population at Tinker AFB only exceeds the model with a single species (*Juniperus virginiana*). The fundamental purpose of promoting species and age diversity in the urban forest is to ensure long-term stability of urban forest structure, function, and value.

When looking at each urban forest management unit separately, the composition differs from the overall composition. The most common species within each UFMU can be found in Appendix A, Figure 29 through Figure 50. The largest population and density of trees is found in the Community (Residential – Military Family Housing) UFMU with 1557 trees (Table 2). This UFMU also has the highest number and density of high and moderate hazard tree (Table 3). The lowest concentration of urban trees was found in the Munitions UFMU, with only 1 tree. Average DBH and height measurements for each species within each UFMU are listed in Table 9 through Table 14.

According to an idealized tree size distribution model proposed by Richards (Richards 1983), 40% of the tree population should be less than 20 cm (~8 in.) DBH, 30% of the tree population should be between 20 and 40 cm (~8 – 15 in.) DBH, 20% of the tree population should be between 40 and 60 cm (~16 – 24 in.) DBH and 10% above 60 cm (~ 24 in.) DBH. The urban forest at Tinker AFB is extremely close to these criteria (Figure 11). The 8 to 15 inch DBH class is just below 30%, at 29%, and the greater than 24 inch DBH class is just above 10%, at 11%. In the future, these goals can be adjusted accordingly with careful planning.

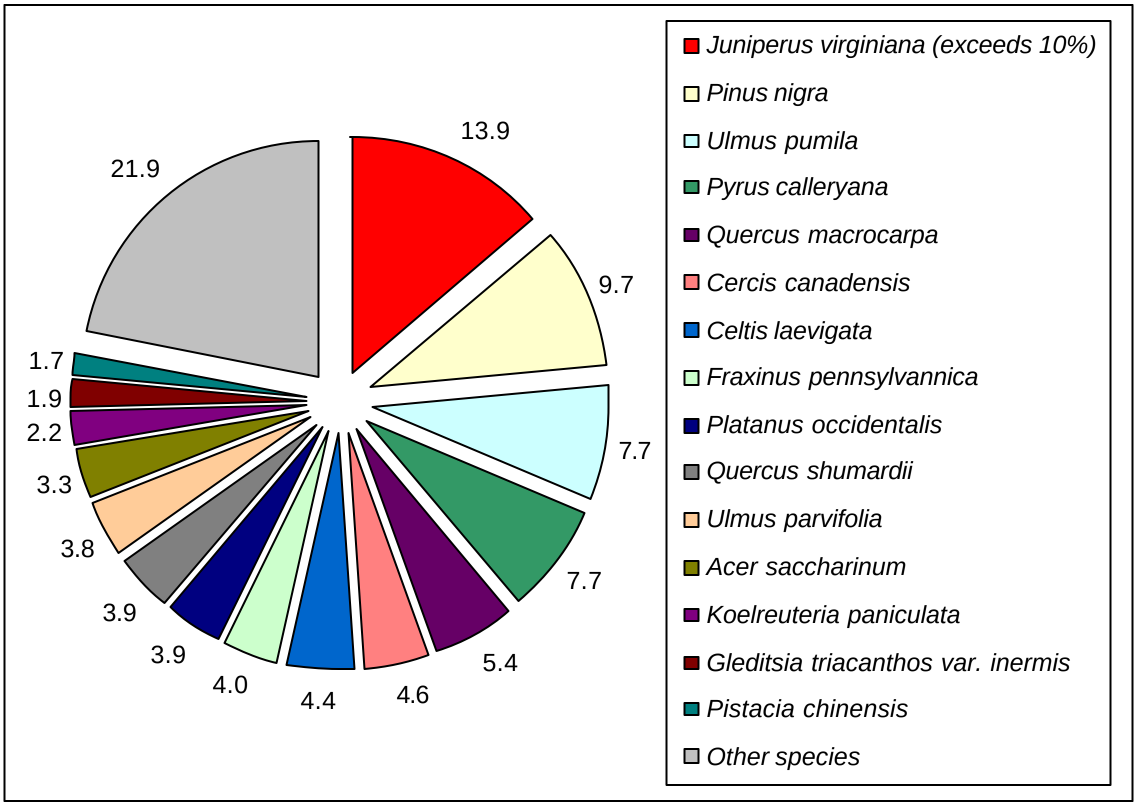

Figure 8: The urban tree species composition (% of all urban trees) at Tinker Air Force Base (top 15 most abundant species shown). *Juniperus virginiana* exceeds the maximum recommended abundance (10%) for a single species in an urban forest (Santamour 1990).

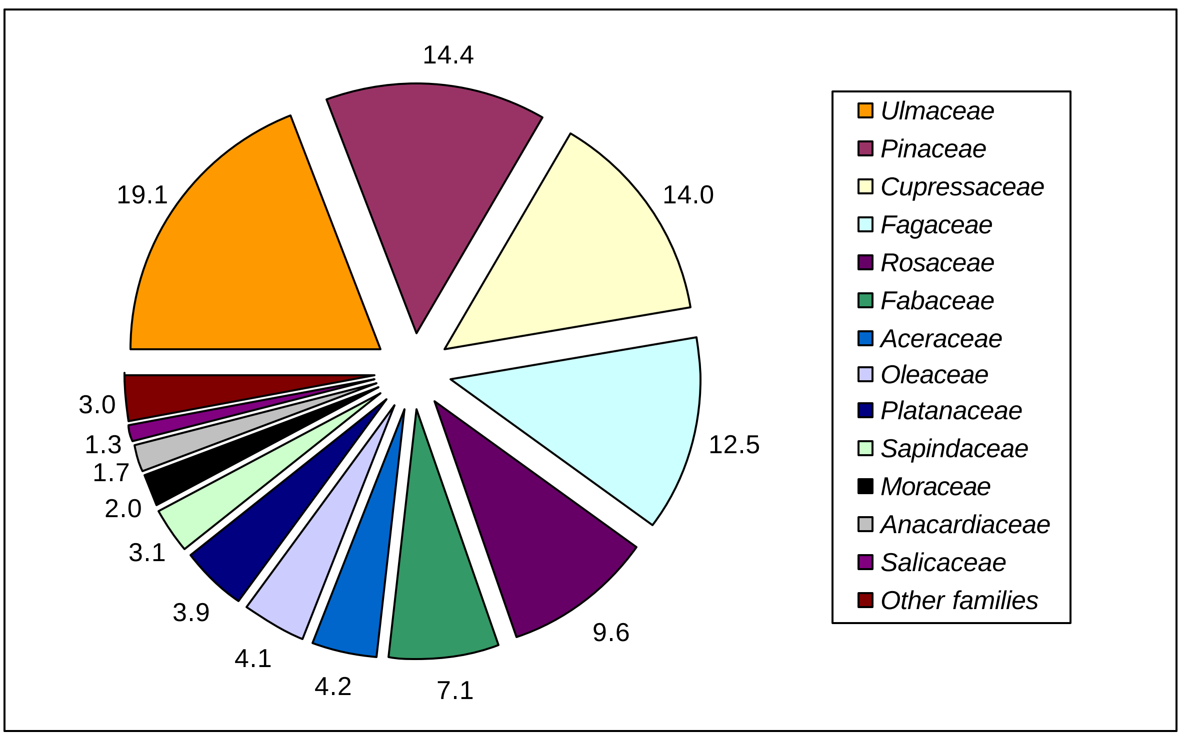

Figure 9: The urban tree family composition (% of all urban trees) at Tinker Air Force Base (> 1% relative abundance shown). No families exceeded the recommended maximum relative abundance of 30% for a single family (Santamour 1990).

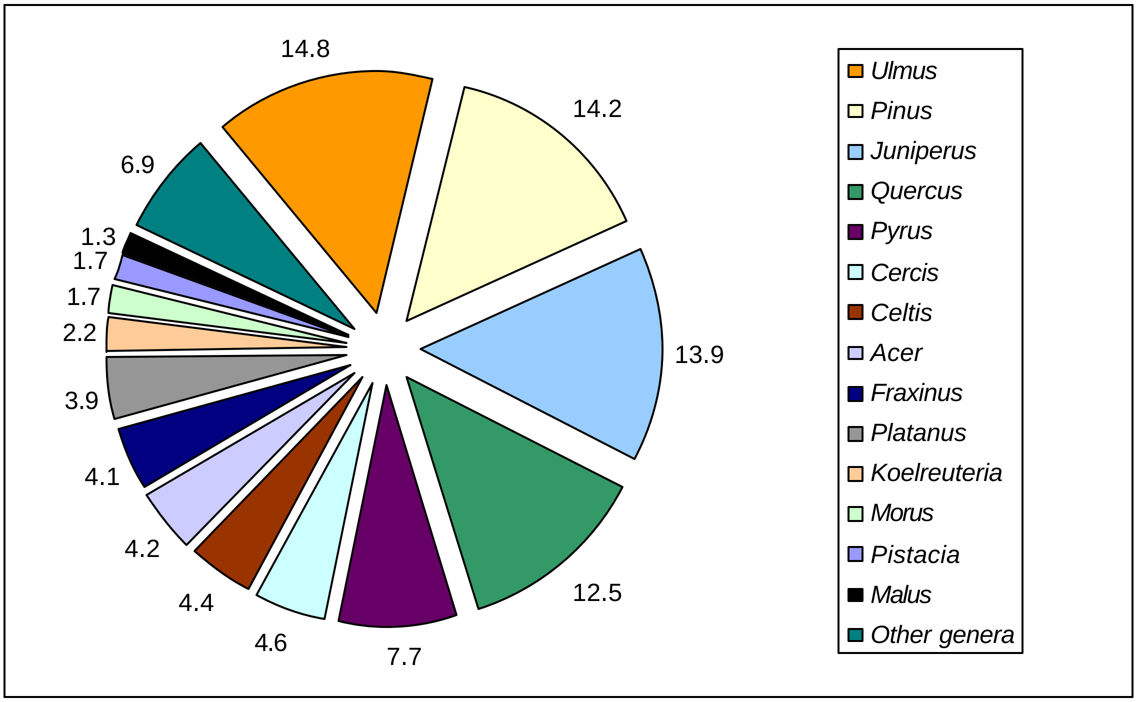

Figure 10: The urban tree genus composition (% of all urban trees) at Tinker Air Force Base (> 1% relative abundance shown). No genera exceeded the recommended maximum relative abundance of 20% for a single genus (Santamour 1990).

Table 1: Tree count, absolute abundance, and relative abundance of all urban trees species at Tinker Air Force Base.

Species	Count	Percent	Species	Count	Percent	Species	Count	Percent
Acer barbatum (saccharum) var. caddo	13	0.20%	*Gleditsia triacanthos var. inermis*	122	1.85%	*Prunus spp*	1	0.02%
Acer ginnala	20	0.30%	*Gymnocladus dioicus*	29	0.44%	*Pyrus calleryana*	501	7.59%
Acer negundo	3	0.05%	*Ilex decidua*	2	0.03%	*Pyrus communis*	1	0.02%
Acer palmatum	8	0.12%	*Juglans nigra*	34	0.51%	*Quercus acutissima*	10	0.15%
Acer rubrum	8	0.12%	*Juniperus virginiana*	908	13.75%	*Quercus alba*	17	0.26%
Acer saccharinum	219	3.32%	*Koelreuteria paniculata*	147	2.23%	*Quercus macrocarpa*	350	5.30%
Acer saccharum	1	0.02%	*Liquidambar styraciflua*	41	0.62%	*Quercus marilandica*	85	1.29%
Acer spp.	2	0.03%	*Liquidambar styraciflua 'Rotundiloba'*	2	0.03%	*Quercus muehlenbergii*	7	0.11%
Albizia julibrissin	9	0.14%	*Maclura pomifera*	14	0.21%	*Quercus nigra*	2	0.03%
Betula lenta	2	0.03%	*Magnolia grandifloria*	5	0.08%	*Quercus palustris*	71	1.08%
Betula nigra	11	0.17%	*Malus spp.*	85	1.29%	*Quercus prinus*	2	0.03%
Carya illinoinensis	6	0.09%	*Morus alba*	31	0.47%	*Quercus robur*	2	0.03%
Catalpa bignonioides	1	0.02%	*Morus rubra*	83	1.26%	*Quercus shumardii*	255	3.86%
Cedrus atlantica	8	0.12%	*Picea pungens*	4	0.06%	*Quercus spp.*	3	0.05%
Cedrus atlantica 'Glauca'	3	0.05%	*Pinus echinata*	8	0.12%	*Quercus texana*	1	0.02%
Cedrus deodara	1	0.02%	*Pinus elliottii*	71	1.08%	*Quercus virginiana*	10	0.15%
Celtis laevigata	285	4.32%	*Pinus halepensis*	19	0.29%	*Salix spp.*	20	0.30%
Cercis canadensis	298	4.51%	*Pinus nigra*	635	9.62%	*Sambucus spp.*	1	0.02%
Chilopsis linearis	3	0.05%	*Pinus sylvestris*	46	0.70%	*Sapindus saponaria*	55	0.83%
Cornus drummondii	4	0.06%	*Pinus taeda*	101	1.53%	*Sideroxylon lanuginosum*	13	0.20%
Crataegus phaenopyrum	2	0.03%	*Pinus thunbergii*	46	0.70%	*Styphnolobium japonicum*	2	0.03%
Crataegus spp.	3	0.05%	*Pistacia chinensis*	111	1.68%	*Taxodium distichum*	41	0.62%
Cupressus arizonica	1	0.02%	*Platanus occidentalis*	258	3.91%	*Thuja occidentalis*	9	0.14%
Dead	66	1.00%	*Populus alba*	1	0.02%	*Ulmus americana*	103	1.56%
Diospyros virginiana	4	0.06%	*Populus deltoides*	60	0.91%	*Ulmus crassifolia*	104	1.57%
Elaeagnus angustifolia	17	0.26%	*Populus nigra 'Italica'*	2	0.03%	*Ulmus parvifolia*	249	3.77%
Fraxinus americana	10	0.15%	*Prunus angustifolia*	7	0.11%	*Ulmus pumila*	506	7.66%
Fraxinus pennsylvannica	261	3.95%	*Prunus cerasifera*	27	0.41%	*Ulmus spp.*	4	0.06%
Ginkgo biloba	1	0.02%	*Prunus persica*	1	0.02%	*Ziziphus obtusifolia*	5	0.08%
Gleditsia triacanthos	4	0.06%						

Table 2: **Urban tree count and density (trees per acre), sorted by density (high to low), for all urban forest management units at Tinker Air Force Base.**

Urban Forest Management Unit	Tree Count	Area (Acres)	Tree Count per Acre
Community (Residential - Military Family Housing)	1557	221.6	7.0
Community (Commercial) 1	933	159.0	5.9
Golf Course	1329	235.8	5.6
EIG	258	90.8	2.8
AWACS	204	80.8	2.5
Community (Commercial) 2	43	19.1	2.2
Industrial North	792	352.5	2.2
Open Space 2	287	158.9	1.8
507th/513th	55	36.7	1.5
Navy	123	85.4	1.4
Industrial South 2	55	42.9	1.3
Industrial East	633	499.0	1.3
Third Herd	59	54.7	1.1
Industrial South 5	40	39.3	1.0
Industrial South 4	44	45.5	1.0
Open Space 3	22	25.6	0.9
Open Space 1	82	108.2	0.8
AWACS Alert	17	28.6	0.6
Industrial South 3	32	61.2	0.5
Industrial South 6	22	45.9	0.5
Gator	7	16.0	0.4
Industrial South 1	9	25.9	0.3
Munitions	1	48.6	0.0
Total	6604	2482	2.7

Table 3: Number and density (tree per acre) of urban trees with high and moderate hazard ratings within each urban forest management unit at Tinker Air Force Base, sorted first by high hazard density (high to low) then moderate hazard density .

Management Units	Area (Acres)	High Count	High Count per Acre	Moderate Count	Moderate Count per Acre
Community (Residential - Military Family Housing)	221.6	235	1.06	287	1.30
Golf Course	235.8	174	0.74	182	0.77
Community (Commercial) 1	159.0	54	0.34	84	0.53
Community (Commercial) 2	19.1	5	0.26	8	0.42
AWACS	80.8	9	0.11	5	0.06
Industrial North	352.5	32	0.09	33	0.09
EIG	90.8	5	0.06	11	0.12
Industrial East	499.0	26	0.05	64	0.13
Open Space 1	108.2	5	0.05	4	0.04
Open Space 2	158.9	3	0.02	7	0.04
Navy	85.4			20	0.23
AWACS Alert	28.6			2	0.07
Third Herd	54.7			2	0.04
Industrial South 5	39.3			1	0.03

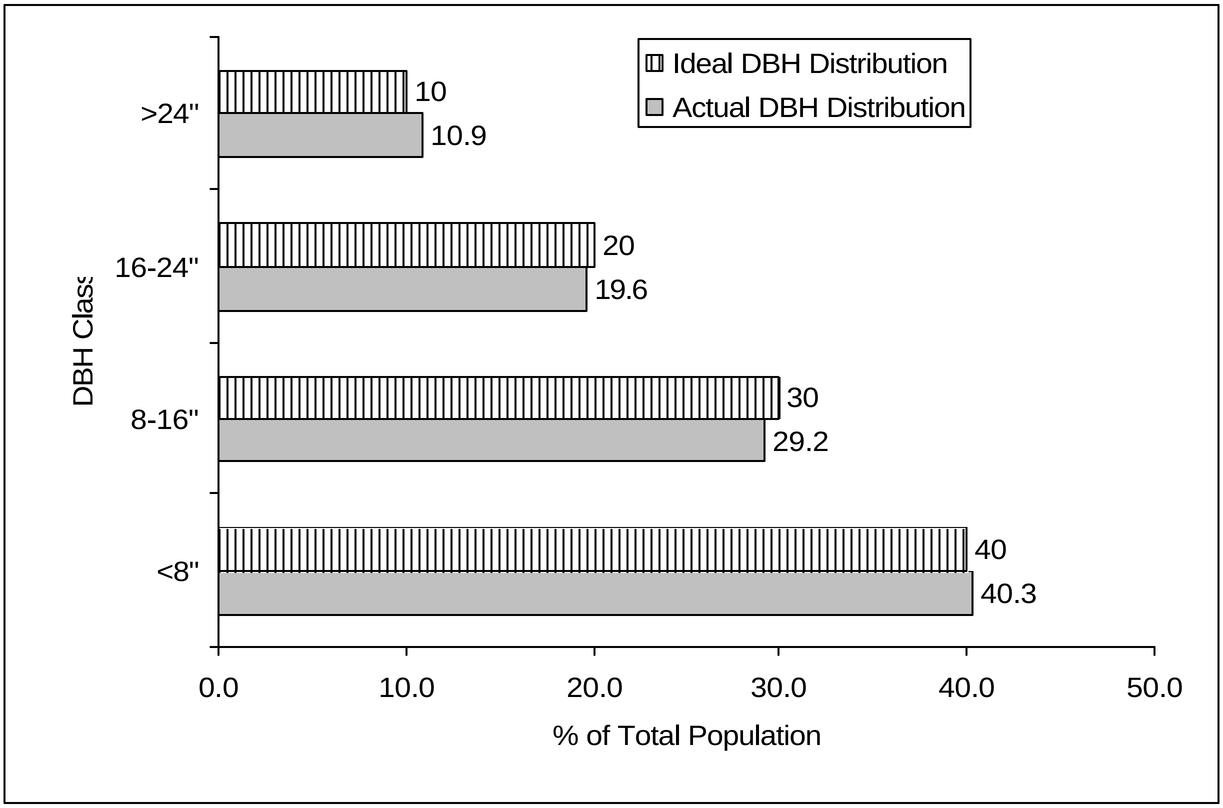

Figure 11: Actual vs. ideal DBH (trunk diameter at 4.5 ft above ground line) distribution of the urban forest at Tinker Air Force Base, ideal distribution from Richards (1983).

3.2. Runway Obstacle Measurements

Part of the goal of the urban tree inventory project at Tinker AFB was to identify trees that are flight or glide slope instrumentation obstacles, which could compromise aircraft and aircrew safety. These trees were identified through field measurements and geospatial analysis. Trees found in the glide slope and transitional zones (Figure 12) were given a higher priority for the Tinker AFB urban tree inventory and, where possible, were measured first.

Figure 12: Trees within the glide slope and transitional zones around the runways were identified as possible runway obstacles and were measured first during the inventory.

Once the majority of trees were measured on the ground, we created separate tree GIS layers (Shapefile format) with species and tree height for the following zones. For example trees in the transitional zone on the west side of the crosswind runway are in the "W_CW_Transitional" layer:

Transitional Surface (Transitional Slope)

1. East Primary Transitional (E_Primary layer)
2. West Primary Transitional (W_Primary_Trans layer)
3. East Crosswind Transitional (E_CW_Transitional layer)
4. West Crosswind Transitional (W_CW_Transitional layer)

Approach-Departure Surface (Glide Slope)

5. North Primary Approach-Departure (N_Primary_Glide layer)

6. South Primary Approach-Departure (S_Primary_Glide layer)
7. North Crosswind Approach-Departure (N_CW_Glide layer)
8. South Crosswind Approach-Departure (S_CW_Glide layer)

Figure 13 is a generalized diagram of the transitional slope calculations. The measurements shown are:

A = the tree height
B = the distance between the centerline or end of the runway and the tree
C = the difference in the allowable and actual tree height
D = the elevation difference between the tree and its reference point

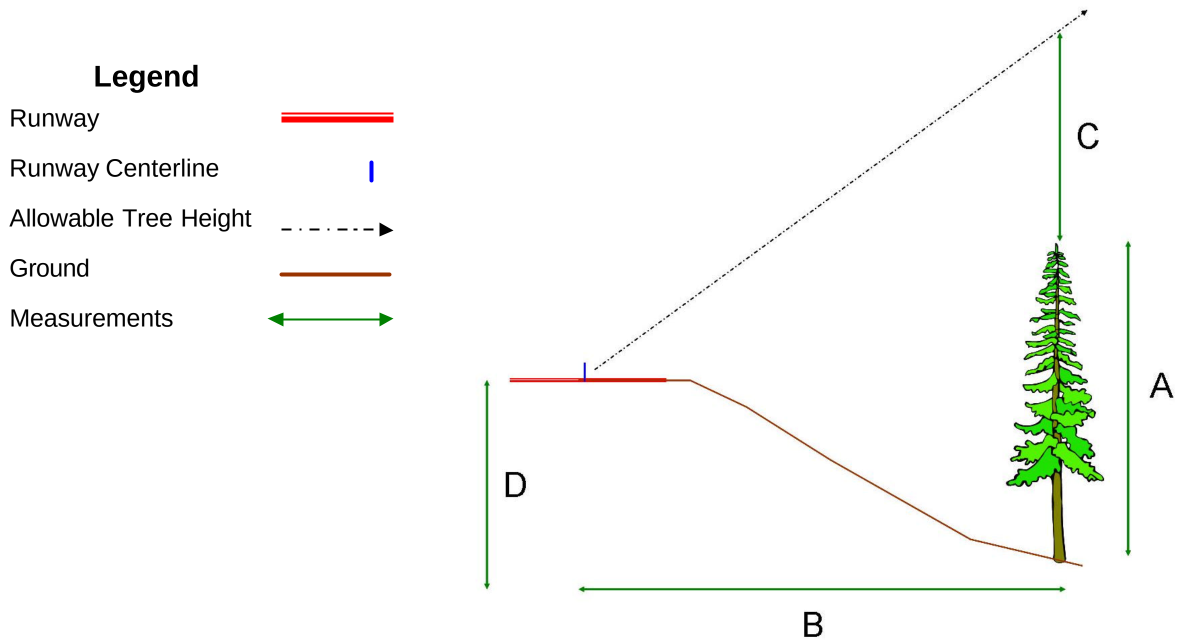

Figure 13: A diagram of measurements made during transitional slope calculations.

