LAND SURFACE CHARACTERIZATION PROJECT FOR EASTERN TEXAS (H-55)
FINAL REPORT

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Project description: The University of Texas Center for Space Research (CSR) is developing a new land cover classification data set, based upon recent collections of satellite and aerial imagery. For this data set to be more useful for air quality modeling and other purposes, additional vegetation data should be obtained for the study area. One approach involves field surveys to collect specific measurements of woody vegetation. Another approach is to tap into the extensive database collected and maintained by the Texas Forest Service (TFS) in support of the USDA Forest Inventory and Analysis (FIA) Program. Both methods have potential to improve the accurate classification of the different land cover units and to estimate the average leaf biomass density of each observed genus for each land cover classification.

The two main goals of the project are to improve methodologies for the development of land cover data and related average leaf biomass density estimates that are required to model biogenics emission in Texas, and to quantify the time and resources required to establish and update a comprehensive database for the eastern half of the State. Field data are required for land cover classification, for accuracy assessment, and for leaf biomass density estimates. Field data collected by TFS will be used by CSR to refine land cover classification for the TexAQS-II study and to assess the accuracy of the classified units. TFS will work on a strategy to calculate average leaf biomass density estimates using FIA data, and will work with CSR to develop efficient ways to use FIA data to improve land cover classification.

To estimate the leaf biomass density, allometric equations will be applied that relate leaf biomass to the data parameters that have been measured. The UFORE model developed by David Nowak of the USDA Forest Service is an appropriate tool for data collected in urban areas. Purves et al. (2004) published a peer-reviewed method that may be appropriate for use with FIA Program data. A portion of the project will be devoted to the identification and use of appropriate allometric equations and/or models to estimate the average leaf biomass density for each tree genus found in each land cover category.

Results abstract: From the field study in the D/FW Metroplex, there are discrete differences in species composition, density, and leaf biomass between the investigated strata, at both the Level 4 and Level 3 ecoregions, and between the low and medium intensity development levels. There are enough differences between the Level 4 DLI classes to warrant continuing this stratification with additional plots, 60 per stratum minimum. There was also a large difference between the DLI and DMI cover classes across the region. At a cost of $200-300/plot, a realistic budget for a follow-up field study of developed cover classes in the region would range from a low of $24,000 to as much as $108,000, depending on the stratification used.

For the accuracy assessment portion of the project, the accuracy rate of the CSR land cover map (vegetation classes) is 27% using FIA plots alone. Using both the FIA plot data and the corresponding TFS DOQQ's, the accuracy rate of the land cover map increased to 56%. TFS DOQQ's could play an important role in resolving the time difference between the FIA data and the Landsat images in order to improve the accuracy of the land cover map for forested cover types.

For the leaf biomass portion of the project, TFS developed a methodology for using FIA plot data to calculate estimates for leaf biomass density and variation in East Texas. However, due to the high variability of species composition and age distribution across the region and between individual FIA plots, the standard error values and coefficients of variation remain high. This is an intrinsic quality for the data being analyzed, at the species or genus level.

Part 1: Field Data Collection in Residential Land Cover Classes in the D/FW Metroplex

In October and November 2005, TFS staff developed a set of procedures for field data collection in urban areas in support of leaf biomass estimates for the most prevalent "developed" land cover classes in the Dallas/Fort Worth Metroplex. The plan called for collecting tree data at between 10 and 30 one-tenth acre circular plots (4,356 sq. ft.; radius = 37.2 ft.) for each of the six land cover classes identified by CSR. Given the available time, this would provide a minimum number of plots for statistical analysis, which Dr. David Nowak agreed to perform using his Urban Forest Effects (UFORE) model.

Methodology:

Plot Selection

CSR used their existing land cover classification to randomly select points eligible for field study. The cover classes chosen for study were "developed-low intensity" (DLI) and "developed-medium intensity" (DMI), within both Level 3 and Level 4 EPA ecoregions that cover the four-county Metroplex (Dallas, Denton, Tarrant, and Collin counties). Level 4 ecoregions included (from west to east) Western Cross Timbers, Grand Prairie, Eastern Cross Timbers, and Texas Blackland Prairie. Level 3 ecoregions were divided into the Cross Timbers (including the Grand Prairie) or Texas Blackland Prairie.

We hypothesized that there would be differences in the tree characteristics for the Level 4 ecoregions, which necessitated this stratification of plots. Plot number and GPS coordinates identified each point on the map. The first ten points in each class were labeled "high priority" and the second ten were labeled as "replacement" locations, since we anticipated that some "high priority" points would not be accessible or landowners would not grant permission to enter their property.

TFS GIS Specialist Jin Zhu created master maps for the field crews, labeling each point by class, plot ID number, and GPS coordinates over the four-county region. He also created plot-level images for each plot using available Digital Ortho-Quad imagery showing the tree cover, the plot center, a circle showing the approximate plot boundary, and local streets (see **Exhibit 1**). A map inset showed the general location of the plot and its relation to major roads and nearby plots. These maps were crucial in determining the placement of the plot center (PC) on the ground. **Exhibit 2** shows the relative location of each plot for which field data was collected within the study area (plot location data also provided as a GIS shapefile).