Calculations were performed using ArcInfo's Near Analysis tool. We created a "runway_endpoints" layer to determine distance from the beginning of the glide slope. The glide slope starts 200 feet from the end of the runway. The slope heights were calculated by dividing the distance from the runway endpoint by 50 (50:1 glide slope ratio). The slope heights for the transitional slope were calculated by finding the distance from the trees to the centerline (Transitional Surface starts 1000 feet from the centerline). Once the distance was found, 1000 was subtracted and the remaining distance was divided by 7 (7:1 transitional slope ratio).

The Near Analysis tool gives the x and y coordinates of the reference point to which the distance was measured. This option was selected so that the reference elevation of each tree point could be determined. Since the elevation of the runway is considered ground level, the difference in elevation of the reference point and the tree can allow for a taller tree. For example, if the tree is at an elevation 20 feet below the reference point, the tree can be up to 20 feet taller.

We added the difference in elevation to the slope height. Ten feet was then subtracted for the 10-foot buffer required below the Imaginary Surface. If a tree extends into this 10-foot buffer it must be topped or removed, according to regulations. We calculated the total allowable height (field = TRANSALLOW or GLIDEALLOW) and the difference between the allowable height and the actual height of the tree (field = X_Height).

The 8 transitional and glide slope layers were combined into one runway obstacles layer. In addition, error measurements were calculated for every tree in the combined layer. We measured the range in elevation within a 15 meter (known GPS error) buffer around each tree. The range was calculated using Zonal Statistics ++ in the Hawth's Analysis Tools Extension. We then subtracted the range in elevation around each point from X_Height giving a measure for error (field = Error_dif).

If the position of the tree is incorrect then the elevation obtained from the DEM is also incorrect as well as any subsequent calculations. Evaluating the range of elevations within an error zone around the coordinates allows us to identify trees in which GPS location error could lead to incorrect calculations and misidentification of obstacle trees.

3.2.1. Calculations

The following attributes were calculated for each tree in the transitional slope and the glide slope.

- Elev_M = the elevation at the tree in meters obtained from the DTM by HawthsTools' Intersect Point Tool (for transitional and glide slope)
- Elev_FT = the elevation at each tree in feet converted from meters using 3.281 as the conversion factor (for transitional and glide slope)
- NEAR_X = the X coordinate for the reference point (for transitional)
- NEAR_Y = the Y coordinate for the reference point (for transitional)
- NearElevM = the elevation of the reference point along the extended centerline of the runway in meters, obtained from the DTM by HawthsTools' Intersect Point Tool (for transitional)
- NearElevFT = the elevation of the reference point in feet converted from meters using 3.281 as the conversion factor (for transitional)
- Elev_Dif =
    - For transitional = the difference in the elevations of the reference point (NearElevFT) and the elevation at the tree (Elev_FT)
    - For glide slope = the difference in the elevations of the reference point (runway) endpoints and the tree (Elev_FT)
- Near_Dist =
    - For transitional = the distance from the tree to the reference point along the extended centerline of the runway in meters
    - For glide slope = the distance from the tree to the reference point
- Dist_FT = the distance between the tree and the reference point in feet converted from meters using 3.281 as the conversion factor (for transitional and glide slope)

- SlopeHeigh =
  - For transitional = Dist_FT minus 1000, divided by 7. The transitional zone starts 1000 feet from the centerline where it begins a 7:1 horizontal to vertical ratio.
  - For glide slope = Dist_FT divided by 50 (50:1 ratio set for the glide slope)
- TRANSALLOW = SlopeHeigh plus Elev_Dif minus 10, due to the 10 foot buffer required for trees below the Imaginary Surface (for transition)
- GLIDEALLOW = SlopeHeigh plus Elev_Dif minus 10, due to the 10 foot buffer required for trees below the Imaginary Surface (for glide slope)
- X_Height = TRANSALLOW or GLIDEALLOW minus HEIGHT (height of tree). If this is negative then the tree may have broken the 10-foot buffer below the Imaginary Surface by the negative amount. If positive, then it is the allowable growth before the tree breaks the 10-foot buffer below the Imaginary Surface (for transition and glide slope).
- Source = original source shapefile for calculations, before merging
- Notes = any special notes
- Tree_Type = Distinguishes tree as from the urban tree inventory (Urban) or a tree or canopy measurement added specifically for the glide slope (Additional)
- Tree_Error = The range in elevation within a 15 meter (known GPS error) buffer of each tree (range was calculated using Zonal Statistics ++ in Hawth's Analysis Tools Extension)
- T_Error_FT = the Tree_Error in feet converted from meters using 3.281 as the conversion factor
- Error_dif = X_HEIGHT minus T_Error_FT. If this is negative then the tree could possibly have broken the 10-foot buffer below the Imaginary Surface by the negative amount. If positive, then it is the allowable growth before the tree breaks the 10-foot buffer below the Imaginary Surface.

The important fields, for management purposes, include X_height and Error_dif. If the value in X_height is negative, the tree may have broken the 10-foot buffer below the Imaginary Surface by the negative amount. If positive, it is the allowable growth before the tree breaks the 10-foot buffer below the Imaginary Surface. According to the original calculations made in X-height, there are 128 trees that may breach the Imaginary Surface.

As with any remote, geospatial calculation, inherent error exists. To account for this, we calculated an error value based on known GPS error in the field Error_dif. If the value in Error_dif is negative, the tree could possibly have broken the 10-foot buffer below the Imaginary Surface by the negative amount (Figure 14). If positive, it is the allowable growth before the tree breaks the 10-foot buffer below the Imaginary Surface. According to the added error calculation, there may be an additional 53 trees that breach the Imaginary Surface, for a total of 181 trees that should be examined further as they are either breaching or are close to breaching the Imaginary Surface (Figure 15). Due to inherent error in geospatial data, the runway obstacles layer should be used as an indication of the trees that may breach the Imaginary Surface.

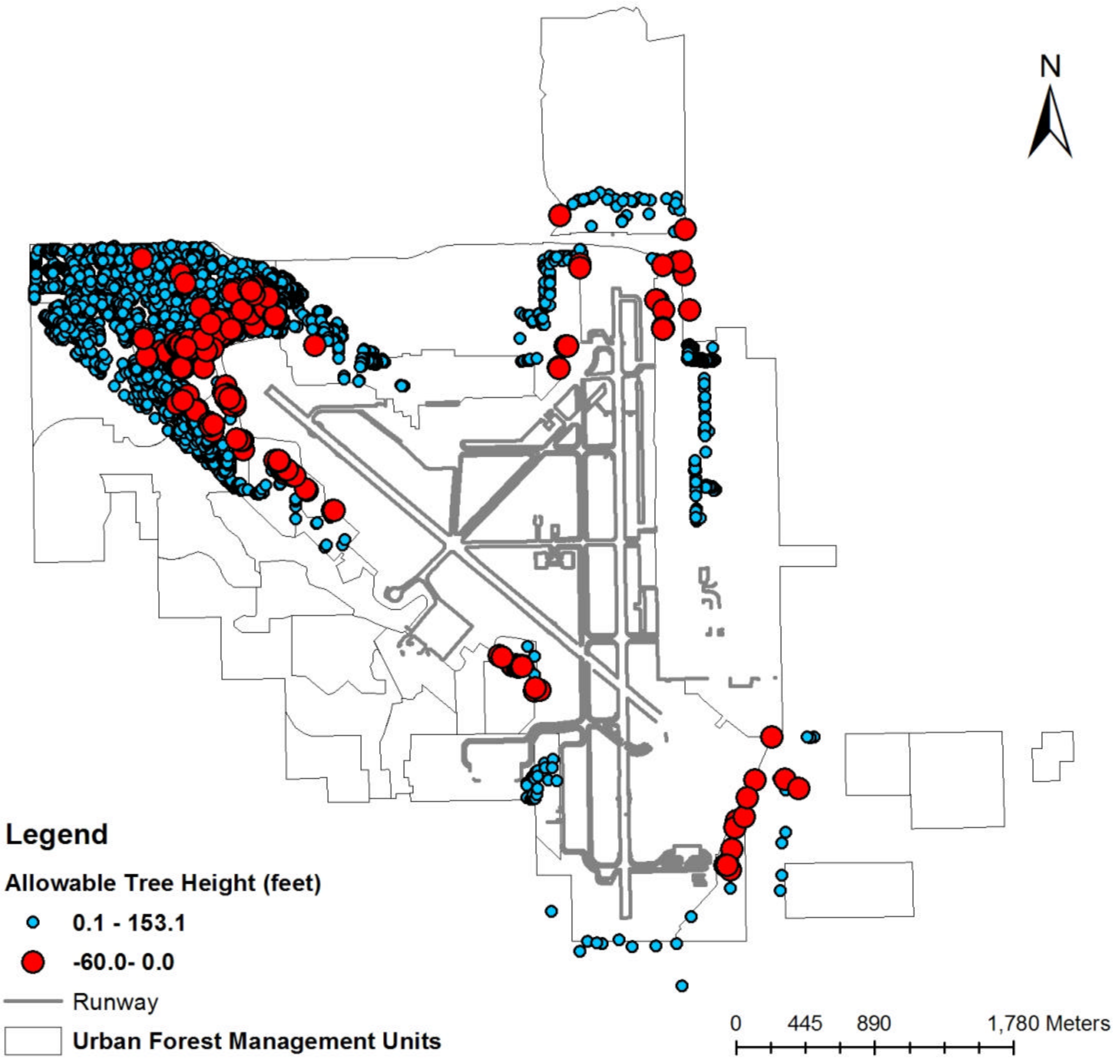

Figure 14: Map of allowable heights for urban trees, additional trees and canopy measurements that may breach the Imaginary Surface at Tinker Air Force Base. A negative value (red point) designates a tree that has exceeded the height allowed at that position. A positive value (blue point) indicates the tree can grow a given amount before it breaches the Imaginary Surface.

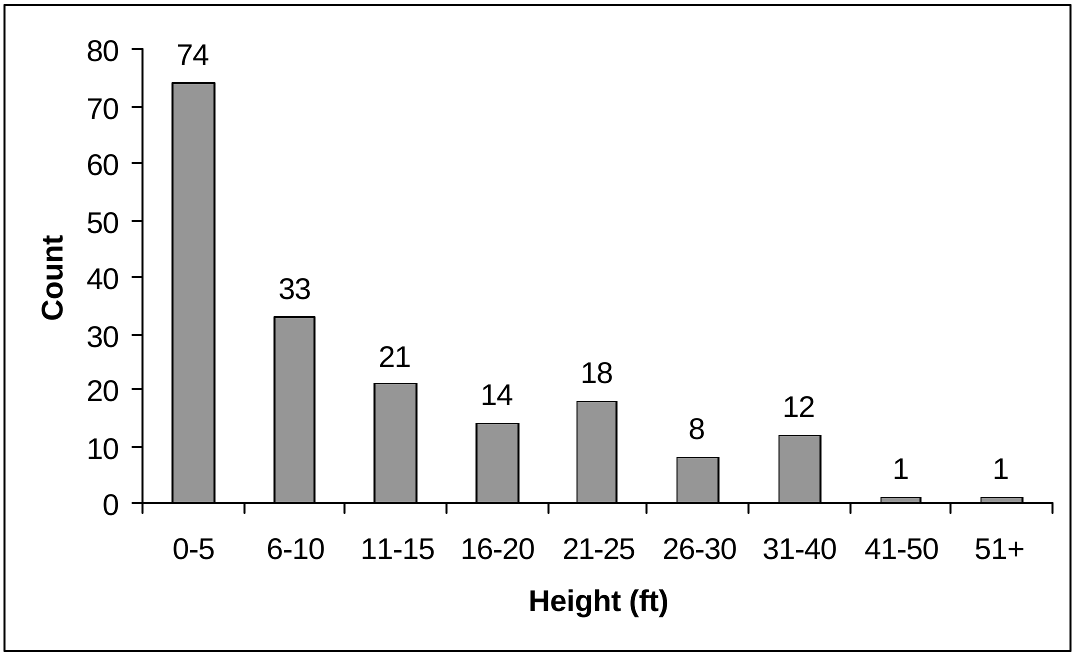

Figure 15: Number of trees per class that breach the Imaginary Surface by height breached at Tinker Air Force Base.

3.3. CITYgreen

The land cover raster layer computed by CITYgreen is shown in Figure 16 through Figure 20. Figure 21 shows the land cover composition of the base after classification in CITYgreen. The tree canopy for each UFMU is listed in Table 4, as well as the overall tree canopy of 9.2% for the entire base (excluding the airfield).

American Forests sets tree canopy cover goals for metropolitan areas in the Southwest and dry west as an overall canopy coverage of 25%, 35% for suburban residential zones, 18% for urban residential zones, and 9% for central business districts. We defined suburban residential as any area containing single family homes as well as naturalized areas such as the golf course or open spaces; urban residential as any area with multiple family housing as well as dorms or schools; and business districts as areas containing commercial or industrial buildings (Table 5). None of the canopy goals set by America Forests for metropolitan areas in the southwest and dry west was attained. Although canopy covers do not meet American Forests' goals, the land use of the base should be taken into account. There is a large portion of the base that cannot have vegetation cover because of the presence of active runways. The canopy cover results should be used as a baseline to set future management goals and a measure against which to gauge progress towards the canopy goals.

Due to the high amount of impervious area, planting trees may help with the urban heat island effect (Miller 1997). The urban heat island effect refers to a city having a higher air temperature than the rural area surrounding it because it has more impervious areas absorbing solar radiation. Furthermore, the farther into a city you venture, the hotter it becomes because there is usually less vegetation. Forest stands moderate extreme temperatures more than adjacent open spaces and researchers have found that the cooling effect produced by urban tree canopies in cities is statistically significant (Miller 1997). Due to the increased heat in cities, there is an increased cost of cooling. As Tinker AFB has an average of 75 days of 32.2° C (90° F) and higher, helping to decrease the heat island effect during the summer could help save energy. As the area is also quite windy, trees and vegetation could act as wind breaks, helping to keep the heating costs of buildings lower.

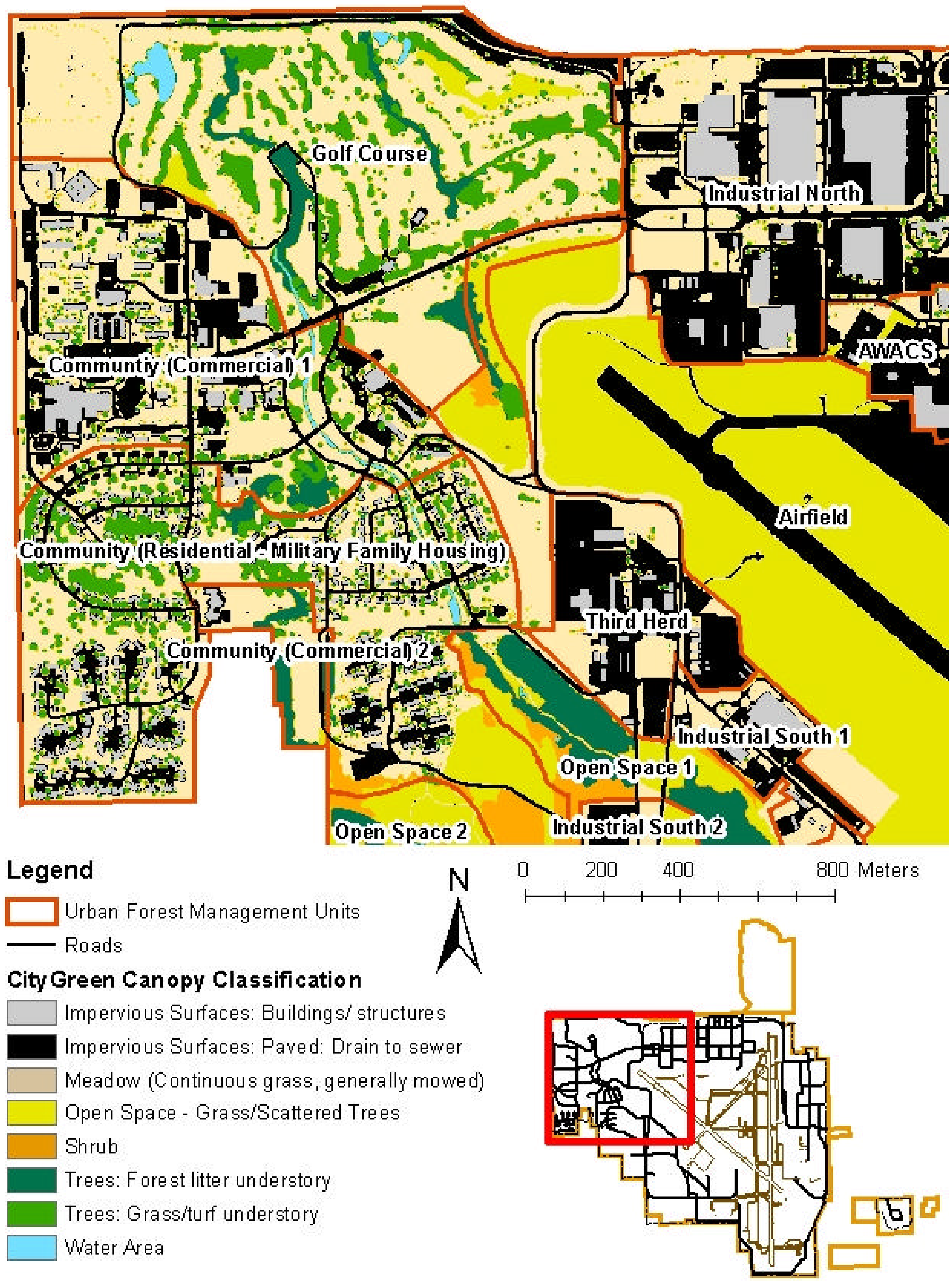

Figure 16: Tinker Air Force Base (northwest sector) CITYgreen land cover classification used for tree canopy calculations.

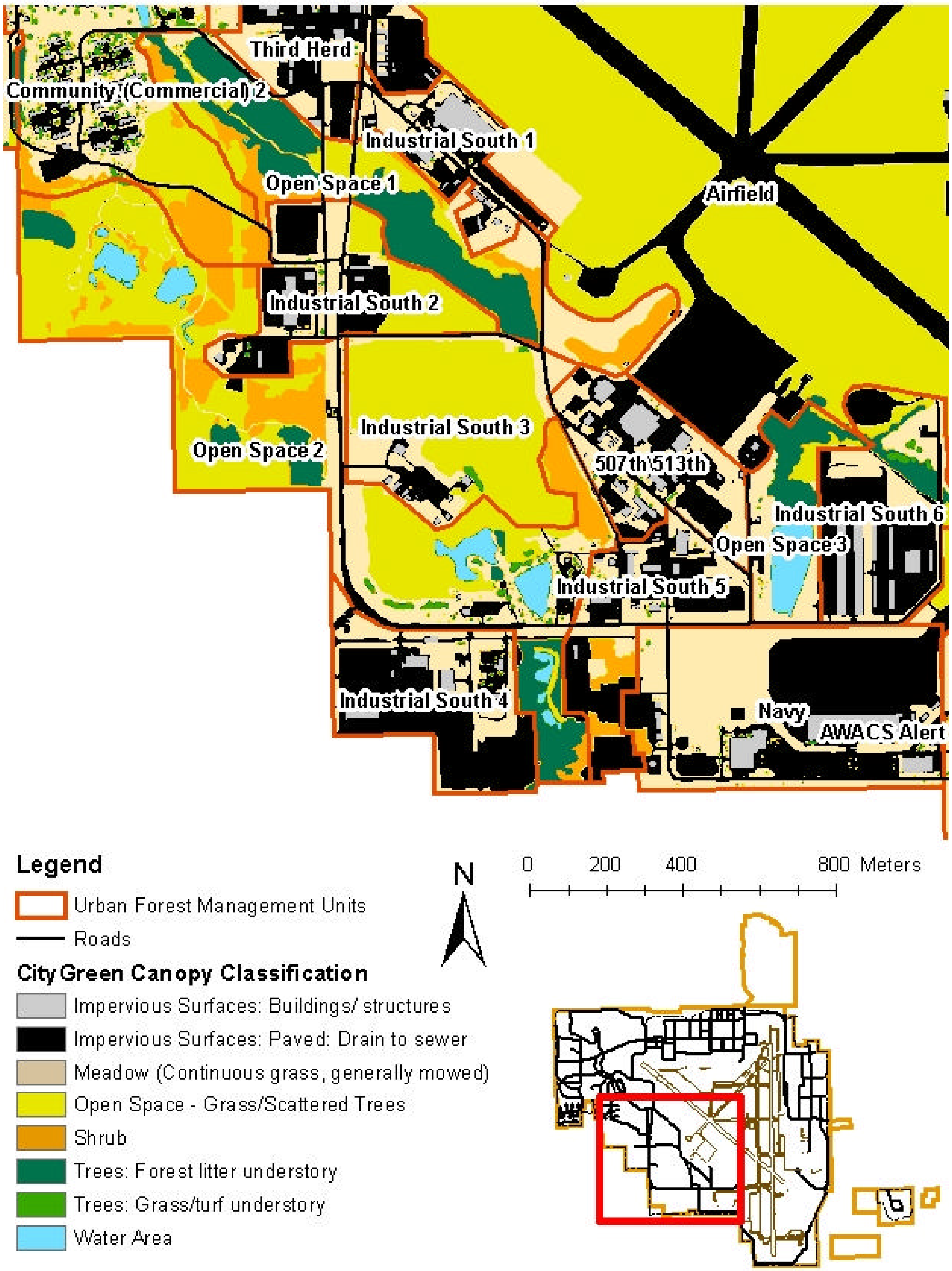

Figure 17: Tinker Air Force Base (southwest sector) CITYgreen land cover classification used for tree canopy calculations.

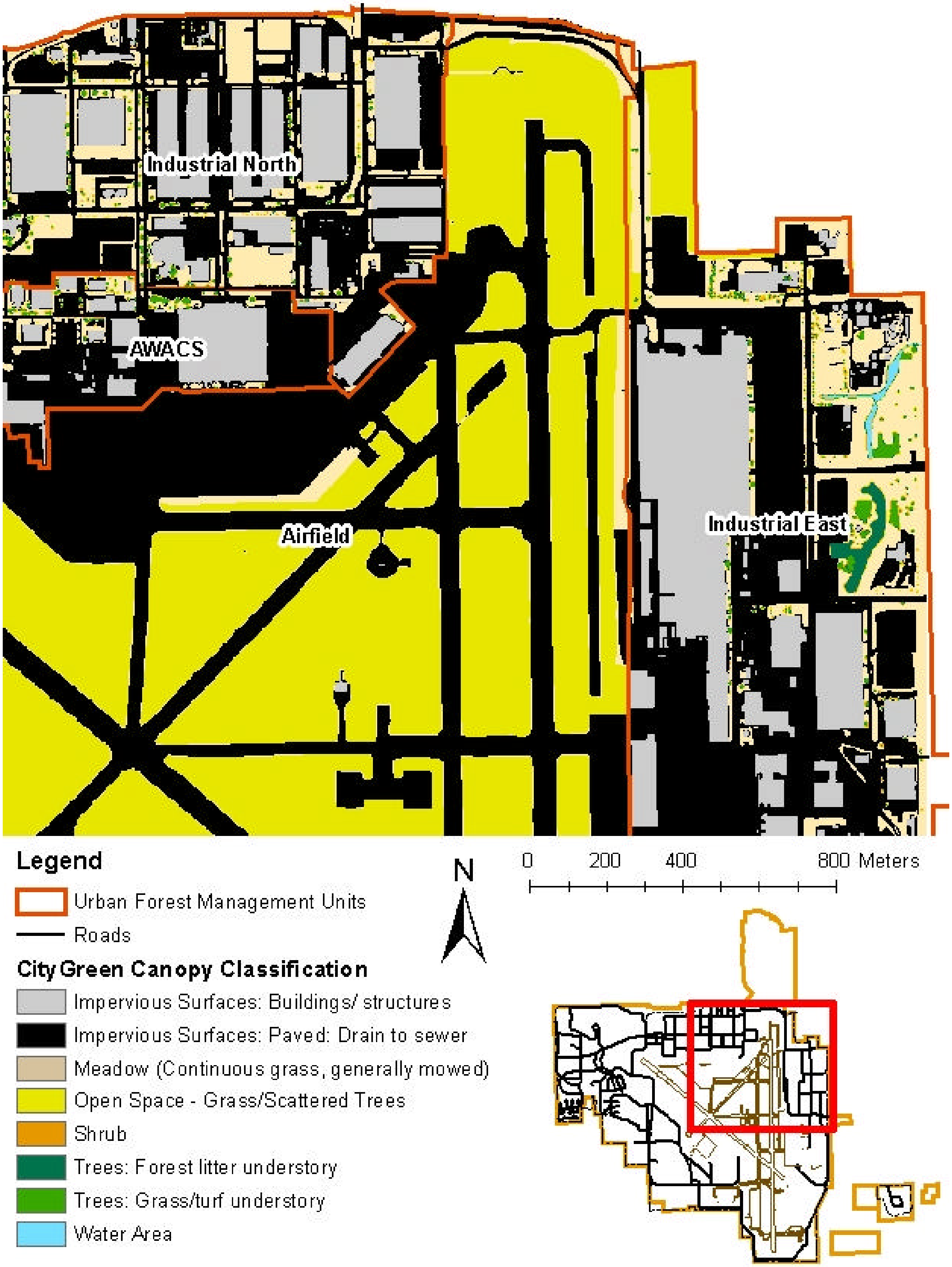

Figure 18: Tinker Air Force Base (northeast sector) CITYgreen land cover classification used for tree canopy calculations.

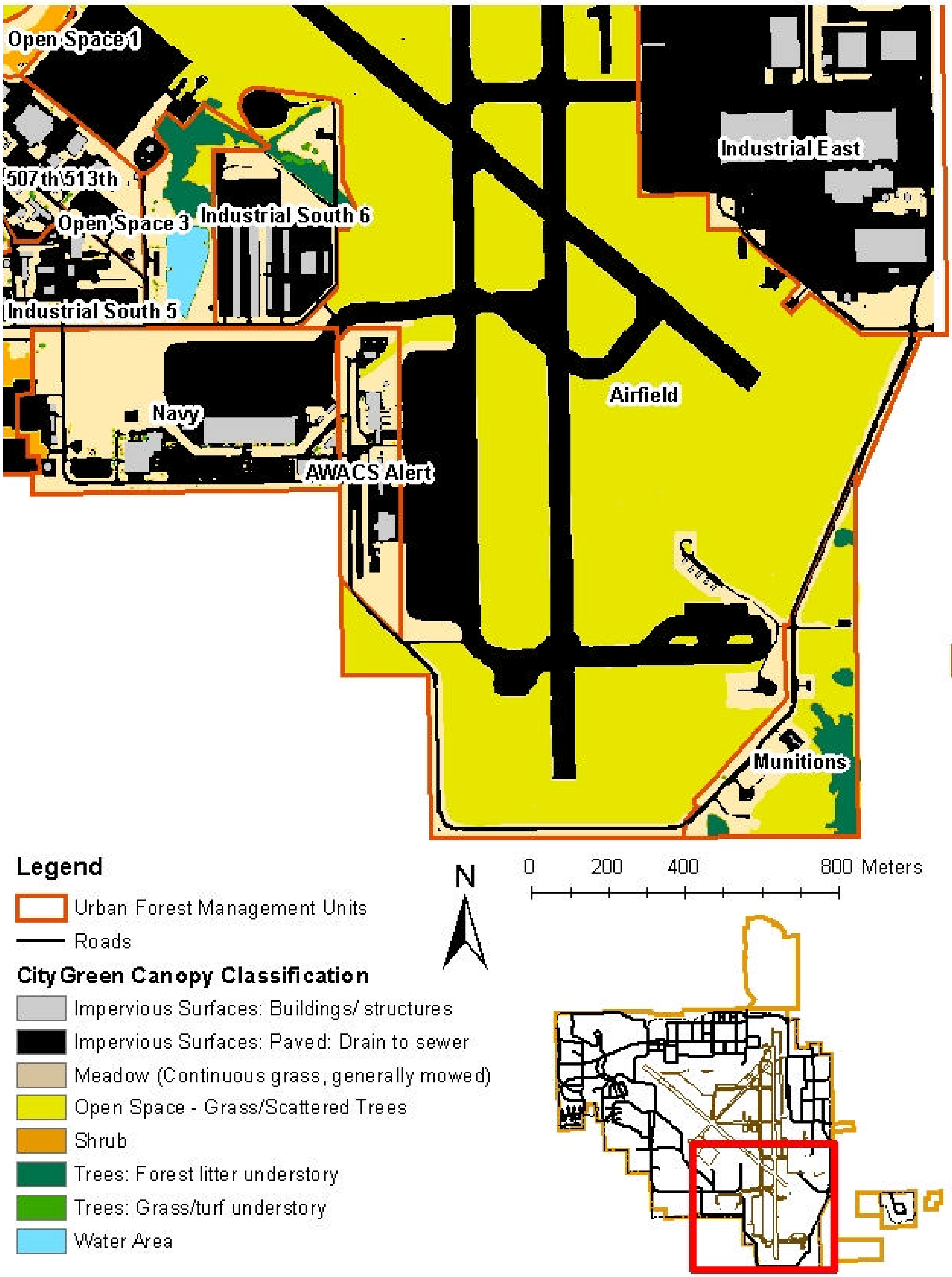

Figure 19: Tinker Air Force Base (southeast sector) CITYgreen land cover classification used for tree canopy calculations.

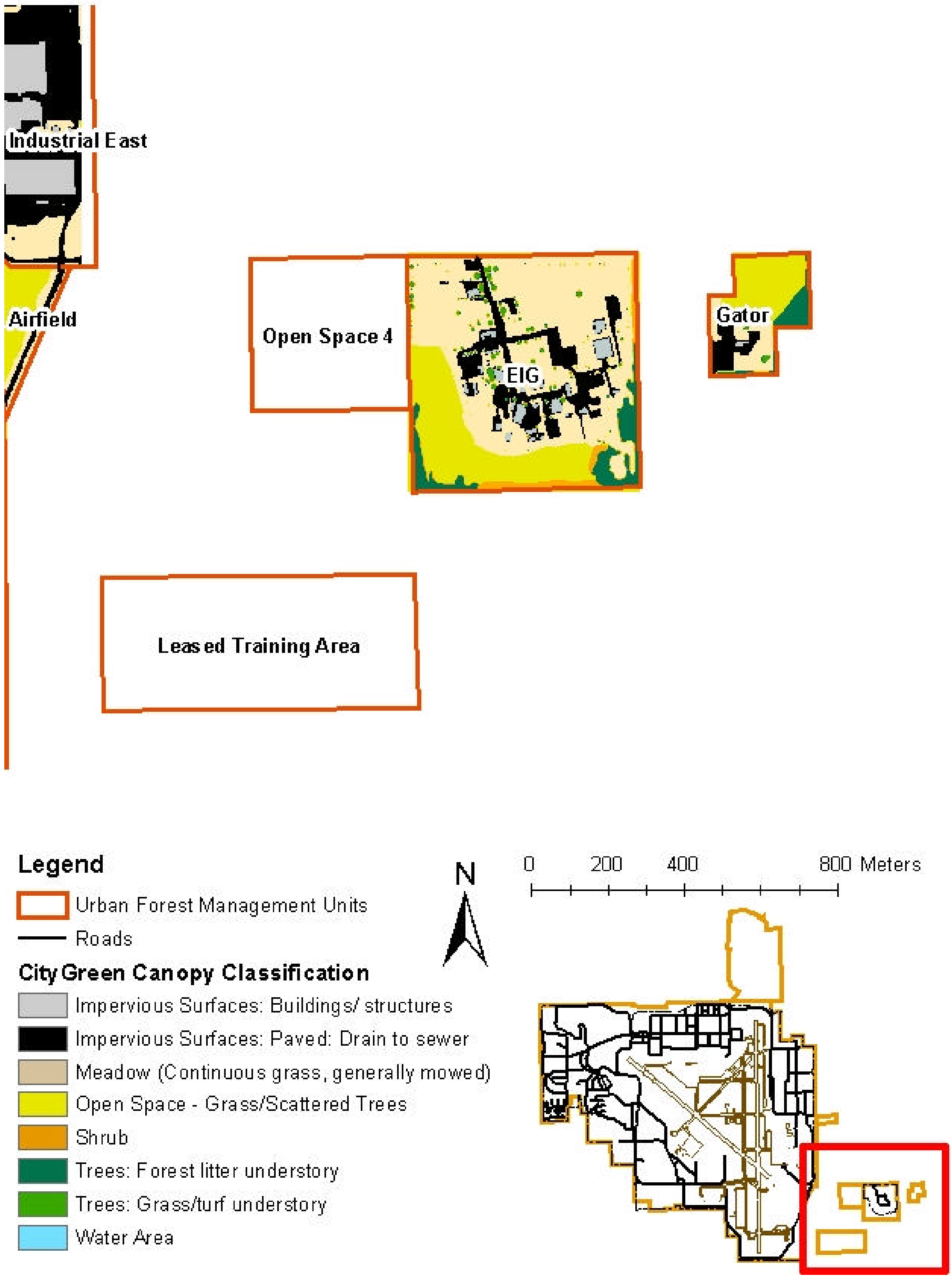

Figure 20: Tinker Air Force Base (EIG & Gator UFMUs) CITYgreen land cover classification used for tree canopy calculations.

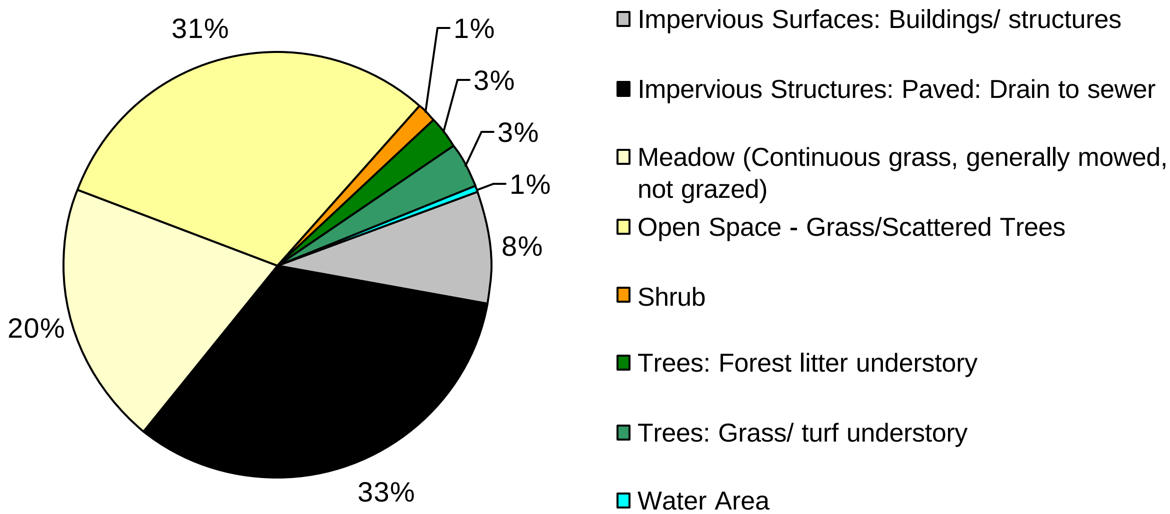

Figure 21: CITYgreen land cover classification for the entire Tinker Air Force Base. The total tree canopy coverage was 227.3 acres, representing 5.8% of the entire Tinker Air Force Base land area or 9.2% of all areas excluding the airfield.

Table 4: Land cover results from the CITYgreen analysis by urban forest management unit at Tinker Air Force Base.

Management Unit	Impervious/ Buildings (Acres)	Impervious/ Paved (Acres)	Meadow (Acres)	Open Space (Acres)	Shrub (Acres)	Trees: forest litter (Acres)	Trees: grass/ turf (Acres)	Water Area (Acres)	Mgmt Area (Acres)	Tree Canopy Area (Acres)	Tree Canopy (%) within each unit
507th\513th	5.2	17.5	13.7	0.0	0.0	0.0	0.3	0.0	36.7	0.3	1.0
Airfield	0.9	448.7	57.3	957.1	0.0	0.7	0.0	0.0	1464.7	0.7	0.0
AWACS	22.9	47.0	8.0	1.6	0.0	0.0	1.6	0.0	81.1	1.6	2.0
AWACS Alert	2.7	10.0	15.1	0.8	0.0	0.0	0.1	0.0	28.6	0.1	0.3
Community (MFH*)	22.3	44.0	86.6	13.7	10.6	2.0	41.6	0.9	221.7	43.7	19.7
Community 1	17.5	54.3	66.1	0.1	0.0	3.0	16.1	1.2	158.3	19.1	12.1
Community 2	0.6	1.8	10.8	0.3	0.0	4.6	1.1	0.0	19.0	5.6	29.7
EIG	3.2	13.1	46.9	17.0	2.4	6.0	2.0	0.0	90.5	8.0	8.9
Gator	0.1	2.5	3.0	7.5	0.0	2.9	0.1	0.0	16.0	3.0	18.5
Golf Course	0.6	19.1	146.0	6.0	0.0	12.4	45.6	3.4	233.2	58.0	24.9
Industrial East	119.2	257.0	76.0	16.6	0.0	3.1	5.1	1.5	478.5	8.2	1.7
Industrial North	100.7	170.4	73.7	1.4	0.0	0.0	5.4	0.0	351.7	5.4	1.5
Industrial South 1	4.5	11.0	9.3	0.7	0.3	0.0	0.0	0.0	25.9	0.0	0.1
Industrial South 2	1.9	19.9	8.7	11.9	0.1	0.3	0.3	0.0	42.9	0.6	1.3
Industrial South 3	0.7	4.9	12.3	42.5	0.2	0.0	0.5	0.0	61.1	0.5	0.9
Industrial South 4	3.2	28.9	12.7	0.1	0.0	0.3	0.2	0.0	45.4	0.5	1.0
Industrial South 5	2.4	22.3	10.8	0.1	3.3	0.0	0.2	0.0	39.2	0.2	0.6
Industrial South 6	5.6	22.5	11.7	2.3	0.0	3.5	0.5	0.0	46.0	4.0	8.7
Munitions	0.2	4.3	13.4	23.0	0.0	7.9	0.0	0.0	48.7	7.9	16.2
Navy	7.4	41.6	35.0	0.0	0.7	0.0	0.7	0.0	85.4	0.7	0.8
Open Space 1	0.0	5.3	29.9	25.4	13.5	31.9	2.0	0.1	108.2	34.0	31.4
Open Space 2	0.2	12.3	23.5	72.8	22.9	14.4	2.6	10.0	158.8	17.0	10.7
Open Space 3	0.1	2.1	8.5	2.3	0.0	7.3	0.1	5.1	25.5	7.5	29.2
Third Herd	4.8	33.9	15.3	0.3	0.0	0.0	0.4	0.0	54.6	0.4	0.8
								Total	4914.0	452.6	

Tree canopy for the entire base excluding the airfield = 9.2%

*MFH = Military Family Housing

Table 5: Each Urban Forest Management Unit (UFMU) at Tinker Air Force Base was classified as 1 of 3 American Forests canopy cover zone, so that the tree canopy cover could be compared with American Forests' canopy cover goals.

UFMU	Suburban residential zone	Urban residential zone	Central business district
507th/513th			X
AWACS			X
AWACS Alert			X
Community (Commercial) 1		X	
Community (Commercial) 2		X	
Community (MFH)	X		
EIG			X
Gator			X
Golf Course	X		
Industrial East			X
Industrial North			X
Industrial South 1			X
Industrial South 2			X
Industrial South 3			X
Industrial South 4			X
Industrial South 5			X
Industrial South 6			X
Munitions	X		
Navy			X
Open Space 1	X		
Open Space 2	X		
Open Space 3	X		
Third Herd			X
Acreage	593.4	380.0	1483.6
Total Percent Tree Canopy	7%	7%	2%
American Forests Goals	35%	18%	9%

3.4. i-Tree STRATUM

The STRATUM analysis was only performed for the AWACS and Industrial North UFMUs, as it was intensely time consuming to format the existing GIS data and to interpret the additional data necessary for the program as well as being able to guarantee all trees analyzed were street trees. Callery pear (Pyrus calleryana) was the most abundant species within the combined study area, comprising 12.7% of the population (Figure 22). It was also the most abundant species within the AWACS zone, comprising 21.8% (

Table 6). Eastern redcedar (*Juniperus virginiana*) was the most abundant species within the Industrial North zone with 11.2% of the zone's population.

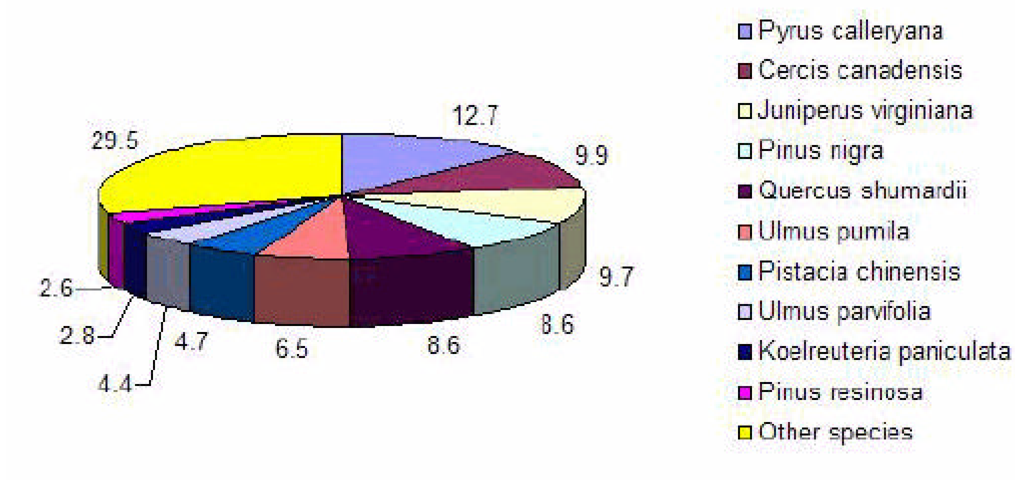

Figure 22: The species composition (%) within the AWACS and Industrial North UFMU at Tinker AFB calculated by the STRATUM program.

Table 6: The top 5 most abundant species (%) for each zone as well as the combined study area calculated by STRATUM.

Zone	1st (%)	2nd (%)	3rd (%)	4th (%)	5th (%)	# of Trees
AWACS	Callery pear (21.8)	Eastern redbud (9.4)	Austrian pine (9.4)	Cherry plum (5.9)	Panicled goldenraint (5.4)	202
INDNORTH	Eastern red cedar (11.2)	Shumard oak (10.2)	Eastern redbud (10.1)	Callery pear (10.1)	Austrian pine (8.3)	686
Citywide total	Callery pear (12.7)	Eastern redbud (9.9)	Eastern red cedar (9.7)	Austrian pine (8.6)	Shumard oak (8.6)	888

Table 7: The importance value for the most abundant tree species within the study area from STRATUM.

Species	Number of Trees	% of Total Trees	Leaf Area (ft^2)	% of Total Leaf Area	Canopy Cover (ft^2)	% of Total Canopy Cover	Importance Value
Pyrus calleryana	113	12.7	80,800	9.3	46,106	14.7	12.2
Cercis canadensis	88	9.9	4,247	0.5	8,126	2.6	4.3
Juniperus virginiana	86	9.7	77,722	8.9	17,067	5.4	8.0
Pinus nigra	76	8.6	104,269	12.0	20,892	6.6	9.1
Quercus shumardii	76	8.6	41,444	4.8	18,625	5.9	6.4
Ulmus pumila	58	6.5	207,106	23.8	77,222	24.6	18.3
Pistacia chinensis	42	4.7	6,299	0.7	5,837	1.9	2.4
Ulmus parvifolia	39	4.4	127,284	14.6	39,698	12.6	10.6
Koelreuteria paniculata	25	2.8	5,191	0.6	6,594	2.1	1.8
Pinus resinosa	23	2.6	17,188	2.0	5,282	1.7	2.1
Malus species	22	2.5	1,811	0.2	3,240	1.0	1.2
Platanus occidentalis	22	2.5	33,198	3.8	12,633	4.0	3.4
Pinus sylvestris	19	2.1	38,132	4.4	6,138	2.0	2.8
Fraxinus pennsylvanica	18	2.0	20,806	2.4	7,974	2.5	2.3
Acer ginnala	16	1.8	469	0.1	1,261	0.4	0.8
Pinus taeda	16	1.8	12,935	1.5	3,621	1.2	1.5
Ulmus species	16	1.8	2,001	0.2	1,062	0.3	0.8
Celtis occidentalis	14	1.6	12,119	1.4	4,323	1.4	1.4
Prunus cerasifera	12	1.4	611	0.1	1,354	0.4	0.6
Fraxinus species	10	1.1	4,751	0.5	3,023	1.0	0.9
Quercus macrocarpa	9	1.0	224	0.0	91	0.0	0.4
Other trees	88	9.9	70,816	8.1	24,225	7.7	8.6
Total	888	100.0	869,423	100.0	314,396	100.0	100.0

STRATUM calculates an importance value (IV) to demonstrate the abundance and dominance of each tree species within the urban forest. The importance value is calculated by adding three relative values, the percent of total trees, the percent of total leaf area, and the percent of canopy cover and dividing by 3. The total leaf area for each species is calculated within the program using DBH and regression equations. If a tree species has an IV of 100, then the urban forest has a total reliance upon that particular species. Table 7 shows that the most important species is the Siberian elm (*Ulmus pumila*) with an IV of 18.3.

The annual benefits of trees can be calculated by zone or species. The more appropriate comparison is the annual benefits by species, as the zones are different sizes and have differing amount of trees. The species with the largest benefit ($/tree) is Siberian elm (Table 8).

Table 8: The annual benefit of trees by species ($/tree) calculated by STRATUM within the combined study area.

Species	Energy	CO_2	Air Quality	Stormwater	Aesthetic/Other	Total ($) Standard Error
Pyrus calleryana	23.95	2.92	3.60	16.98	24.55	72.00 (N/A)
Cercis canadensis	5.38	0.54	0.73	1.95	1.85	10.45 (N/A)
Juniperus virginiana	10.55	0.75	0.78	17.57	13.54	43.20 (N/A)
Pinus nigra	15.27	1.39	1.52	24.56	19.18	61.92 (N/A)
Quercus shumardii	12.79	1.79	1.96	11.15	20.25	47.94 (N/A)
Ulmus pumila	57.06	6.79	9.83	65.83	39.35	178.87 (N/A)
Pistacia chinensis	8.76	1.11	1.20	4.71	11.82	27.60 (N/A)
Ulmus parvifolia	47.69	6.61	7.89	56.38	49.11	167.68 (N/A)
Koelreuteria	15.11	1.53	2.24	6.22	5.59	30.69 (N/A)
Pinus resinosa	13.11	1.09	1.43	16.56	15.40	47.59 (N/A)
Malus species	8.48	0.84	1.16	3.16	3.06	16.69 (N/A)
Platanus	30.28	4.20	4.95	28.46	34.96	102.85 (N/A)
Pinus sylvestris	17.48	1.60	1.43	31.57	21.09	73.17 (N/A)
Fraxinus	22.80	3.16	3.65	21.89	28.44	79.94 (N/A)
Acer ginnala	4.55	0.47	0.60	1.55	1.68	8.85 (N/A)
Pinus taeda	12.58	0.95	1.36	17.23	17.77	49.88 (N/A)
Ulmus species	3.52	0.49	0.51	2.79	9.68	16.98 (N/A)
Celtis occidentalis	13.19	1.28	2.24	14.75	12.76	44.21 (N/A)
Prunus cerasifera	6.47	0.66	0.86	2.30	2.42	12.71 (N/A)
Fraxinus species	18.17	2.24	2.68	11.97	19.83	54.89 (N/A)
Quercus	0.66	0.05	0.08	0.48	5.26	6.54 (N/A)
Other street trees	13.73	1.66	1.98	14.35	20.13	51.86 (N/A)

3.5. CITYgreen vs i-Tree STRATUM

A comparison of CITYgreen and i-Tree STRATUM software could not be done, as they do not produce the same type of information. CITYgreen computes ecological benefits and their monetary values based on the UFORE formula and STRATUM does not. There is a component of the i-Tree software suite, Urban Forest Effects, that quantifies urban forest structure and function based on standard inputs of field, meteorological, and pollution data, but it requires more data than those collected during the original inventory. CITYgreen also looks at the tree canopy as one entity instead of a collection of individual tree canopies and does not consider tree species. STRATUM assesses the value of each tree, using a calculated estimate of a tree species' leaf area. The programs are evaluating the urban forest at different levels.

CITYgreen and STRATUM are useful tools for urban forest managers. To decide which one should be used the managers first need to look at the desired output and then at the required data for each program and decide which one is most appropriate. Both can use inventory data, but i-Tree is easier to use if the data does not have a spatial component or was collected using the program initially. It is very time consuming to reformat an existing GIS inventory to comply with the program. Both programs can estimate a variety of environmental benefits including stormwater and air quality. Overall, both programs are user friendly and can provide estimates of environmental benefits.

3.6. Virginia Tech Campus

The Virginia Tech inventory is incomplete. As of July 2007, 2393 urban trees have been inventoried on the Virginia Tech campus (Figure 23). The central part of campus has been completed and is now being checked for errors and incorrect species identification. Based on existing data, the most abundant species is Sugar maple (*Acer saccharum*), accounting for almost 9% of inventoried trees (Figure 26). Because unnamed maples (*Acer spp.*) comprise 4%, the species composition could appear different after errors have been corrected and species fully identified.

According to Santamour's species diversity model (Santamour 1990), less than 30% of the total tree population should be comprised of single family (Figure 24), less than 20% should be comprised of a single genus (Figure 25), and less than 10% should be comprised of a single species (Figure 26).This guideline is only exceeded by a single genus, Acer with 24%.

Figure 27 shows the tree condition ratings for the current Virginia Tech inventory. Over 50% of the trees are in good condition, while 36% are in fair condition, with only 7% in poor condition.

According to an idealized tree size distribution model proposed by Richards (Richards 1983), 40% of the tree population should be less than 20 cm (~8 in.) DBH, 30% of the tree population should be between 20 and 40 cm (~8 – 15 in.) DBH, 20% of the tree population should be between 40 and 60 cm (~16 – 24 in.) DBH and 10% above 60 cm (~ 24 in.) DBH. The Virginia Tech urban forest loosely follows these criteria (Figure 28). In the future, these goals can be adjusted accordingly with careful planning.

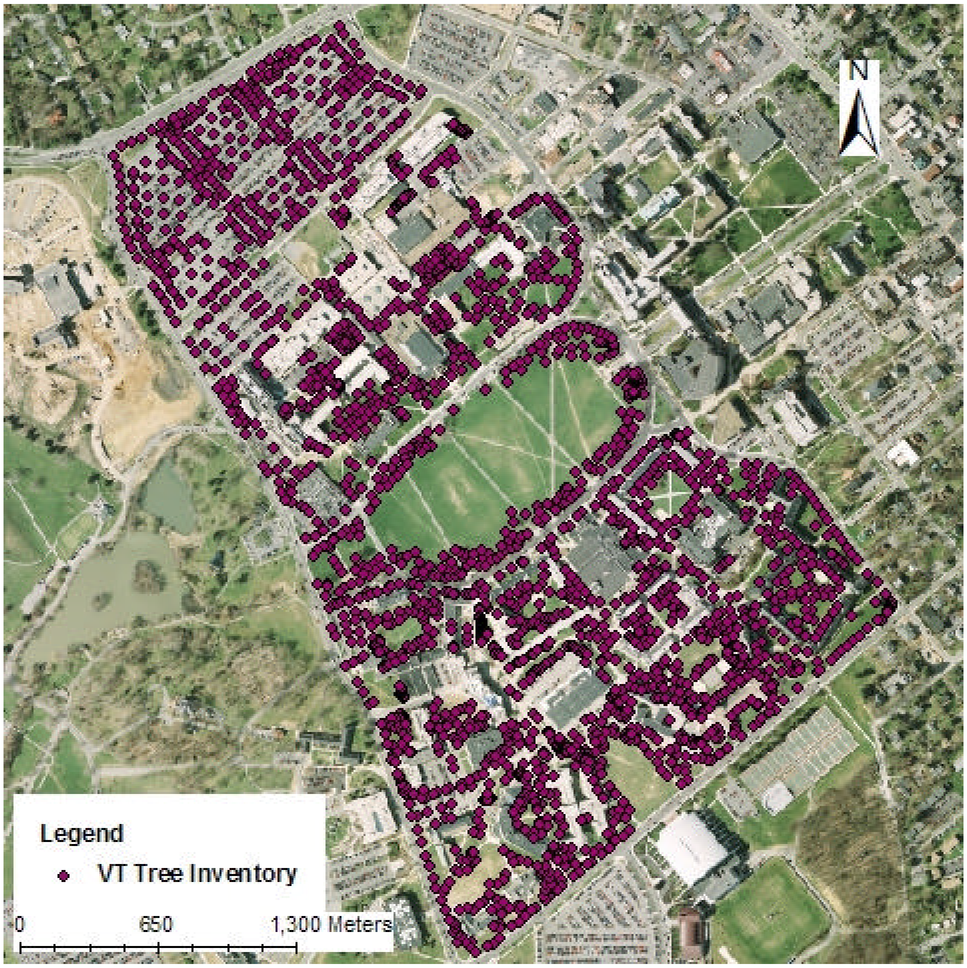

Figure 23: A map of trees inventoried on the Virginia Tech campus between February 2006 and July 2007.

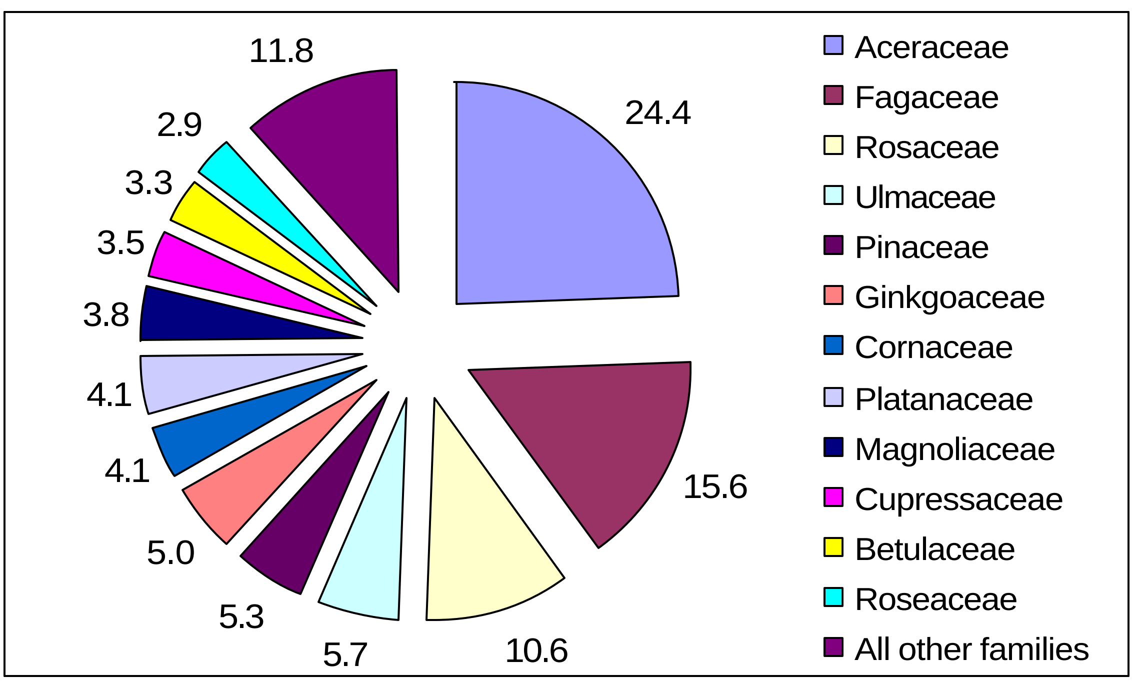

Figure 24: The family composition (% of total tree count) of trees on the VT campus based on the existing inventory data.

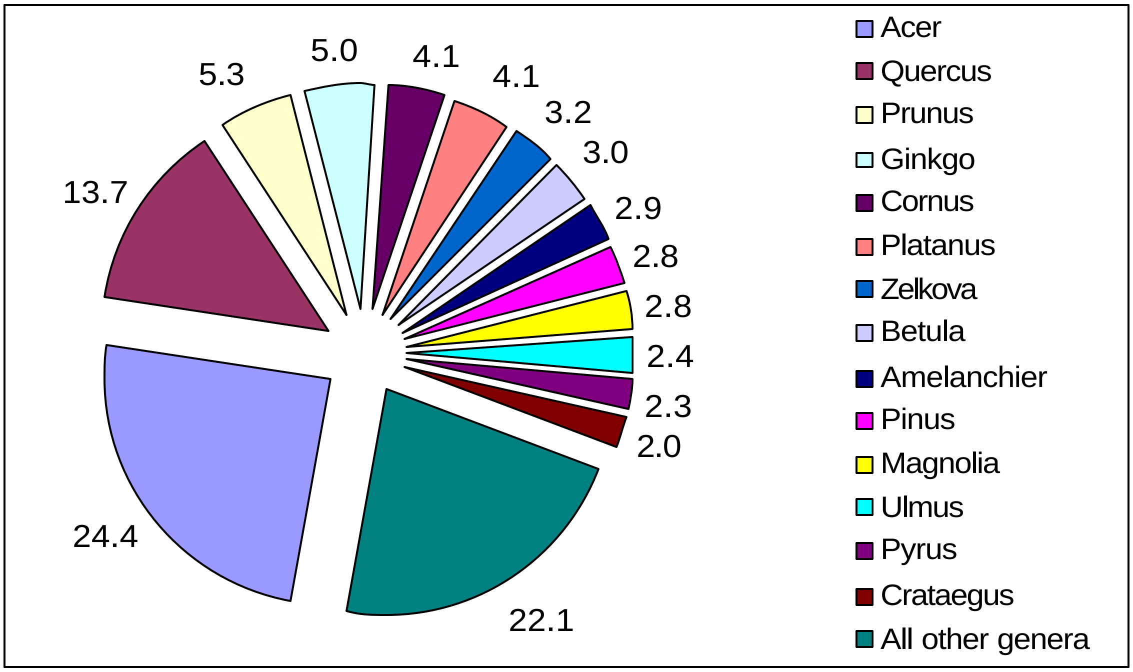

Figure 25: The genus composition (% of total tree count) of trees on the VT campus based on the existing inventory data.

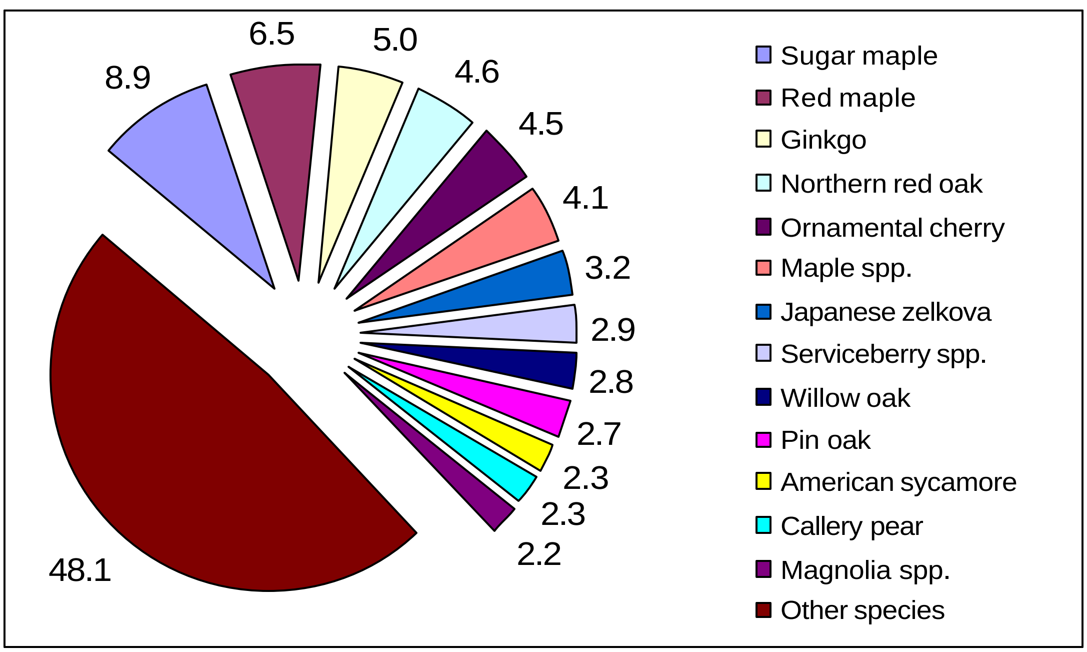

Figure 26: The species composition (% of total tree count) of trees on the VT campus based on the existing inventory data.

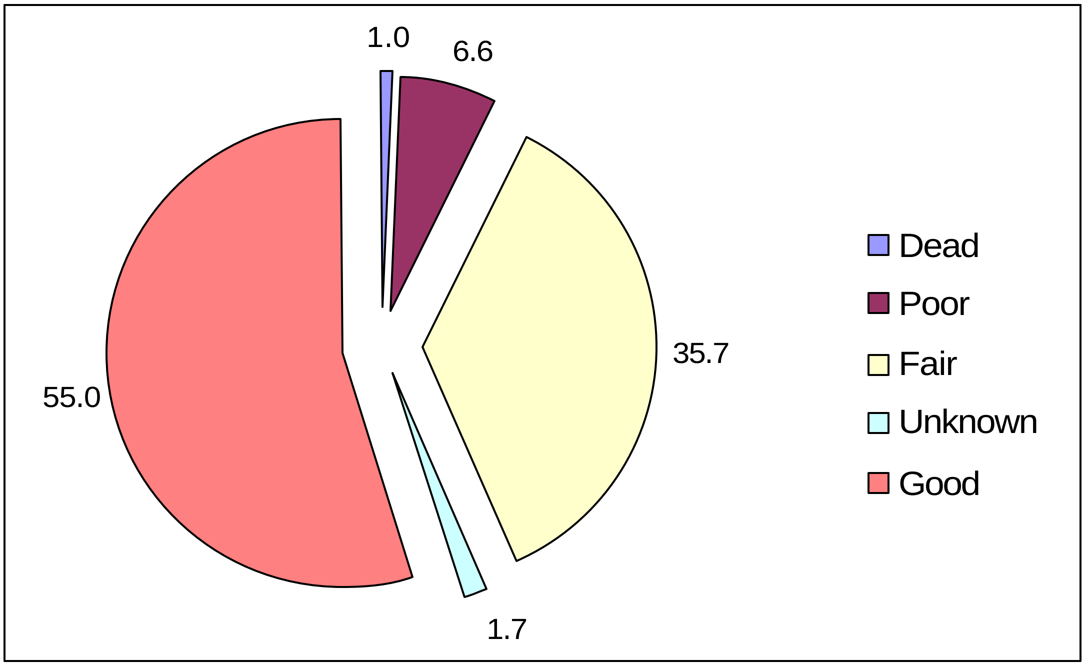

Figure 27: The condition composition (% of total tree count) of trees on the VT campus based on the existing inventory data.

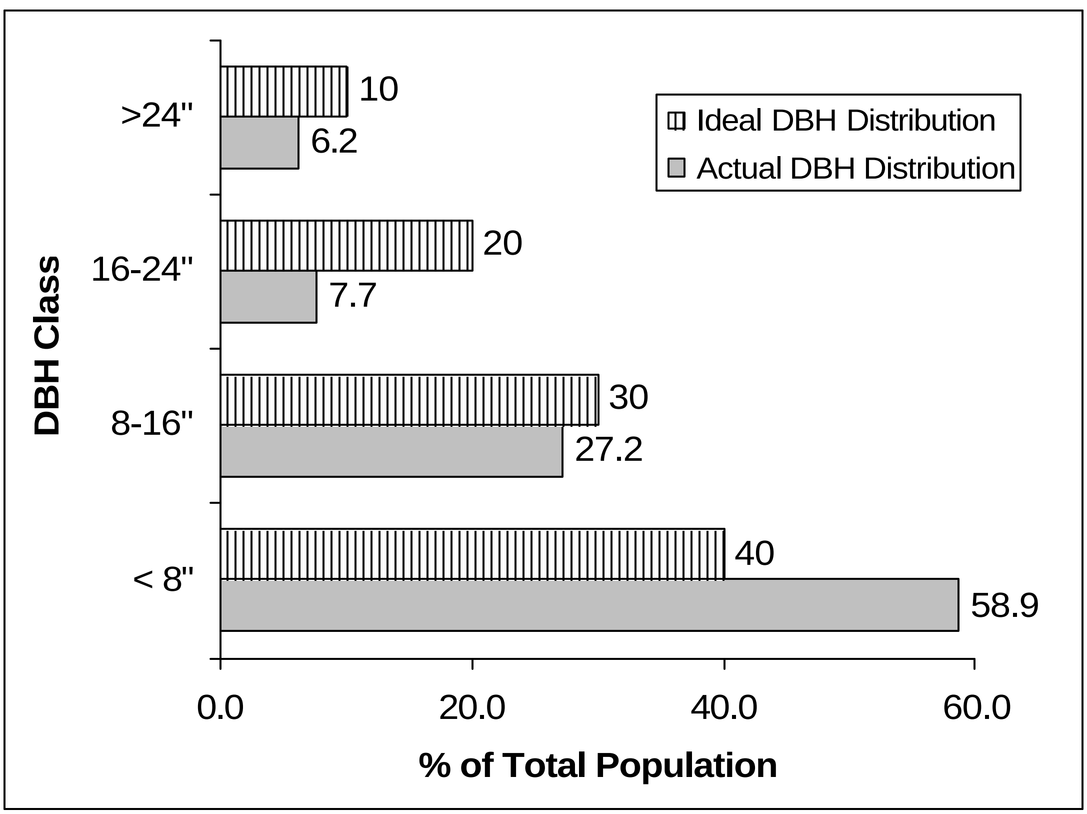

Figure 28: Actual vs. ideal DBH (trunk diameter at 4.5 ft above ground line) distribution of the urban forest on the VT campus based on the existing inventory data. The ideal DBH distribution is from Richards (1983).

3.7. Conclusion

Urban forest inventories are an important part of managing an urban forest. They provide a baseline of the urban forest to work from, facilitate management decisions, and provide a basis for evaluation of management efforts over time.

The urban forest at Tinker AFB contains 6604 urban trees. The overall canopy cover for the base is 9.2%. The most numerous species within the urban forest is Eastern redcedar (*Juniperus virginiana*). According to Santamour's species diversity model (Miller 1997), this species is exceeding the 10% guideline for a single species. This model addresses the problem of planting too many of a single species, which could be lost during an event or have undesirable traits. Using Santamour's species diversity model, Richard's age diversity model, and the knowledge of an arborist, attainable management goals can be set for Tinker AFB.

Virginia Tech's urban forest contains 2393 urban trees, at its current inventory status. The most abundant species is Sugar maple (*Acer saccharum*), comprising approximately 9% of the population. This could change once the inventory is checked for errors and species are fully identified. Only the genus Acer exceeds Santamour's species diversity model with 24%

GIS can be a powerful tool in a manager's toolbox. By implementing a GIS tree inventory, managers can calculate which trees may be obstacles without having to survey every tree. Once possible obstacles are known, those trees can be surveyed and management can decide on their course of action. GIS not only allows managers to perform analysis of all kinds, they can also use it to disseminate information. A possible use for the Virginia Tech tree inventory is to create a webGIS, allowing anyone with internet access to explore the data. WebGIS is a website that displays interactive GIS maps and can be customized for functions and content. Possible functions could be updating data from the field or allowing users to search for a specific piece of information and then download it for personal use. GIS can be a powerful tool for anyone in just about any field.

An urban forest is a living entity and requires constant vigilance to keep it healthy and safe for people. Dedicated staff members and an up-to-date or periodically updated inventory can aid in the management of this important resource. GIS can aid in keeping an inventory up-to-date and can help managers create detailed management plans and goals for their areas.

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Appendix A: Tinker AFB Data Collection

1) Geographic location from high resolution digital orthophotography (Tobin International 2004) and/or field computer with ±15 meter GPS unit
2) Scientific and common names
3) Diameter at breast height (DBH)
4) Tree height
5) Crown radius
6) Age Class
   a) Young – Still establishing, transplanted less than 4 years ago
   b) Immature – Has not reached the typical maximum size for the species
   c) Mature – Has reached the typical maximum size for species
7) Condition
   a) Good – No apparent problems
   b) Fair – Minor problems
   c) Poor – Major problems
   d) Dead – No signs of life
8) Soil/root problems (could pick up to 3 most applicable)
   a) Poor drainage – Soil drains poorly due to low topography, concentrated runoff, over-irrigation, high water table, compacted subsoil
   b) Compaction – Soil compacted due to vehicular/pedestrian traffic and lack of protection with mulch
   c) Low volume – Rootable soil volume limited by hardscape, compacted soil, waterlogged soil
   d) Soil heave – Uplifting of soil near base of tree due to root system failure
   e) Buried root collar – Root flares are not visible above soil line
   f) Wound – Tearing of bark, crushing of inner bark/cambium from physical contact by equipment, vandalism, lightning
   g) Decay – Decomposition of wood by microorganisms
   h) Construction, cut – Evidence of past grading during which soil within root zone was removed
   i) Construction, fill – Evidence of past grading during which soil was placed within the root zone
   j) Construction, trench – Evidence of past trenching within the root zone
   k) Deep planting – Tree planted too deeply
   l) Poor planting – Evidence that root ball packaging material was not removed at planting
   m) Girdling root – A root that encircles more than 1/3 of the stem circumference above the root collar
   n) Deep mulch – Mulch more than 4 inches deep or burying the root collar
   o) Pest – Signs/symptoms of damaging insects, disease pathogens, animals, or parasitic plants
   p) Arborist Evaluation – Has major soil problems, needs expert evaluation
9) Trunk problem (could pick up to 3 most applicable)
   a) Decay – Decomposition of wood by microorganisms
   b) Crack – Separation of the wood; a deep split through the bark and into the wood
   c) Lean – Orientation of the trunk is not vertical
   d) Cavity – Void caused by complete decay of wood

   e) Codominant – Multiple upright stems of similar height and diameter
   f) Wound – Tearing of bark, crushing of inner bark/cambium from physical contact by equipment, vandalism, lightning
   g) Pest – Signs/symptoms of damaging insects, disease pathogens, animals, or parasitic plants
   h) Object – Any object that is physically attached or situated close to the stem and causing injury
   i) Arborist Evaluation – Has major trunk problems, needs expert evaluation

10) Crown problem (could pick up to 3 most applicable)
   a) Decay – Decomposition of wood by microorganisms in major scaffold branch(es)
   b) Crack – Separation of the wood; a deep split through the bark and into the wood in major scaffold branch(es)
   c) Weak union – Large epicormic branch(es) or major scaffold branch(es) with included bark
   d) Poor form – Vertical or horizontal imbalance in branch distribution
   e) Wound – Tearing of bark, crushing of inner bark/cambium from physical contact by equipment, vandalism, lightning
   f) Pest – Signs/symptoms of damaging insects, disease pathogens, animals, or parasitic plants
   g) Dead wood – Significant accumulation of dead branches in crown
   h) Object – Any object that is physically attached or situated close to the stem and causing injury
   i) Decline – Overall thinning of foliage and live branches due to stress
   j) Chlorosis – Yellowing of foliage
   k) Necrosis – Death of foliage
   l) Topped – Inappropriate pruning to reduce crown size
   m) Ugly – Structurally sound, but not aesthetically pleasing
   n) Arborist Evaluation – Has major crown problems, needs expert evaluation

11) Conflict – The tree is in direct conflict with one of the following or breached the required clearance (could pick up to 3 most applicable), clearances were provided by Tinker AFB personnel
   a) Fence
   b) Sidewalk - Requires 8 foot clearance
   c) Utility
   d) Sign
   e) Light
   f) Road - Requires 14 foot clearance
   g) Building - Requires 4 foot clearance
   h) Parking lot - Requires 12 foot clearance
   i) Mower - Requires 8 foot clearance

12) Pruning Priority
   a) Major – Major pruning is needed to improve health, safety, or appearance
   b) Moderate – Moderate pruning is needed to improve health, safety, or appearance
   c) Minor – Minor pruning is needed to improve health, safety, or appearance
   d) None – No pruning is needed at this time

13) Pruning Type
   a) Structural
   b) Raising
   c) Cleaning

d) Thinning
e) Reducing
f) Arborist Evaluation - Has major problems, needs expert evaluation

14) Hazard rating
   a) High – Failure is imminent and personal injury/property damage is inevitable; corrective action is required
   b) Moderate – Failure and personal injury/property damage are likely; corrective action is recommended
   c) Low – Failure and personal injury/property damage are unlikely; corrective action is not necessary

Notes – additional information deemed important: tree guard, poison ivy, staking, etc.

Appendix B: Additional Tinker AFB Graphs and Tables

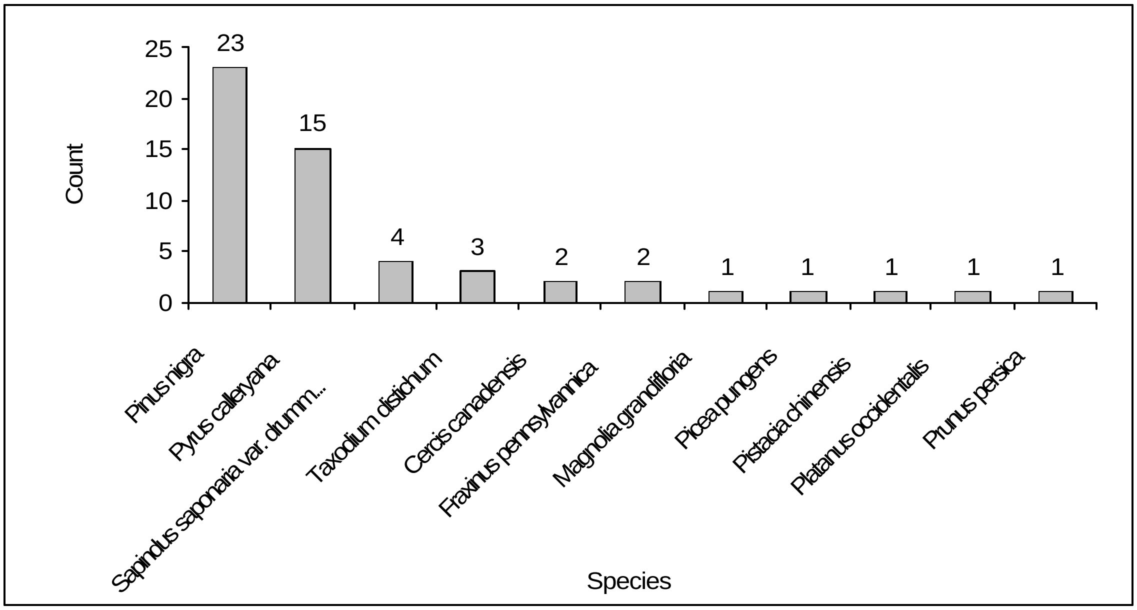

Figure 29: All urban tree species in the 507th/513th urban forest management unit at Tinker Air Force Base.

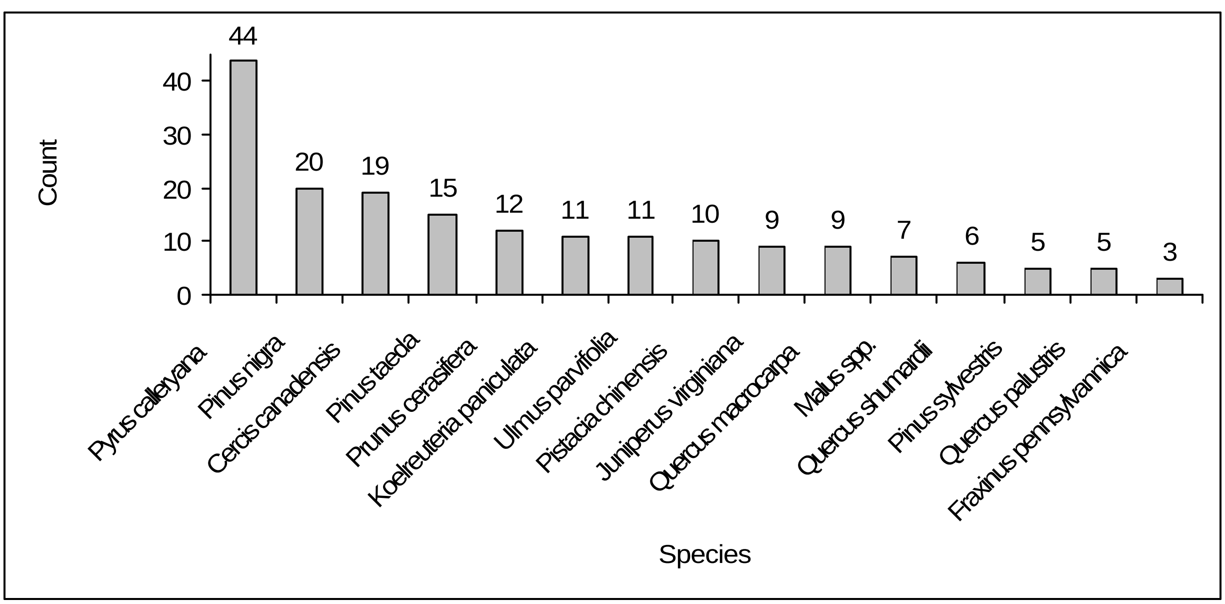

Figure 30: The 15 most common urban tree species in the AWACS urban forest management unit at Tinker Air Force Base.

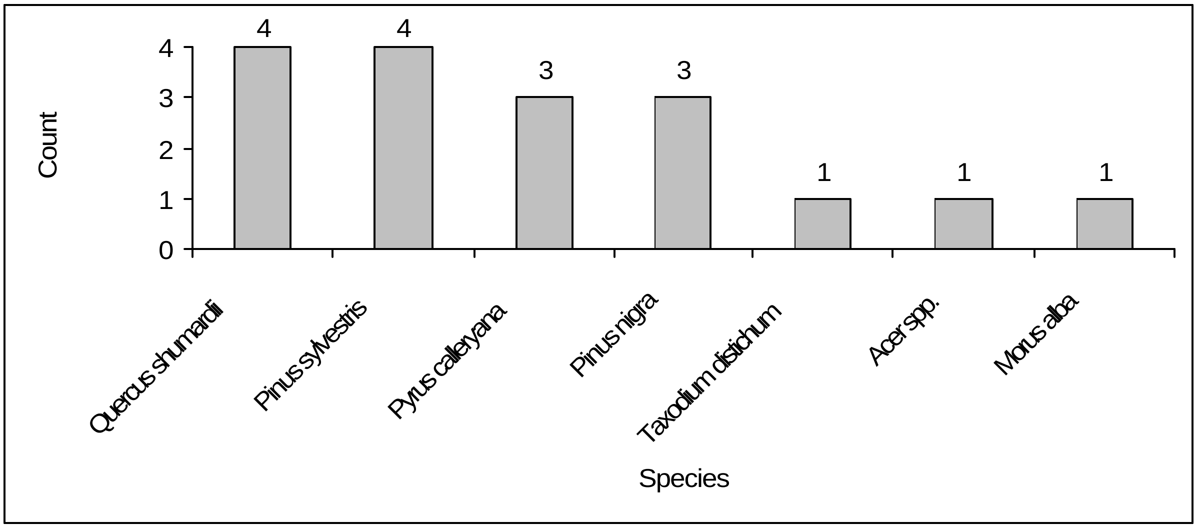

Figure 31: All urban tree species in the AWACS Alert urban forest management unit at Tinker Air Force Base.

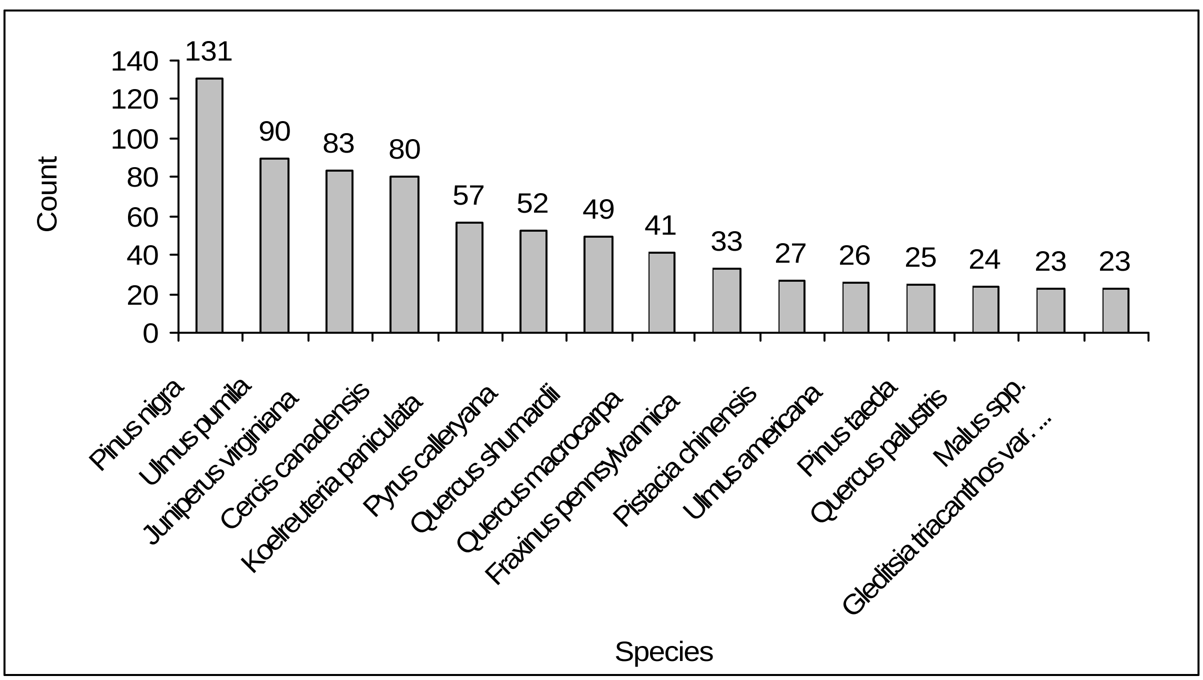

Figure 32: The 15 most common urban tree species in the Community (Commercial) 1 urban forest management unit at Tinker Air Force Base.

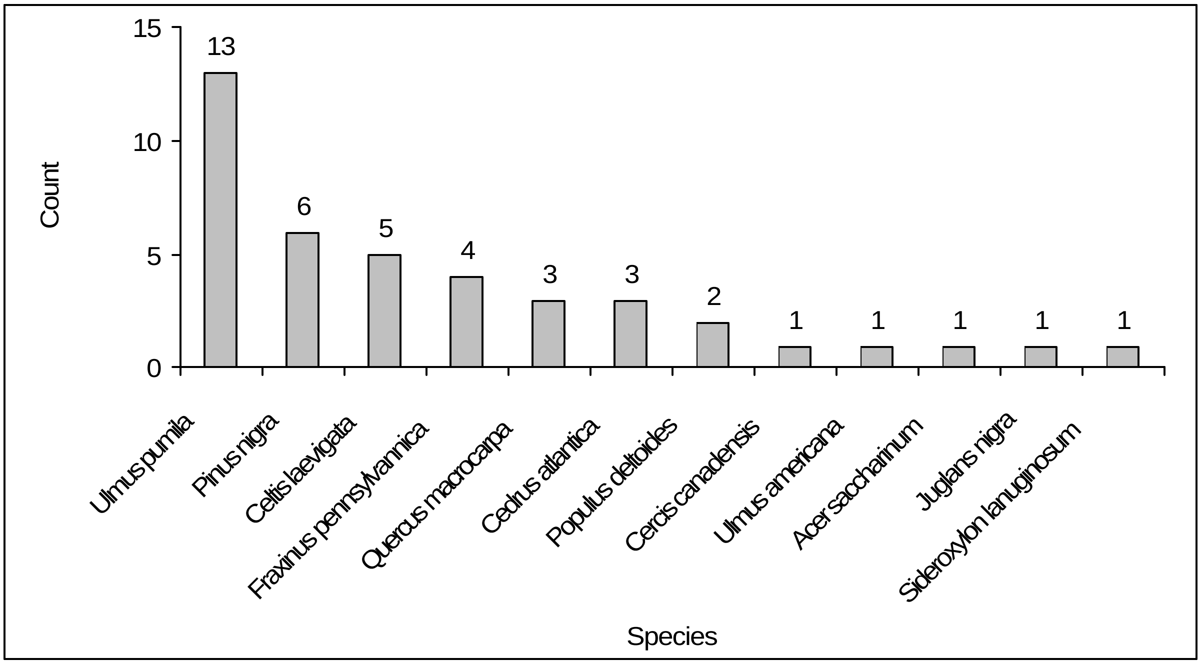

Figure 33: The 15 most common urban tree species in the Community (Commercial) 2 urban forest management unit at Tinker Air Force Base.

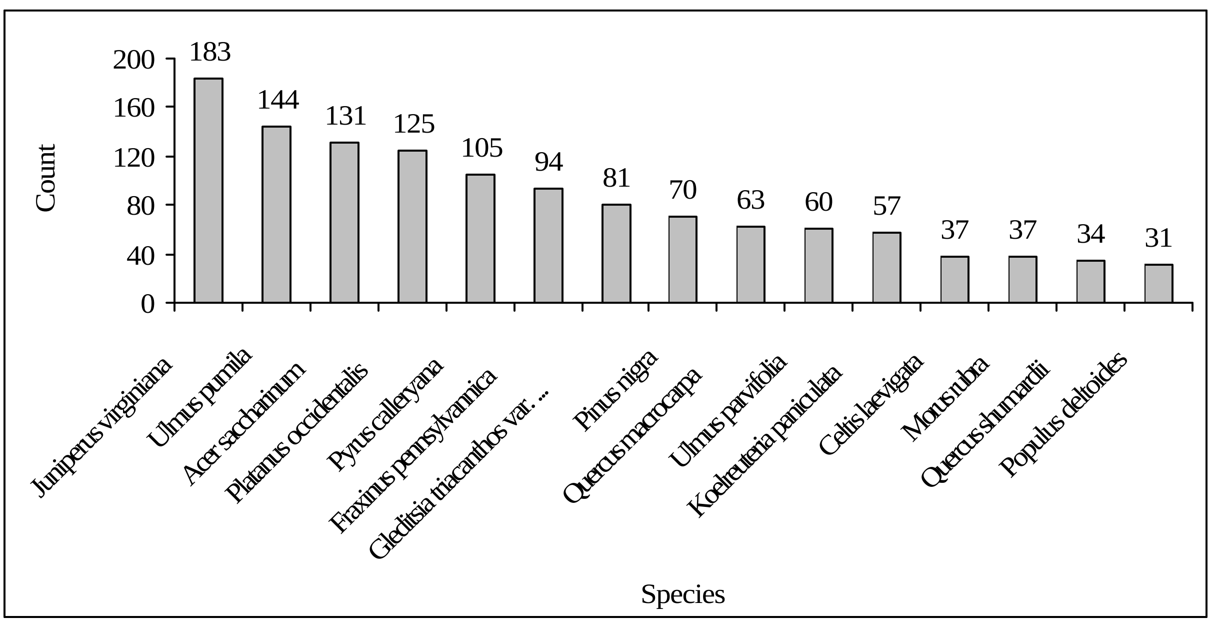

Figure 34: The 15 most common urban tree species in the Community (Residential - Military Family Housing) urban forest management unit at Tinker Air Force Base.

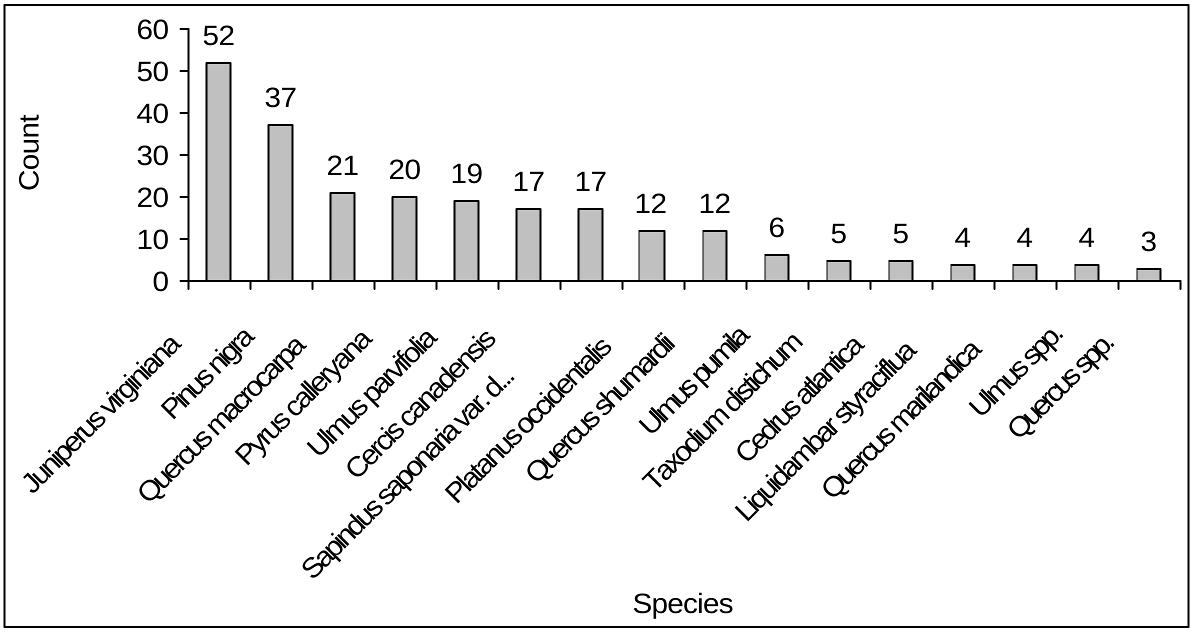

Figure 35: All urban tree species in the EIG urban forest management unit at Tinker Air Force Base.

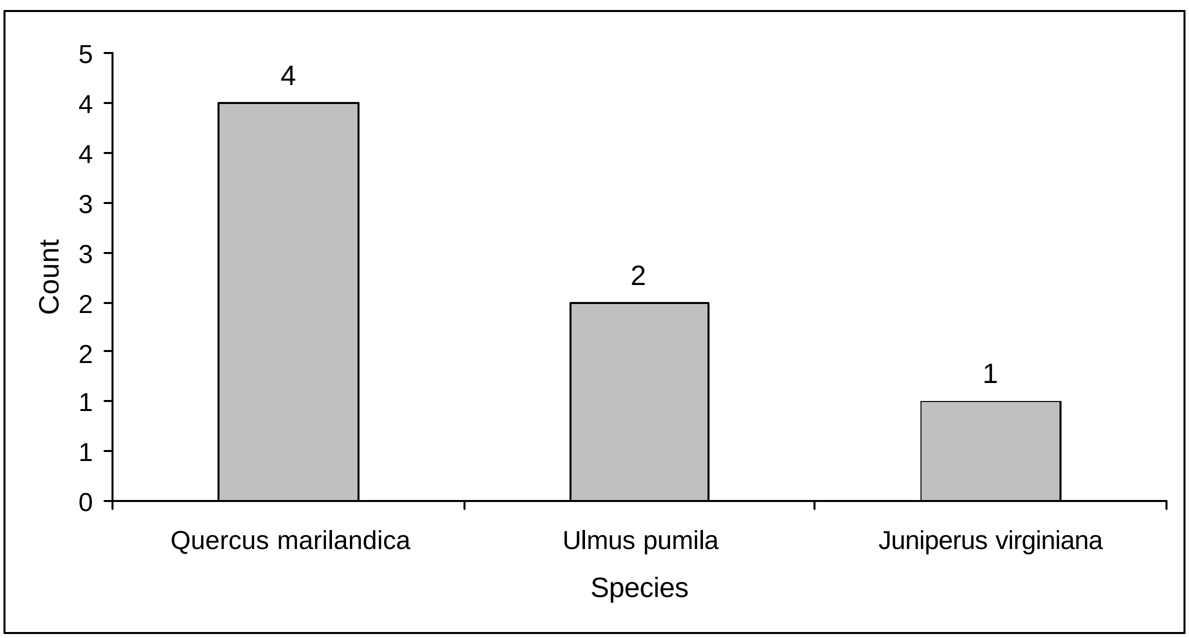

Figure 36: All urban tree species in the Gator urban forest management unit at Tinker Air Force Base.

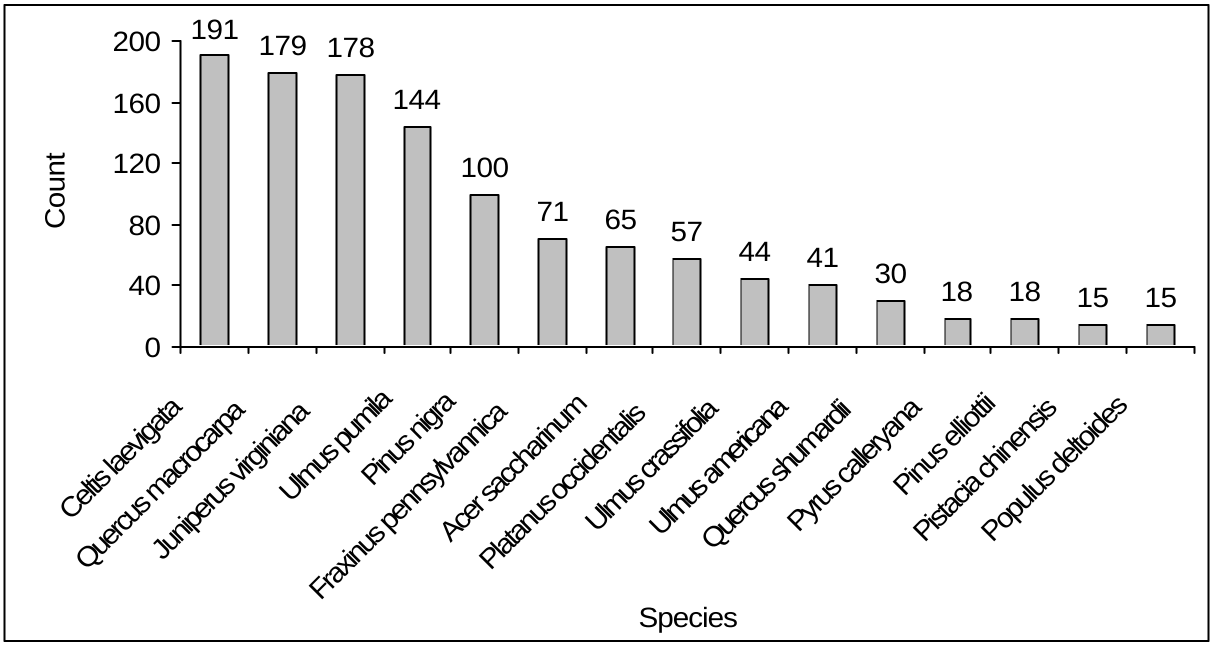

Figure 37: The 15 most common urban tree species in the Golf Course urban forest management unit at Tinker Air Force Base.

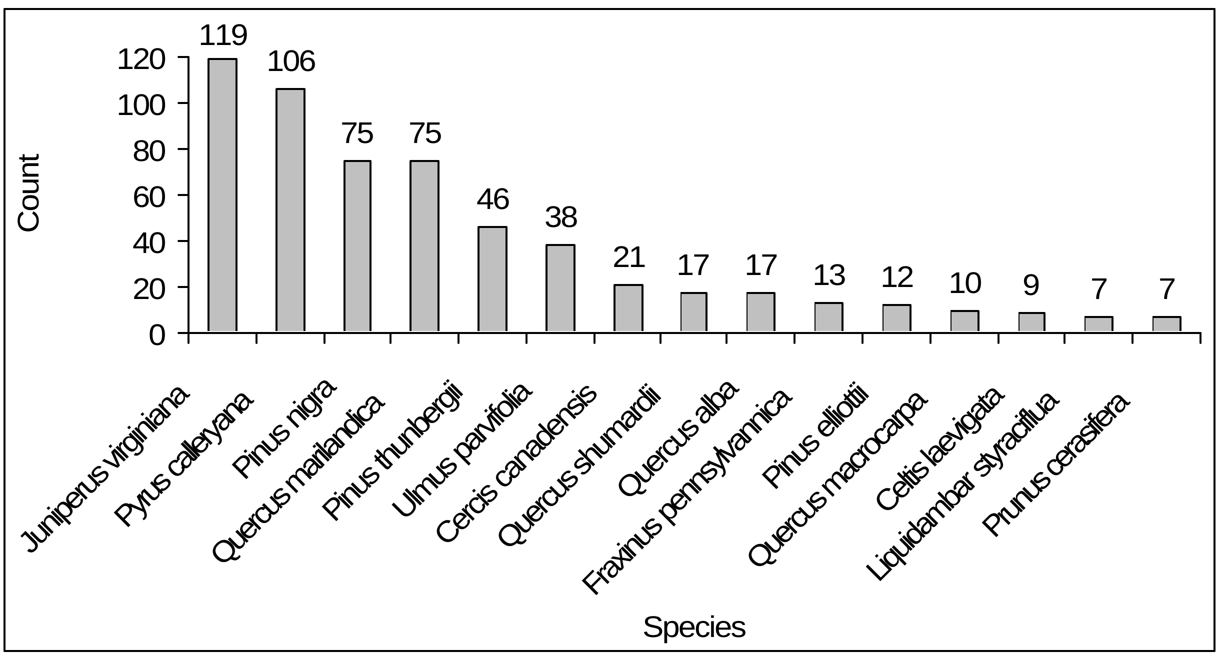

Figure 38: The 15 most common urban tree species in the Industrial East urban forest management unit at Tinker Air Force Base.

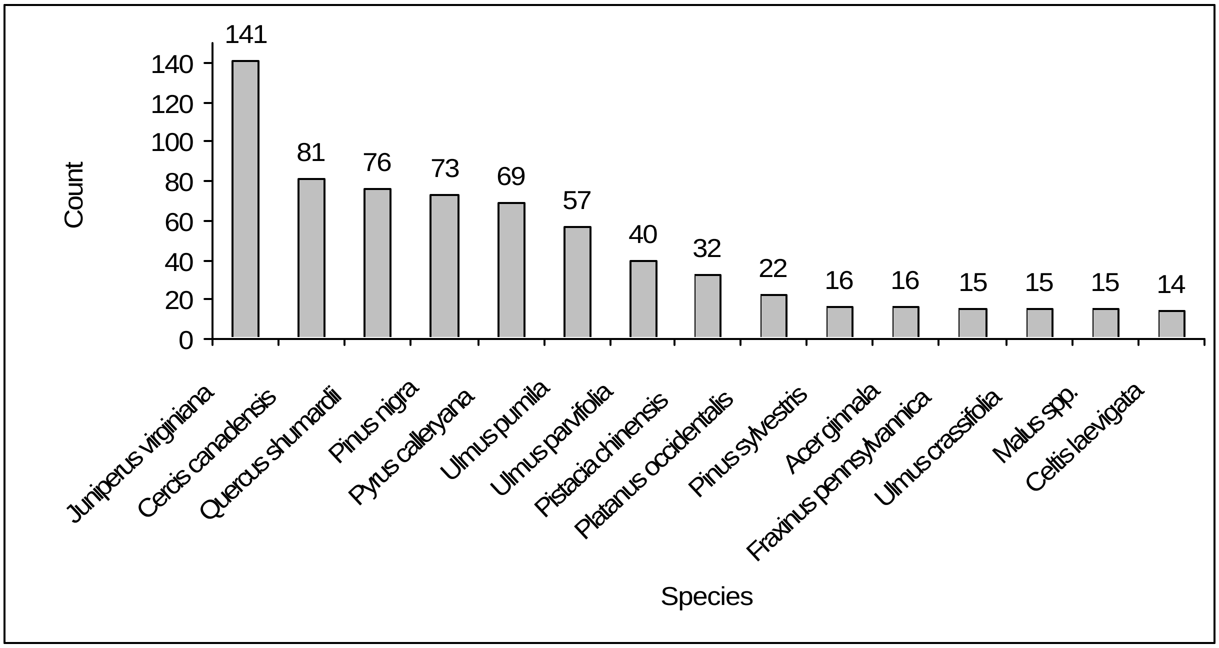

Figure 39: The 15 most common urban tree species in the Industrial North urban forest management unit at Tinker Air Force Base.

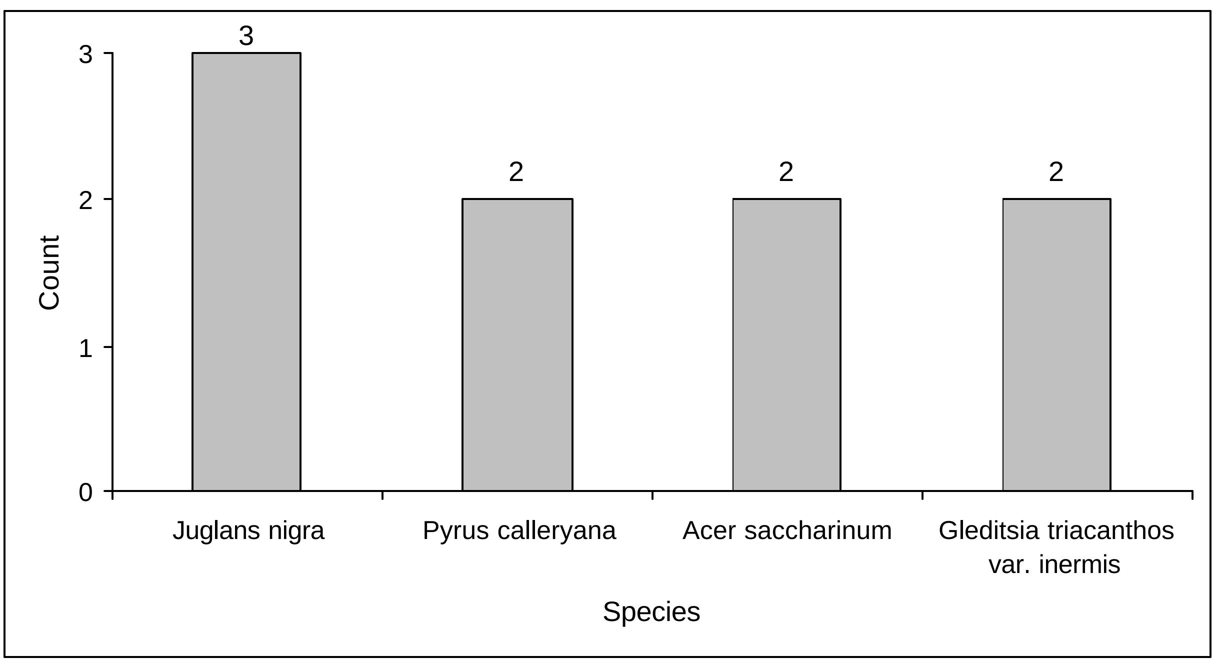

Figure 40: All urban tree species in the Industrial South 1 urban forest management unit at Tinker Air Force Base.

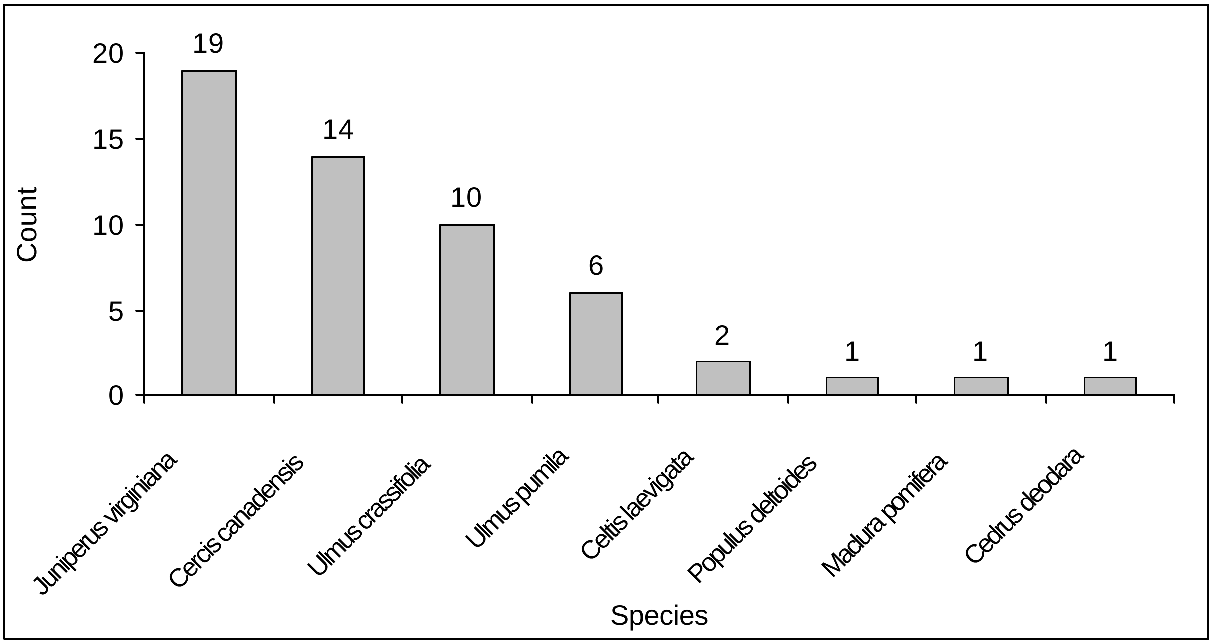

Figure 41: All urban tree species in the Industrial South 2 urban forest management unit at Tinker Air Force Base.

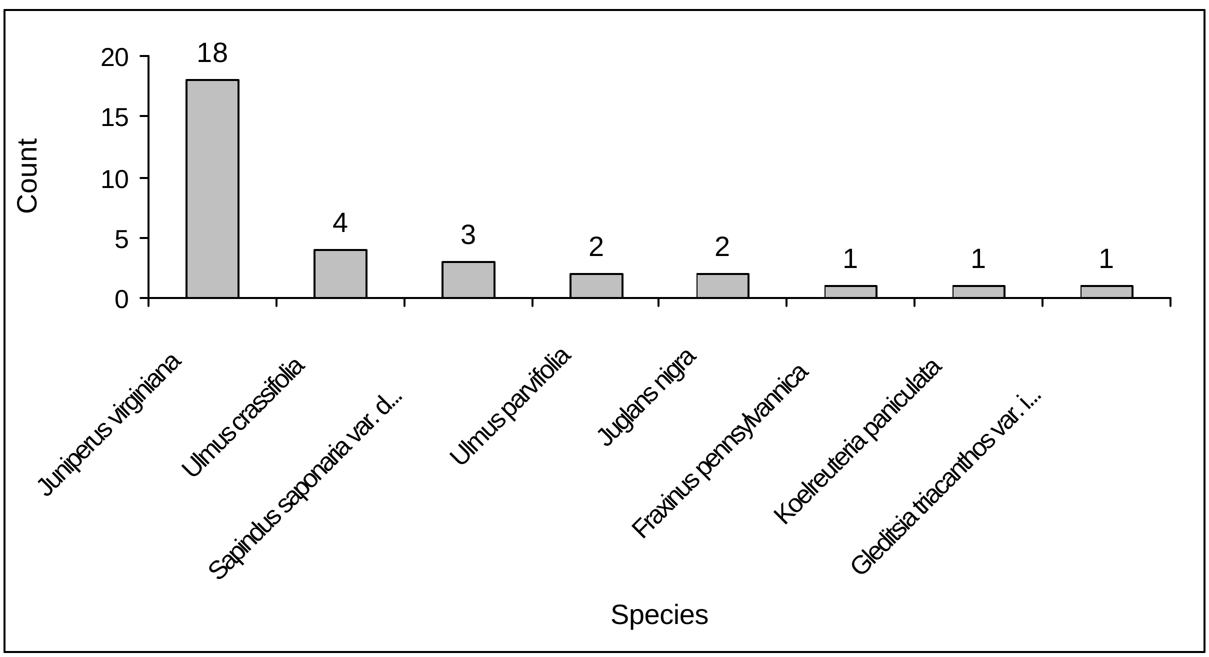

Figure 42: All urban tree species in the Industrial South 3 urban forest management unit at Tinker Air Force Base.

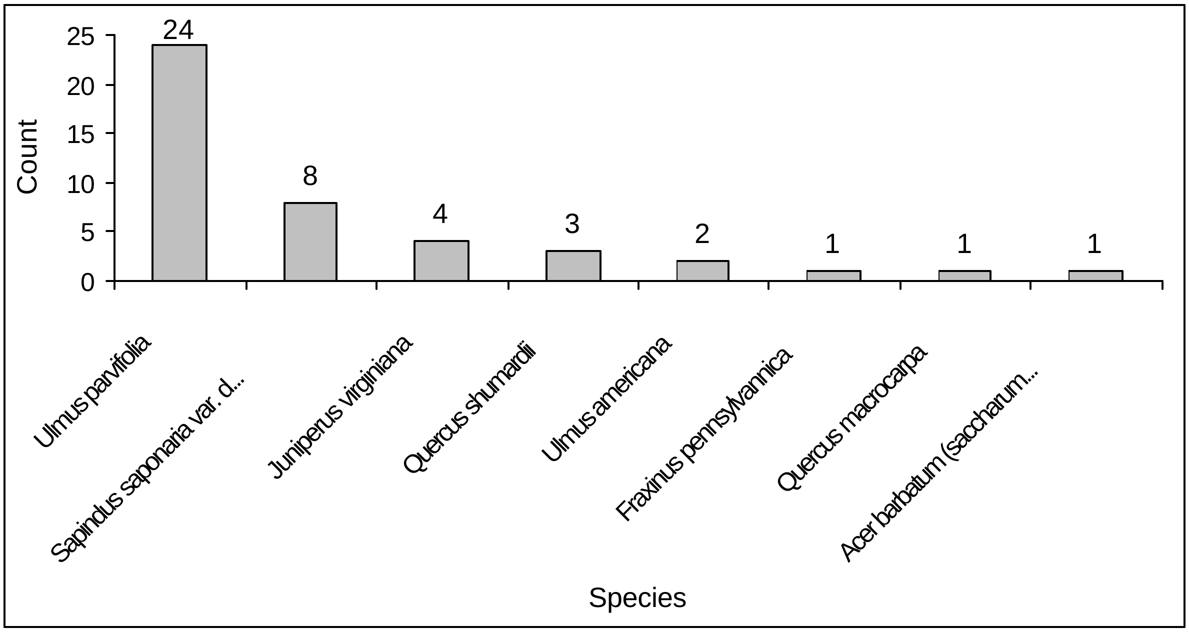

Figure 43: All urban tree species in the Industrial South 4 urban forest management unit at Tinker Air Force Base.

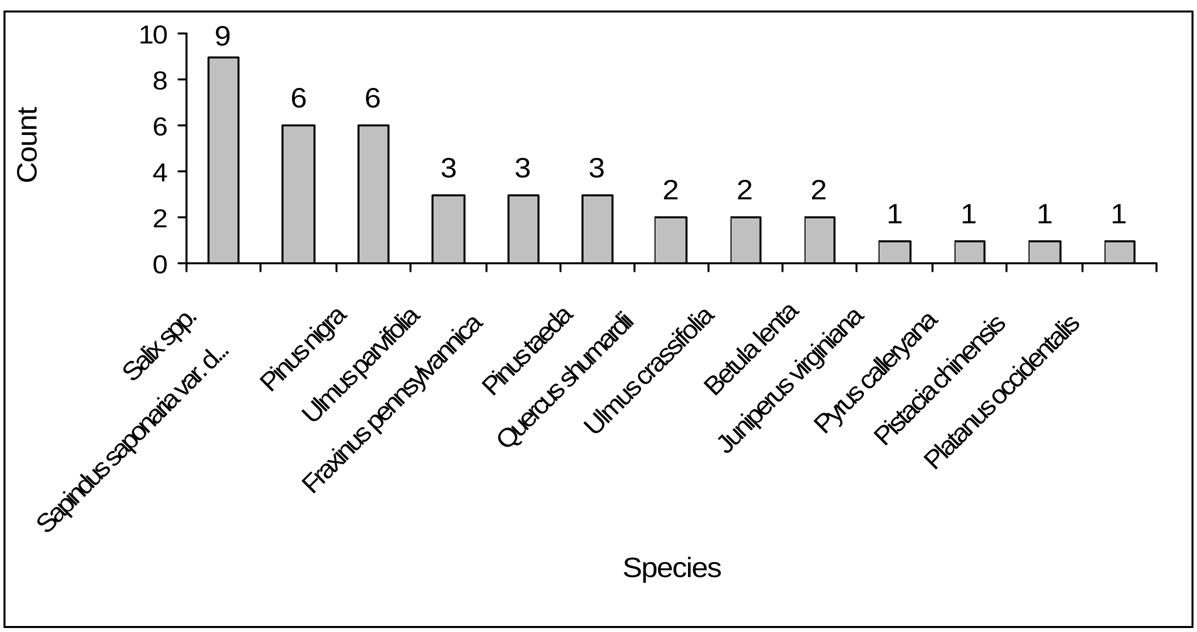

Figure 44: All urban tree species in the Industrial South 5 urban forest management unit at Tinker Air Force Base.

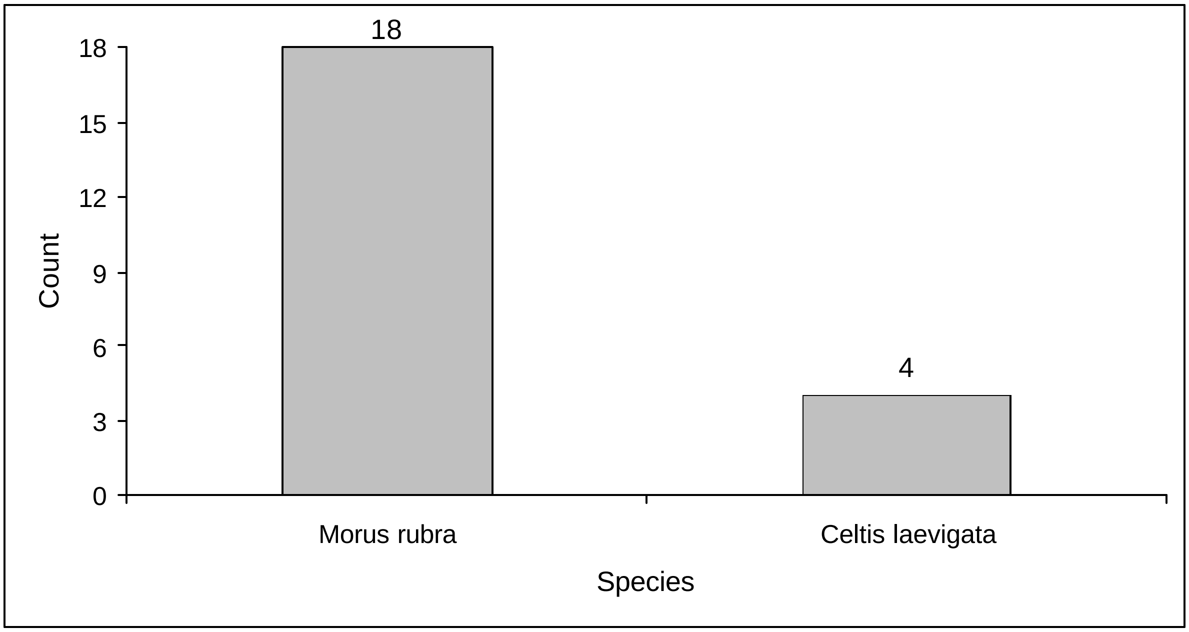

Figure 45: All urban tree species in the Industrial South 6 urban forest management unit at Tinker Air Force Base.

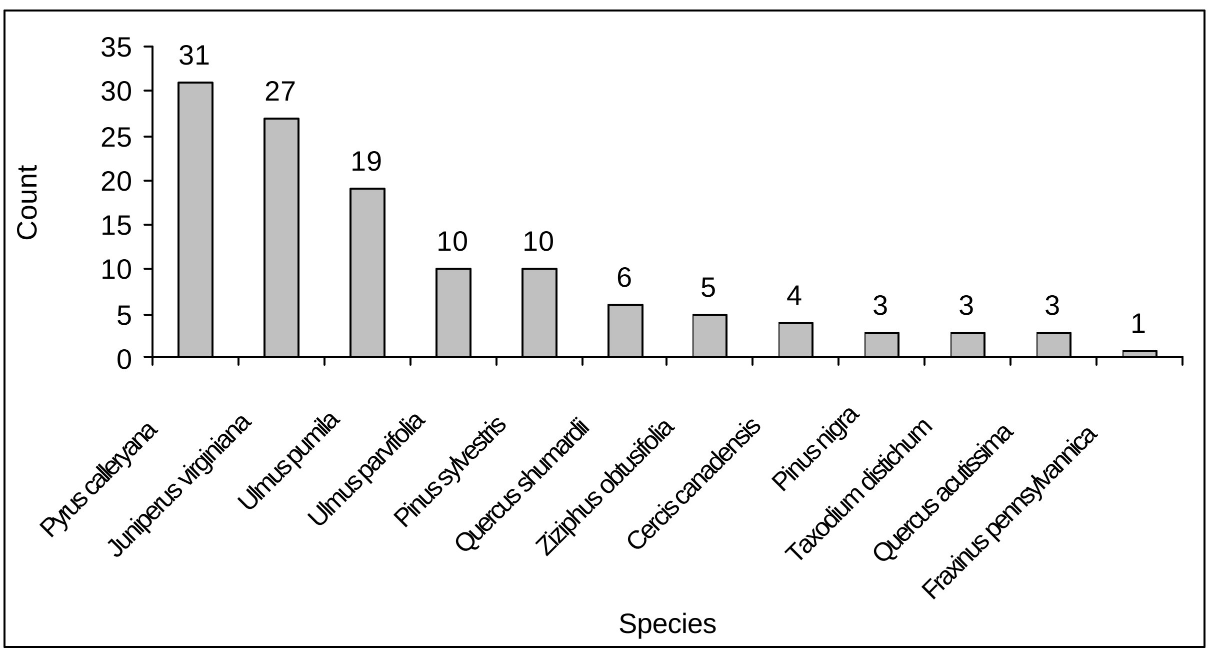

Figure 46: All urban tree species in the Navy urban forest management unit at Tinker Air Force Base.

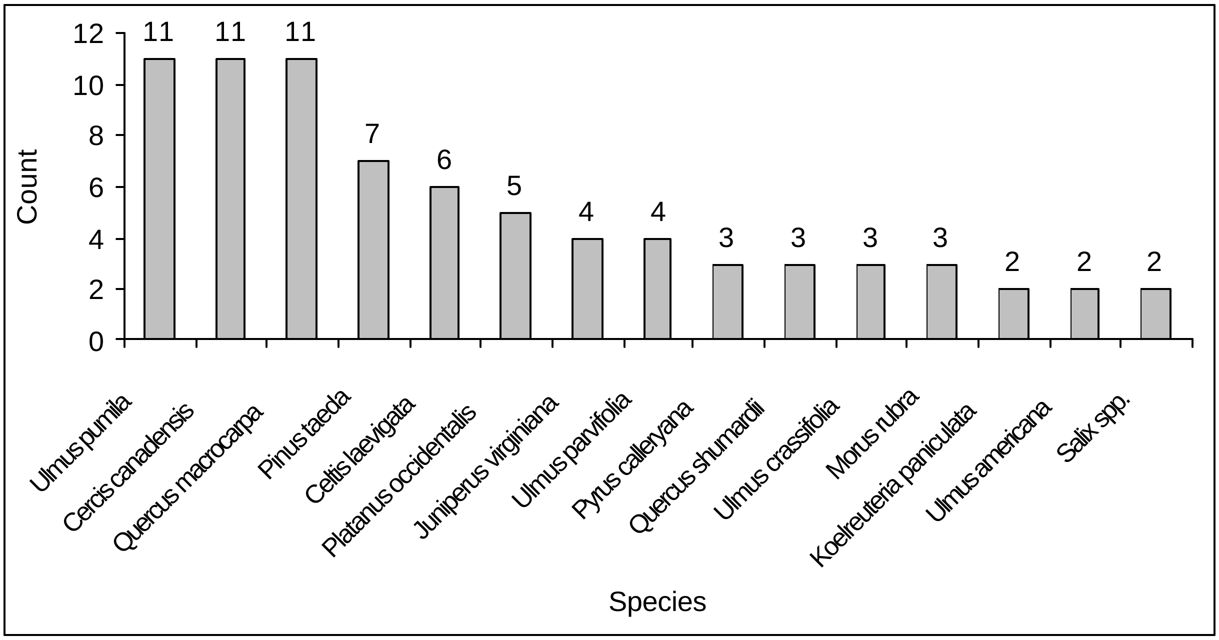

Figure 47: All urban tree species in the Open Space 1 urban forest management unit at Tinker Air Force Base.

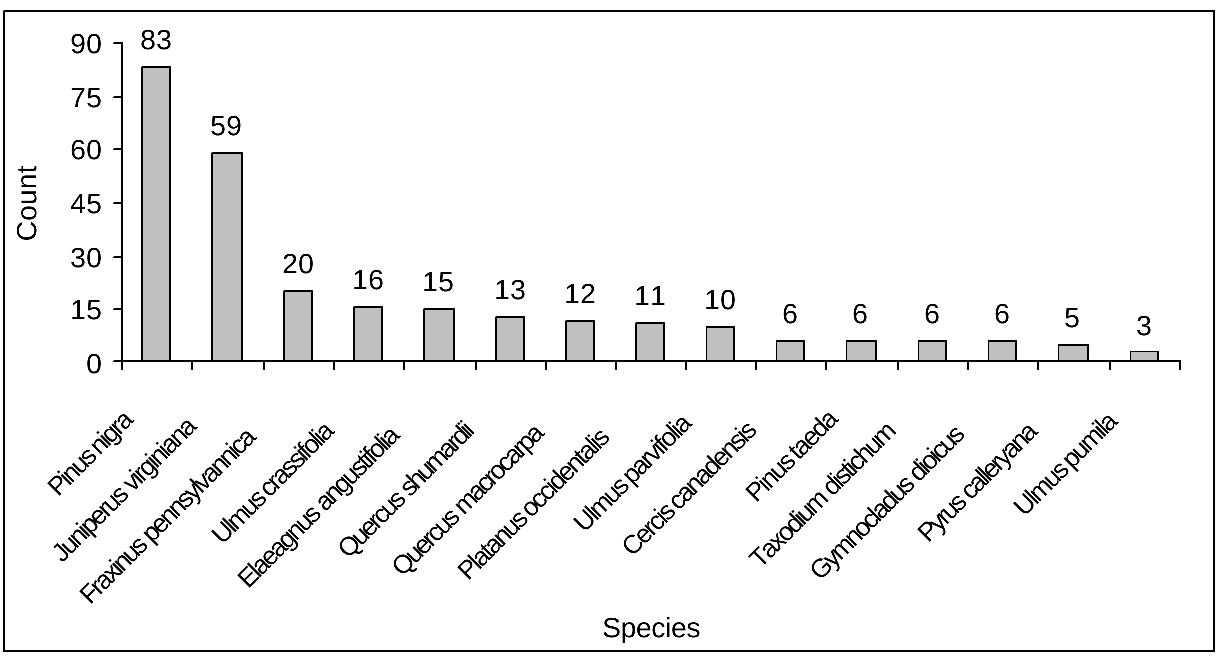

Figure 48: All urban tree species in the Open Space 2 urban forest management unit at Tinker Air Force Base.

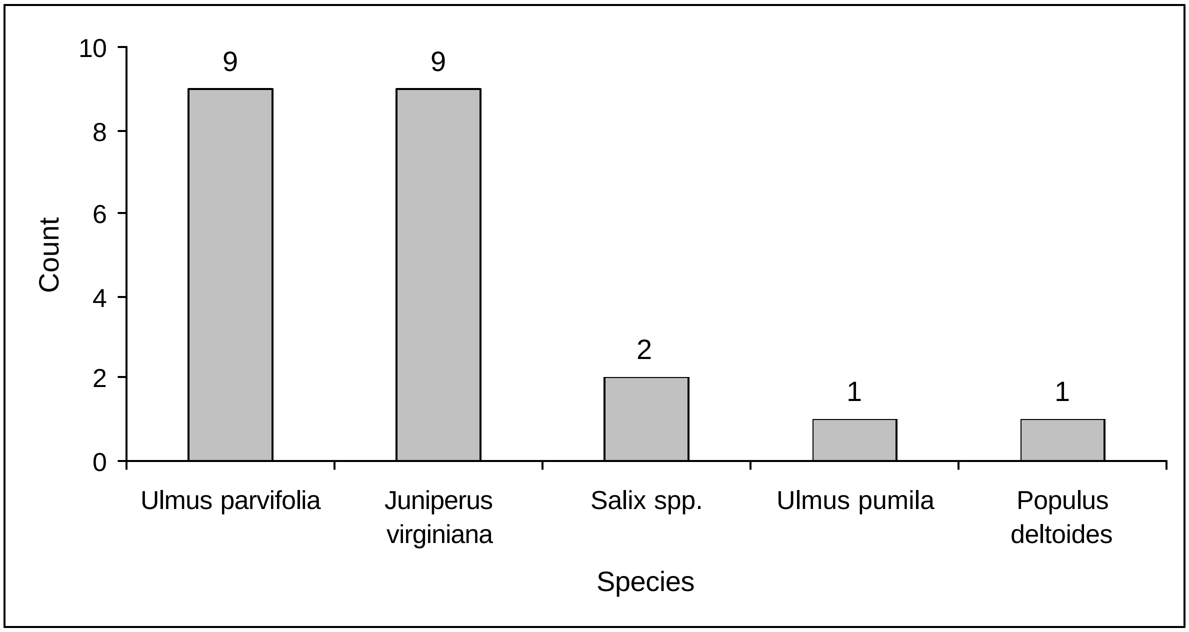

Figure 49: All urban tree species in the Open Space 3 urban forest management unit at Tinker Air Force Base.

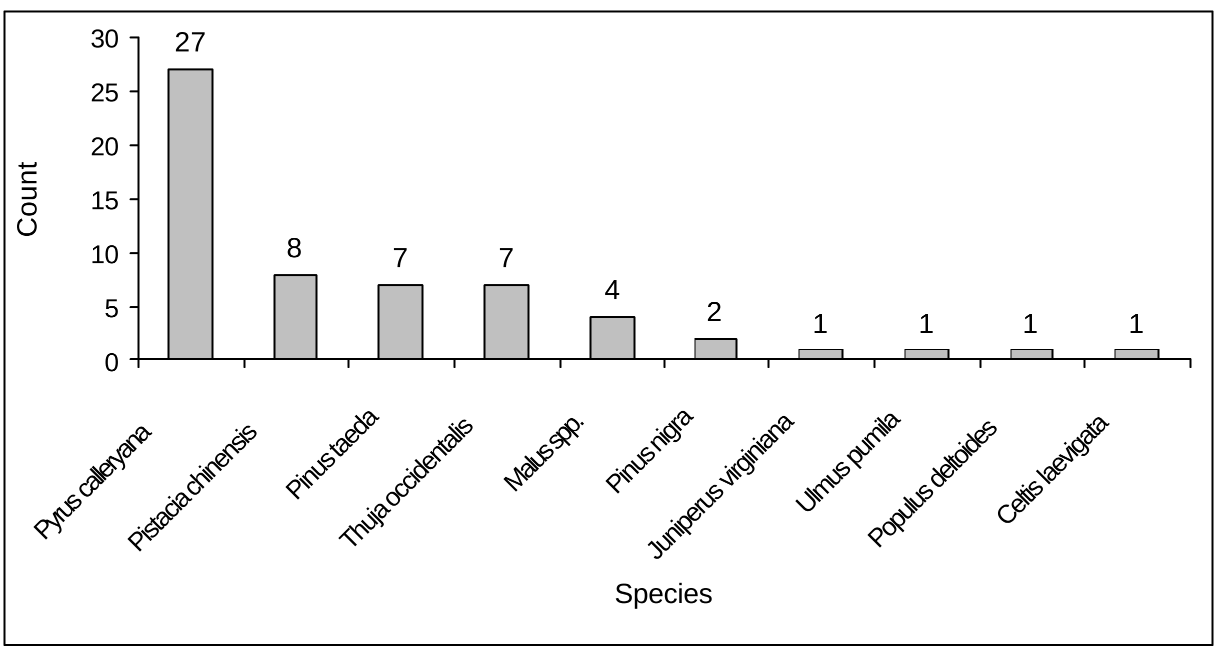

Figure 50: All urban tree species in the Third Herd urban forest management unit at Tinker Air Force Base.

Table 9: Average DBH (in inches) for all urban tree species by urban forest management unit at Tinker Air Force Base.

Species	Avg. DBH 507th/513th	Avg. DBH AWACS	Avg. DBH AWACS Alert	Avg. DBH Community 1	Avg. DBH Community 2	Avg. DBH Community (MFH*)	Avg. DBH EIG	Avg. DBH Gator
Acer barbatum (saccharum) var. caddo		2.0		4.5		5.3		
Acer ginnala								
Acer negundo						8.0		
Acer palmatum						2.5		
Acer rubrum		5.0				7.5		
Acer saccharum				5.0				
Acer saccharinum		2.0		14.4	28.0	24.8		
Acer spp.			4.0					
Albizia julibrissin						13.1		
Betula lenta								
Betula nigra				9.0		13.0	7.7	
Carya illinoinensis				6.3		25.0		
Catalpa bignonioides						15.0		
Cedrus atlantica					3.0		1.0	
Cedrus atlantica 'Glauca'						2.3		
Cedrus deodara								
Celtis laevigata				15.7	16.0	13.6		
Cercis canadensis	2.0	4.2		3.8	2.0	4.9	7.0	
Chilopsis linearis								
Cornus drummondii				7.0		2.0		
Crataegus phaenopyrum		3.0		8.0				
Crataegus spp.								
Cupressus arizonica								
Diospyros virginiana						16.0		
Elaeagnus angustifolia				11.0				
Fraxinus americana								
Fraxinus pennsylvannica	19.5	4.0		10.8	2.3	19.0		
Ginkgo biloba								
Gleditsia triacanthos				11.5		5.0		
Gleditsia triacanthos var. inermis				12.3		15.9	6.0	

*MFH = Military Family Housing

Species	Avg. DBH 507th/513th	Avg. DBH AWACS	Avg. DBH AWACS Alert	Avg. DBH Community 1	Avg. DBH Community 2	Avg. DBH Community (MFH*)	Avg. DBH EIG	Avg. DBH Gator
Gymnocladus dioicus				7.0		9.0		
Ilex decidua							3.0	
Juglans nigra				23.5	18.0	16.1		
Juniperus virginiana		4.7		9.8		13.6	13.2	5.0
Koelreuteria paniculata		8.3		5.5		6.4		
Liquidambar styraciflua		8.3		6.8		19.2	3.0	
Liquidambar styraciflua 'Rotundiloba'								
Maclura pomifera				20.3		18.1		
Magnolia grandifloria	4.0							
Malus spp.		6.7		7.6		9.1		
Morus alba			6.0			8.3		
Morus rubra		19.0		17.0		12.1		
Picea pungens	11.0			6.0				
Pinus echinata								
Pinus elliottii		12.0		12.2		9.3		
Pinus halepensis				6.1				
Pinus nigra	10.3	11.9	10.7	11.8	11.5	15.7	9.0	
Pinus sylvestris		11.4	7.3	11.0		9.0		
Pinus taeda		6.9		9.4		8.3	10.0	
Pinus thunbergii								
Pistacia chinensis	8.0	2.7		5.9		8.6		
Platanus occidentalis	10.0			17.6		23.6	12.0	
Populus alba						7.0		
Populus deltoides				13.5	26.5	24.7		
Populus nigra 'Italica'						7.0		
Prunus angustifolia								
Prunus cerasifera		4.1		4.4		4.0		
Prunus persica	6.0							
Prunus spp							3.0	
Pyrus calleryana	12.0	9.0	8.0	11.4		10.9	3.6	
Pyrus communis								
Quercus acutissima				7.0				

*MFH = Military Family Housing

Species	Avg. DBH 507th/513th	Avg. DBH AWACS	Avg. DBH AWACS Alert	Avg. DBH Community 1	Avg. DBH Community 2	Avg. DBH Community (MFH*)	Avg. DBH EIG	Avg. DBH Gator
Quercus alba								
Quercus macrocarpa		1.9		19.5	23.7	14.5	3.0	
Quercus marilandica							20.0	10.0
Quercus muehlenbergii						15.7		
Quercus nigra				10.0				
Quercus palustris		7.8		17.7		19.8	21.0	
Quercus prinus						18.5		
Quercus robur								
Quercus shumardii		8.5	6.0	9.2		11.0	2.9	
Quercus spp.								
Quercus texana						11.0		
Quercus virginiana				10.3		18.0		
Salix spp.					4.0	16.0		
Sambucus spp.								
Sapindus saponaria var. drummondii	5.8					12.0	3.4	
Sideroxylon lanuginosum				16.5	22.0	16.0		
Styphnolobium japonicum								
Taxodium distichum	5.3		4.0	8.7		5.8		
Thuja occidentalis		9.0				9.0		
Ulmus americana		32.0		10.3	9.0	21.4	9.0	
Ulmus crassifolia		9.0		2.5		8.0		
Ulmus parvifolia		15.1		6.1		7.7	18.4	
Ulmus pumila		19.7		24.5	20.2	22.6	17.5	16.5
Ziziphus obtusifolia								

*MFH = Military Family Housing

Table 10: Average DBH (in inches) for all urban tree species by urban forest management unit at Tinker Air Force Base.

Species	Avg. DBH Golf Course	Avg. DBH Industrial East	Avg. DBH Industrial North	Avg. DBH Industrial South 1	Avg. DBH Industrial South 2	Avg. DBH Industrial South 3	Avg. DBH Industrial South 4	Avg. DBH Industrial South 5
Acer barbatum (saccharum) var. caddo	6.0		2.5				2.0	
Acer ginnala	7.5		3.1					
Acer negundo	33.0							
Acer palmatum			2.0					
Acer rubrum	7.5		8.0					
Acer saccharum								
Acer saccharinum	26.6	17.5	5.7	12.0				
Acer spp.								
Albizia julibrissin	23.0							
Betula lenta								7.5
Betula nigra	10.8							
Carya illinoinensis								
Catalpa bignonioides								
Cedrus atlantica								
Cedrus atlantica 'Glauca'								
Cedrus deodara					3.0			
Celtis laevigata	16.2	13.0	5.3		5.0			
Cercis canadensis	8.0	3.5	3.1		2.7			
Chilopsis linearis		3.7						
Cornus drummondii	2.5							
Crataegus phaenopyrum								
Crataegus spp.								
Cupressus arizonica	10.0							
Diospyros virginiana	16.0							
Elaeagnus angustifolia			10.0					
Fraxinus americana			5.8					
Fraxinus pennsylvannica	18.0	8.3	9.3			25.0	8.0	9.0
Ginkgo biloba	4.0							
Gleditsia triacanthos								
Gleditsia triacanthos var. inermis	17.2	18.0	19.3	8.0		3.0		
Gymnocladus dioicus	13.6		3.0					

Species	Avg. DBH Golf Course	Avg. DBH Industrial East	Avg. DBH Industrial North	Avg. DBH Industrial South 1	Avg. DBH Industrial South 2	Avg. DBH Industrial South 3	Avg. DBH Industrial South 4	Avg. DBH Industrial South 5
Ilex decidua								
Juglans nigra	19.3					20.5		
Juniperus virginiana	13.3	5.1	7.6		2.3	2.8	5.0	2.0
Koelreuteria paniculata	10.3	15.0	6.0			44.0		
Liquidambar styraciflua	18.3	8.3	11.0					
Liquidambar styraciflua 'Rotundiloba'		2.0						
Maclura pomifera	44.0				3.0			
Magnolia grandifloria			1.8					
Malus spp.	4.6		3.8					
Morus alba	27.1	6.0						
Morus rubra		27.0	4.7					
Picea pungens			2.0					
Pinus echinata	16.0							
Pinus elliottii	13.2	11.9	16.4					
Pinus halepensis								
Pinus nigra	13.5	10.1	9.2	7.7				15.2
Pinus sylvestris	15.0	9.5	10.4					
Pinus taeda	12.6	14.0	5.7					8.0
Pinus thunbergii		6.0						
Pistacia chinensis	6.4	11.8	3.8					5.0
Platanus occidentalis	21.9	16.8	10.8					7.0
Populus alba								
Populus deltoides	23.3	34.0	5.0		17.0			
Populus nigra 'Italica'	13.0							
Prunus angustifolia			1.7					
Prunus cerasifera		2.7						
Prunus persica								
Prunus spp								
Pyrus calleryana	8.4	5.0	8.0	5.0				7.0
Pyrus communis	17.0							
Quercus acutissima	11.3							
Quercus alba		12.8						

Species	Avg. DBH Golf Course	Avg. DBH Industrial East	Avg. DBH Industrial North	Avg. DBH Industrial South 1	Avg. DBH Industrial South 2	Avg. DBH Industrial South 3	Avg. DBH Industrial South 4	Avg. DBH Industrial South 5
Quercus macrocarpa	7.2	2.3					2.0	
Quercus marilandica	16.0	15.3						
Quercus muehlenbergii								
Quercus nigra	7.0							
Quercus palustris	23.9		10.0					
Quercus prinus								
Quercus robur	16.0							
Quercus shumardii	8.1	3.9	5.3				1.0	4.0
Quercus spp.								
Quercus texana								
Quercus virginiana	12.0	6.3	8.5					
Salix spp.	16.0							7.7
Sambucus spp.			3.0					
Sapindus saponaria var. drummondii	2.4	6.0				11.7	5.3	6.7
Sideroxylon lanuginosum								
Styphnolobium japonicum	13.0							
Taxodium distichum	11.0	7.5	3.6					
Thuja occidentalis								
Ulmus americana	23.5	16.0					9.0	
Ulmus crassifolia	2.8	4.3	2.5		5.0	3.3		3.0
Ulmus parvifolia	9.5	5.9	15.0			6.0	5.7	7.7
Ulmus pumila	26.8	26.3	20.7		21.2			
Ziziphus obtusifolia								

Table 11: Average DBH (in inches) for all urban tree species by urban forest management unit at Tinker Air Force Base.

Species	Avg. DBH Industrial South 6	Avg. DBH Munitions	Avg. DBH Navy	Avg. DBH Open Space 1	Avg. DBH Open Space 2	Avg. DBH Open Space 3	Avg. DBH Third Herd
Acer barbatum (saccharum) var. caddo							
Acer ginnala					11.0		
Acer negundo							
Acer palmatum							
Acer rubrum							
Acer saccharum							
Acer saccharinum							
Acer spp.							
Albizia julibrissin							
Betula lenta							
Betula nigra							
Carya illinoinensis				30.0			
Catalpa bignonioides							
Cedrus atlantica							
Cedrus atlantica 'Glauca'							
Cedrus deodara							
Celtis laevigata	18.5			29.8			14.0
Cercis canadensis			5.5	1.1	5.5		
Chilopsis linearis							
Cornus drummondii							
Crataegus phaenopyrum							
Crataegus spp.					2.3		
Cupressus arizonica							
Diospyros virginiana							
Elaeagnus angustifolia					5.1		
Fraxinus americana							
Fraxinus pennsylvannica			6.0		4.1		
Ginkgo biloba							
Gleditsia triacanthos					11.0		
Gleditsia triacanthos var. inermis							
Gymnocladus dioicus					6.8		

Species	Avg. DBH Industrial South 6	Avg. DBH Munitions	Avg. DBH Navy	Avg. DBH Open Space 1	Avg. DBH Open Space 2	Avg. DBH Open Space 3	Avg. DBH Third Herd
Ilex decidua							
Juglans nigra							
Juniperus virginiana			2.0	12.5	5.2	5.8	20.0
Koelreuteria paniculata				5.0			
Liquidambar styraciflua							
Liquidambar styraciflua 'Rotundiloba'							
Maclura pomifera							
Magnolia grandifloria							
Malus spp.							7.8
Morus alba							
Morus rubra	26.6			17.7			
Picea pungens							
Pinus echinata					10.3		
Pinus elliottii							
Pinus halepensis							
Pinus nigra			6.7		10.8		16.5
Pinus sylvestris			7.3				
Pinus taeda				7.0	10.5		10.6
Pinus thunbergii							
Pistacia chinensis							12.6
Platanus occidentalis				11.0	12.5		
Populus alba							
Populus deltoides					29.3	11.0	2.0
Populus nigra 'Italica'							
Prunus angustifolia							
Prunus cerasifera							
Prunus persica							
Prunus spp							
Pyrus calleryana			7.5	3.7	4.6		9.0
Pyrus communis							
Quercus acutissima			4.7				
Quercus alba							

Species	Avg. DBH Industrial South 6	Avg. DBH Munitions	Avg. DBH Navy	Avg. DBH Open Space 1	Avg. DBH Open Space 2	Avg. DBH Open Space 3	Avg. DBH Third Herd
Quercus macrocarpa				2.0	3.8		
Quercus marilandica		14.0					
Quercus muehlenbergii							
Quercus nigra							
Quercus palustris							
Quercus prinus							
Quercus robur							
Quercus shumardii			4.7	7.0	3.5		
Quercus spp.							
Quercus texana							
Quercus virginiana							
Salix spp.				14.0		8.5	
Sambucus spp.							
Sapindus saponaria var. drummondii							
Sideroxylon lanuginosum							
Styphnolobium japonicum							
Taxodium distichum			4.7	3.0	13.5		
Thuja occidentalis							8.3
Ulmus americana				29.5			
Ulmus crassifolia				12.3	2.8		
Ulmus parvifolia			3.2	4.5	16.5	6.7	
Ulmus pumila			10.4	20.5	21.0	4.0	14.0
Ziziphus obtusifolia			5.2				

Table 12: Average height (in feet) for all urban tree species by urban forest management unit at Tinker Air Force Base.

Species	Avg. Height 507th/513th	Avg. Height AWACS	Avg. Height AWACS Alert	Avg. Height Community 1	Avg. Height Community 2	Avg. Height Community (MFH*)	Avg. Height EIG	Avg. Height Gator
Acer barbatum (saccharum) var. caddo		11.0		15.5		20.3		
Acer ginnala								
Acer negundo						54.0		
Acer palmatum						11.5		
Acer rubrum		14.0				24.5		
Acer saccharum				19.0				
Acer saccharinum		7.0		37.1	69.0	51.6		
Acer spp.			12.0					
Albizia julibrissin						31.3		
Betula lenta								
Betula nigra				29.0		30.0	24.7	
Carya illinoinensis				25.0		60.0		
Catalpa bignonioides						32.0		
Cedrus atlantica					10.3		6.0	
Cedrus atlantica 'Glauca'						11.0		
Cedrus deodara								
Celtis laevigata				33.9	37.2	34.4		
Cercis canadensis	8.5	10.7		13.4	10.0	15.9	13.4	
Chilopsis linearis								
Cornus drummondii				18.0		14.0		
Crataegus phaenopyrum		16.0		18.0				
Crataegus spp.								
Cupressus arizonica								
Diospyros virginiana						51.0		
Elaeagnus angustifolia				32.0				
Fraxinus americana								
Fraxinus pennsylvannica	27.0	14.3		28.2	11.3	40.1		
Ginkgo biloba								
Gleditsia triacanthos				32.0		20.0		
Gleditsia triacanthos var. inermis				30.6		39.2	16.0	

*MFH = Military Family Housing

Species	Avg. Height 507th/513th	Avg. Height AWACS	Avg. Height AWACS Alert	Avg. Height Community 1	Avg. Height Community 2	Avg. Height Community (MFH*)	Avg. Height EIG	Avg. Height Gator
Gymnocladus dioicus				26.5		32.8		
Ilex decidua							11.5	
Juglans nigra				63.9	60.0	40.5		
Juniperus virginiana		15.7		21.1		26.7	22.2	15.0
Koelreuteria paniculata		18.7		18.5		18.3		
Liquidambar styraciflua		24.0		19.6		53.0	13.0	
Liquidambar styraciflua 'Rotundiloba'								
Maclura pomifera				34.7		41.3		
Magnolia grandifloria	11.0							
Malus spp.		22.1		18.7		20.9		
Morus alba			11.0			27.9		
Morus rubra		22.0		28.4		33.0		
Picea pungens	26.0			10.0				
Pinus echinata								
Pinus elliottii		33.5		30.8		20.9		
Pinus halepensis				19.4				
Pinus nigra	21.6	20.0	19.0	25.1	21.3	31.8	16.4	
Pinus sylvestris		20.6	16.7	21.3		24.0		
Pinus taeda		21.7		28.0		26.3	22.5	
Pinus thunbergii								
Pistacia chinensis	17.0	12.7		20.0		25.1		
Platanus occidentalis	32.0			56.4		58.6	30.2	
Populus alba						29.0		
Populus deltoides				41.0	64.5	55.3		
Populus nigra 'Italica'						32.0		
Prunus angustifolia								
Prunus cerasifera		15.4		13.9		13.0		
Prunus persica	19.0							
Prunus spp							10.0	
Pyrus calleryana	24.3	21.2	20.7	28.6		25.9	11.8	
Pyrus communis								
Quercus acutissima				27.8				

*MFH = Military Family Housing

Species	Avg. Height 507th/513th	Avg. Height AWACS	Avg. Height AWACS Alert	Avg. Height Community 1	Avg. Height Community 2	Avg. Height Community (MFH*)	Avg. Height EIG	Avg. Height Gator
Quercus alba								
Quercus macrocarpa		11.0		33.4	48.7	31.5	11.0	
Quercus marilandica							29.8	23.8
Quercus muehlenbergii						36.4		
Quercus nigra				25.0				
Quercus palustris		18.8		38.7		47.0	45.5	
Quercus prinus						32.5		
Quercus robur								
Quercus shumardii		21.7	16.3	24.8		30.4	11.3	
Quercus spp.								
Quercus texana						30.0		
Quercus virginiana				33.0		64.0		
Salix spp.					22.0	31.5		
Sambucus spp.								
Sapindus saponaria var. drummondii	14.5					22.3	12.2	
Sideroxylon lanuginosum				41.8	52.0	39.2		
Styphnolobium japonicum								
Taxodium distichum	15.7		12.0	20.3		19.2		
Thuja occidentalis		21.0				29.0		
Ulmus americana		34.0		26.6	43.0	42.4	27.0	
Ulmus crassifolia		19.0		13.5		22.8		
Ulmus parvifolia		32.3		20.3		25.7	35.7	
Ulmus pumila		28.7		40.1	43.2	42.5	26.3	35.0
Ziziphus obtusifolia								

*MFH = Military Family Housing

Table 13: Average height (in feet) for all urban tree species by urban forest management unit at Tinker Air Force Base.

Species	Avg. Height Golf Course	Avg. Height Industrial East	Avg. Height Industrial North	Avg. Height Industrial South 1	Avg. Height Industrial South 2	Avg. Height Industrial South 3	Avg. Height Industrial South 4	Avg. Height Industrial South 5
Acer barbatum (saccharum) var. caddo	21.0		11.0				12.0	
Acer ginnala	21.5		13.7					
Acer negundo	51.0							
Acer palmatum			10.0					
Acer rubrum			22.0					
Acer saccharum	26.0							
Acer saccharinum	48.5	33.0	17.3	28				
Acer spp.								
Albizia julibrissin	28.0							
Betula lenta								26.0
Betula nigra	42.0							
Carya illinoinensis								
Catalpa bignonioides								
Cedrus atlantica								
Cedrus atlantica 'Glauca'								
Cedrus deodara					9.0			
Celtis laevigata	38.5	28.7	12.9		22.5			
Cercis canadensis	18.8	11.5	11.4		11.6			
Chilopsis linearis		12.0						
Cornus drummondii	10.5							
Crataegus phaenopyrum								
Crataegus spp.								
Cupressus arizonica	18.0							
Diospyros virginiana	47.3							
Elaeagnus angustifolia			25.0					
Fraxinus americana			21.4					
Fraxinus pennsylvannica	38.2	22.0	23.9			47.0	16.0	24.3
Ginkgo biloba	18.0							

Species	Avg. Height Golf Course	Avg. Height Industrial East	Avg. Height Industrial North	Avg. Height Industrial South 1	Avg. Height Industrial South 2	Avg. Height Industrial South 3	Avg. Height Industrial South 4	Avg. Height Industrial South 5
Gleditsia triacanthos								
Gleditsia triacanthos var. inermis	36.2	32.0	36.7	22.5		16.0		
Gymnocladus dioicus	55.8		15.0					
Ilex decidua								
Juglans nigra	45.6					48.5		
Juniperus virginiana	24.3	15.5	17.8		9.5	13.1	11.3	8.0
Koelreuteria paniculata	25.0	21.0	15.0			11.0		
Liquidambar styraciflua	39.0	24.1	23.3					
Liquidambar styraciflua 'Rotundiloba'		12.5						
Maclura pomifera	46.0				16.0			
Magnolia grandifloria			6.8					
Malus spp.	12.4		13.9					
Morus alba		32.0						
Morus rubra	34.3	33.0	16.3					
Picea pungens			6.0					
Pinus echinata	27.0							
Pinus elliottii	24.1	23.4	31.0					
Pinus halepensis								
Pinus nigra	24.6	20.5	19.2	14.3				24.8
Pinus sylvestris	24.3	14.3	19.3					
Pinus taeda	23.7	22.0	18.1					23.0
Pinus thunbergii		18.2						
Pistacia chinensis	21.4	22.8	13.2					20.0
Platanus occidentalis	56.2	43.0	30.6					22.0
Populus alba								
Populus deltoides	66.0	48.5	30.0		46.0			
Populus nigra 'Italica'	34.0							
Prunus angustifolia			8.3					
Prunus cerasifera		8.7						
Prunus persica								

Species	Avg. Height Golf Course	Avg. Height Industrial East	Avg. Height Industrial North	Avg. Height Industrial South 1	Avg. Height Industrial South 2	Avg. Height Industrial South 3	Avg. Height Industrial South 4	Avg. Height Industrial South 5
Prunus spp								
Pyrus calleryana	28.1	17.4	20.2	17				19.0
Pyrus communis	27.0							
Quercus acutissima	30.7							
Quercus alba		32.0						
Quercus macrocarpa	19.8	8.1					10.0	
Quercus marilandica	40.0	29.5						
Quercus muehlenbergii								
Quercus nigra	28.0							
Quercus palustris	52.0		23.5					
Quercus prinus								
Quercus robur	32.0							
Quercus shumardii	26.8	14.4	17.8				7.7	18.5
Quercus spp.								
Quercus texana								
Quercus virginiana	25.0	18.3	17.5					
Salix spp.	35.0							30.7
Sambucus spp.			19.0					
Sapindus saponaria var. drummondii	13.1	19.0				29.3	19.5	15.5
Sideroxylon lanuginosum								
Styphnolobium japonicum	48.0							
Taxodium distichum	29.3	24.3	12.4					
Thuja occidentalis								
Ulmus americana	45.0	33.4					20.5	
Ulmus crassifolia	11.4	10.7	11.5		22.0	16.3		17.0
Ulmus parvifolia	24.8	22.3	27.1			26.0	21.3	26.7
Ulmus pumila	47.8	34.7	28.8		43.5			
Ziziphus obtusifolia								

Table 14: Average height (in feet) for all urban tree species by urban forest management unit at Tinker Air Force Base.

Species	Avg. Height Industrial South 6	Avg. Height Munitions	Avg. Height Navy	Avg. Height Open Space 1	Avg. Height Open Space 2	Avg. Height Open Space 3	Avg. Height Third Herd
Acer barbatum (saccharum) var. caddo							
Acer ginnala					40.0		
Acer negundo							
Acer palmatum							
Acer rubrum							
Acer saccharum							
Acer saccharinum							
Acer spp.							
Albizia julibrissin							
Betula lenta							
Betula nigra							
Carya illinoinensis				40.0			
Catalpa bignonioides							
Cedrus atlantica							
Cedrus atlantica 'Glauca'							
Cedrus deodara							
Celtis laevigata	42.5			48.2			32.0
Cercis canadensis			14.5	6.6	11.3		
Chilopsis linearis							
Cornus drummondii							
Crataegus phaenopyrum							
Crataegus spp.					9.7		
Cupressus arizonica							
Diospyros virginiana							
Elaeagnus angustifolia					14.3		
Fraxinus americana							
Fraxinus pennsylvannica			16.0		13.5		
Ginkgo biloba							

Species	Avg. Height Industrial South 6	Avg. Height Munitions	Avg. Height Navy	Avg. Height Open Space 1	Avg. Height Open Space 2	Avg. Height Open Space 3	Avg. Height Third Herd
Gleditsia triacanthos					21.0		
Gleditsia triacanthos var. inermis							
Gymnocladus dioicus					22.2		
Ilex decidua							
Juglans nigra							
Juniperus virginiana			9.1	20.3	15.7	14.6	23.0
Koelreuteria paniculata				13.0			
Liquidambar styraciflua							
Liquidambar styraciflua 'Rotundiloba'							
Maclura pomifera							
Magnolia grandifloria							
Malus spp.							15.5
Morus alba							
Morus rubra	48.0			33.0			
Picea pungens							
Pinus echinata					20.0		
Pinus elliottii							
Pinus halepensis							
Pinus nigra			16.0		22.2		27.5
Pinus sylvestris			17.5				
Pinus taeda				24.0	26.7		31.3
Pinus thunbergii							
Pistacia chinensis							19.5
Platanus occidentalis				27.6	36.8		
Populus alba							
Populus deltoides					49.3	33.0	15.0
Populus nigra 'Italica'							
Prunus angustifolia							
Prunus cerasifera							
Prunus persica							

Species	Avg. Height Industrial South 6	Avg. Height Munitions	Avg. Height Navy	Avg. Height Open Space 1	Avg. Height Open Space 2	Avg. Height Open Space 3	Avg. Height Third Herd
Prunus spp							
Pyrus calleryana			19.8	14.3	20.2		17.9
Pyrus communis							
Quercus acutissima			13.3				
Quercus alba							
Quercus macrocarpa				7.9	10.3		
Quercus marilandica		21.0					
Quercus muehlenbergii							
Quercus nigra							
Quercus palustris							
Quercus prinus							
Quercus robur							
Quercus shumardii			16.0	31.3	10.8		
Quercus spp.							
Quercus texana							
Quercus virginiana							
Salix spp.				35.0		26.0	
Sambucus spp.							
Sapindus saponaria var. drummondii							
Sideroxylon lanuginosum							
Styphnolobium japonicum							
Taxodium distichum			10.0	14.0	29.8		
Thuja occidentalis							25.0
Ulmus americana				30.0			
Ulmus crassifolia				24.0	13.7		
Ulmus parvifolia			11.1	23.5	33.8	15.9	
Ulmus pumila			23.1	35.8	39.3	12.0	21.0
Ziziphus obtusifolia			14.0				

Appendix C: i-Tree STRATUM

Inventory Formatting

This is from the i-Tree manual that is included with the installation disk (USDA Forest Service et al. 2006).

Before you can begin a STRATUM project, you must prepare your data, which is most likely in the form of an Excel worksheet or an Access database. Though STRATUM is flexible, it has very strict limits on the way data can be organized.

The only exception to this STRATUM-formatting convention is the Access table (STRATUM_MCTI_Inventory) created if you collected your inventory data using the i-Tree PDA Utility application. STRATUM accepts the i-Tree format and recognizes its data fields.

<u>Data Fields</u>

STRATUM inventories must be organized according to specific field names, though to some extent the field names can be defined differently. In order to import your data into STRATUM, the data must include 17 data fields, which must have specific names and formatting and must be in a specific order. The field names and order are as follows:

1. TreeId
2. Zone
3. StreetSeg
4. CityManaged
5. SpCode
6. LandUse
7. LocSite
8. DBH
9. MtncRec
10. PriorityTask
11. SwDamg
12. WireConflict
13. CondWood
14. CondLvs
15. OtherOne
16. OtherTwo
17. OtherThree

STRATUM can run with a minimum amount of data, though reports will be limited; however, there must be values for TreeId, SpCode, and DBH. Additionally, all 17 data fields must be present and records must be filled with null values (e.g., 0) if no data were collected.

The 17 STRATUM data fields are defined as follows:

TreeId - a number assigned to each tree within a particular city in order to distinguish trees and count the number of trees per city. Each record must have a TreeId; it must be numeric and it is recommended that this number be unique.

Zone - an alphanumeric code or name that represents the management area or zone that the tree is located in within a particular city. If no zones or areas are associated with inventoried trees, 1 is entered for each record. Up to 20 zones can be defined.

StreetSeg - a numeric code to identify the street segment within a city where the tree is located. If TIGER/Line files have been used to create a sample inventory, the Tiger Line ID (TLID) is the StreetSeg. For full inventories, 0 (zero) is entered for each record.

CityManaged - a numeric code to distinguish trees owned by the city (1) and those privately planted and managed (2). If private trees were not included, 1 should be entered for each record.

SpCode - an alphanumeric code consisting of the first two letters of the genus name and the first two letters of the species name followed by two optional letters or numbers to distinguish two species with the same four-letter code. Additional codes for available planting sites or empty planting basins may be entered (e.g., AVPS [available planting site] or EMBA [empty basin]). A SpCode must be entered for each record.

NOTE: If you are creating a new inventory, it will greatly facilitate your use of STRATUM if you assign your species the same codes as STRATUM uses. Similarly, if you are working with an existing inventory, you may find it easiest to change your species codes directly in your database to match those on the pre-installed list. This will save you time and effort in creating a project. A list of installed species codes and their respective species for each climate zone can be found in this appendix.

LandUse - a numeric code to describe the type of area where the tree is growing. The default values are as follows:

1 = Single-family residential

2 = Multi-family residential (duplex, apartments, condos)

3 = Industrial/large commercial

4 = Park/vacant/other (agricultural, riparian areas, greenbelts, park, etc.)

5 = Small commercial (minimart, retail boutiques, etc.)

Additional or alternative definitions (up to 10) can be defined in STRATUM. If no LandUse value is available, 0 (zero) is entered for each record.

LocSite - a numeric code to describe the kind of site where the tree is growing. The default values are as follows:

1 = Front yard

2 = Planting strip

3 = Cutout (tree root growth restricted on all four sides by hardscape within dripline)

4 = Median (defined as any median smaller than 3 by 10 meters)

5 = Other maintained locations (defined as any median larger than 3 by 10 meters)

6 = Other un-maintained locations

7 = Backyard

Additional or alternative definitions (up to 10) can be defined in STRATUM. If no LocSite value is available, 0 (zero) is entered for each record.

DBH – a numeric entry for the diameter at breast height (4.5 ft [1.37 m] above the ground). Alternatively, up to 9 numerical categories can be used to define classes (e.g., 1 = trees within the 0–6 in DBH size class). If the class option is used, a minimum of 5 classes must be defined in STRATUM. Each record must have a DBH value. Enter 0 (zero) for all non-tree SpCode entries.

MtncRec - a numeric code to describe the recommended maintenance for the tree. The default values are as follows:

1 = None – tree does not need immediate or routine maintenance.

2 = Young tree (routine) – tree is less than 18 ft. tall and in need of maintenance; health or longevity of tree is not compromised by deferring maintenance for up to five years.

3 = Young tree (immediate) – tree is less than 18 ft. tall and in need of maintenance; deferring maintenance beyond one year would compromise health or longevity of tree.

4 = Mature tree (routine) – tree is more than 18 ft. tall and in need of maintenance; health or longevity of tree is not compromised by deferring maintenance for up to five years.

5 = Mature tree (immediate) – tree is more than 18 ft. tall and in need of maintenance; deferring maintenance beyond one year would compromise health or longevity of tree.

6 = Critical concern (public safety) – tree should be inspected without delay.

Additional or alternative definitions (up to 10) can be defined in STRATUM. If no MtncRec value is available, 0 (zero) is entered for each record.

PriorityTask - a numeric code to describe the highest priority task to perform on the tree. The default values are as follows:

1 = None – tree does not need maintenance.

2 = Stake/train – staking or training needed to encourage a straight trunk, strong scaffold branching, or eliminate multiple leaders, crossing branches, and girdling ties. Includes removing or replacing stakes and ties to prevent damage to tree bole.

3 = Clean – crown needs cleaning to remove dead, diseased, damaged, poorly attached, or crossing branches to increase health or longevity of tree.

4 = Raise – crown should be raised by removing lower branches from the tree trunk to eliminate obstructions or clearance issues.

5 = Reduce – crown should be reduced/thinned by pruning to reduce tree height, spread, overcrowding, wind resistance, or an increase of light penetration.

6 = Remove – tree is dangerous, dead or dying, and no amount of maintenance will increase longevity or safety.

7 = Treat pest/disease – insects, pathogens, or parasites are present and detrimental to tree longevity; treatment should be given to maintain longevity.

Additional or alternative definitions (up to 10) can be defined in STRATUM. If no PriorityTask value is available, 0 (zero) is entered for each record.

SwDamg – a numeric code to describe the amount of sidewalk damage. The default values are as follows:

1 = None – sidewalk heaved less than ¾ inch, requiring no remediation.

2 = Low – sidewalk heaved ¾ to 1½ inches, requiring minor grinding or ramping.

3 = Medium – sidewalk heaved 1½ to 3 inches, requiring grinding or ramping and/or replacement.

4 = High – sidewalk heaved more than 3 inches, requiring complete removal and replacement.

Alternative definitions (up to 4) can be defined in STRATUM. If no SwDamg value is available, 0 is entered for each record.

WireConflict – a numeric code to describe utility lines that interfere with or are present above a tree. The default values are as follows:

1 = No lines – no utility lines within vicinity of tree crown

2 = Present and not conflicting – utility lines occur within vicinity of tree crown, but crown does not presently intersect wires.

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3 = Present and conflicting – utility lines occur and intersect with tree crown.

Additional or alternative definitions (up to 5) can be defined in STRATUM. If no WireConflict value is available, 0 (zero) is entered for each record.

CondWood – a numeric code to describe the health of the tree's wood (its structural health) as per adaptation of the Council of Tree and Landscape Appraisers (CTLA) tree appraisal standards (CTLA, 2000. Guide for Plant Appraisal, 9th Ed. Savoy, IL: ISA, 143 pp). The default values are as follows:

1 = Dead or Dying - extreme problems

2 = Poor - major problems

3 = Fair - minor problems

4 = Good - no apparent problems

Classes must be ordered in ascending order, with the poorest rating having the lowest numerical value. Additional or alternative definitions (up to 10) can be defined in STRATUM. If no condition value is available, 0 (zero) is entered for each record.

If only one condition rating is inventoried, enter the same values for both CondWood and CondLvs.

CondLvs – a numeric code for the health of the tree's leaves (its functional health) as per adaptation of CTLA tree appraisal (CTLA, 2000. Guide for Plant Appraisal, 9th Ed. Savoy, IL: ISA, 143 pp):

1 = Dead or dying - extreme problems

2 = Poor - major problems

3 = Fair - minor problems

4 = Good - no apparent problems

Classes must be ordered in ascending order, with the poorest rating having the lowest numerical value. Additional or alternative definitions (up to 10) can be defined in STRATUM. If no condition value is available, 0 (zero) is entered for each record.

If only one condition rating is inventoried, enter the same values for both CondWood and CondLvs.

OtherOne – a numeric field with up to 10 variables to be defined by user. If no OtherOne value is available, 0 (zero) is entered for each record.

OtherTwo – a numeric field with up to 10 variables to be defined by user. If no OtherTwo value is available, 0 (zero) is entered for each record.

OtherThree – a numeric field with up to 10 variables to be defined by user. If no OtherThree value is available, 0 (zero) is entered for each record.

Final Data Prep

The simplest way to prepare for STRATUM is to save your city's tree inventory under a new name (e.g., YourCityData) so that you can manipulate it and organize your data into the data fields described above. Make sure that the data field names are spelled exactly as they are here, without spaces, and that they appear in this order. Check to be sure that the values in each category are appropriate; for example, do not distinguish seven degrees of sidewalk heave (only four are allowed). If your inventory has other information not described above that you would like to include, you can organize it under the categories OtherOne, OtherTwo, and OtherThree. Any other information should be deleted.

Program Settings

1. Define City
    a. Total Municipal Budget ($): left blank
    b. Population: 24,000

c. Total land area (sq mi): 8
d. Average street width (ft): 30
e. Average sidewalk width (ft): 7
f. Total linear miles of street (mile): 9

2. Define Cost (all but Other annual expenditures was unknown)
    a. Annual planting ($)
    b. Annual pruning ($)
    c. Annual tree and stump removal and disposal ($)
    d. Annual pest and disease control ($)
    e. Annual establishment/irrigation ($)
    f. Annual price of repair/mitigation of infrastructure damage ($)
    g. Annual price of litter/storm clean-up ($)
    h. Average annual litigation and settlements due to tree-related claims ($)
    i. Annual expenditure for program administration ($)
    j. Annual expenditures for inspection/answer service requests ($)
    k. Other annual expenditures ($)
    l. All annual total program cost ($): automatically calculated
3. Benefit Prices (default settings)
    a. Electricity ($/Kwh): 0.0759
    b. Natural gas ($/Therm): 0.98
    c. CO_2 ($/lb): 0.0075
    d. PM_{10} ($/lb): 2.84
    e. NO_2 ($/lb): 3.34
    f. SO_2 ($/lb): 2.06
    g. VOC ($/lb): 3.75
    h. Stormwater interception ($/gallon): 218,000
    i. Average home resales value ($)