Data Collection

TFS staff (Pete Smith) adapted the field data collection methodology from Dr. David Nowak's published UFORE data collection procedures to streamline the time required for fieldwork. Only data variables crucial to calculating leaf biomass were retained in the procedure manual (**Exhibit 3**) and data sheet (**Exhibit 4**). After the training session with field crews, and clarification from Dr. Nowak, several variables were eliminated to speed up data collection even more (**Exhibit 5**). A list of tree species likely to be found was created to assist with assigning the correct species code (**Exhibit 6**).

A training session for field crews was held December 1-2, 2005. TFS Staff Foresters Courtney Blevins (Fort Worth), Matt Grubisich (Dallas), Carrie Atchison (Granbury), Jim Carse (Austin), Mickey Merritt (Houston), and Eric Copeland (Abilene) were joined by Plano City Arborist Renee Burke for the two-day field session. The whole group visited several sample plots to practice taking the necessary measurements in order to create consistency between work crews and fully understand the variables described in Dr. Nowak's manual.

Fieldwork proceeded for three weeks in December 2005 according to the adjusted field manual, using two-person crews in most cases. Data was collected for a total of 61 plots in the study area; an additional 11 points were visited but no data collected due to problems gaining permission to enter private property (see **Exhibit 7**). When this occurred, crews were instructed to use the first listed "replacement" plot for that class to avoid lost time spent finding landowners and securing permission. Only one "high priority" plot in class 6 was not visited, due to time constraints at the end of December 2005. Approximately 240 person-hours were spent collecting field data, equal to about two hours per plot, including travel time. A small amount of office work was required of each team to send plot photo images and data sheets to Pete Smith in College Station.

<u>Data Compilation & Analysis</u>
Plot photos and data sheets were correlated and photos digitally renumbered to correspond to plot number and direction of image (i.e. photo 28-N; see **Exhibit 8** and complete gallery of plot photos). Three plots had no associated photos. Photos were useful in documenting that crews went to a point on the ground, as well as matching up features on the sketch map (such as fences, buildings, etc.). In some cases, a photo helped identify a miscoded tree species on the data sheet. Next, an Access database was constructed to collect all the field data for transfer to Dr. Nowak for processing (see **Exhibit 9—CSR_Plots.mdb**). All data was entered by a TFS student worker and checked for accuracy. This was feasible due to the small number of plots in the study.

CSR and TFS staff met to review the plot data and confirm the appropriate cover class to which the plot belonged. Several plots were reassigned to a more appropriate class, based on a closer review of the imagery. This resulted in a spreadsheet list of plots to analyze in 12 separate groupings (**Exhibit 10**), based on the EPA Level 3 & 4 ecoregions and the intensity of the "developed" classification (DLI or DMI).

The database and related spreadsheet were sent to Dr. Nowak on August 11, 2006. Using the UFORE model, he was able to generate tables of leaf biomass and standard errors for each species within each of the 12 groupings of plots provided. Results are discussed below.

Part 1 Study Results:

As expected, there are discrete differences in species composition and density between the investigated strata, at both the Level 4 and Level 3 ecoregions, and between the low and medium intensity development levels (see **Exhibit 11**). There are also differences in leaf biomass totals and composition, which are critical to estimating volatile organic compound (VOC) emissions in air quality studies.

Among the Level 4 ecoregion plot groupings (DLI), the Western Cross Timbers had the highest density of trees (250 trees/hectare) and was dominated in total tree numbers by two species: post oak (Quercus stellata) and cedar elm (Ulmus crassifolia). The Eastern Cross Timbers plots were dominated by post oak, sugarberry (Celtis laevigata), and silver maple (Acer saccharinum) at a much lower density (80 trees/hectare). Both the Grand Prairie and the Blackland Prairie groups were more diverse (23 and 19 species, respectively) than the Cross Timbers groups (9-10 species), perhaps owing to the number of introduced species planted by property owners in former prairies with lower native tree densities and diversity.

At the Level 3 ecoregion groupings (Cross Timbers or Blackland Prairie), there are both similarities and differences that stand out. When all developed plots for each ecoregion are combined, the Cross Timbers and Blackland Prairies contain similar densities of leaf biomass (1,172 kg/ha and 1,146 kg/ha, respectively), but with slightly different species compositions. Ranked by leaf biomass (kg/ha), the Cross Timbers has as its top five species: post oak, sugarberry, cedar elm, live oak (Quercus virginiana), and pecan (Carya illinoensis); the Blackland Prairie has a top five species of sugarberry, eastern redcedar (Juniperus virginiana), Shumard oak (Quercus shumardii), red mulberry (Morus rubra), and live oak. From a leaf biomass standpoint, oaks make up about 475 kg/ha in the Cross Timbers, but only 225 kg/ha in the Blackland Prairie.

Also significant are the differences in the intensity of development. DLI plots averaged 145 trees/ha with a leaf biomass of 1,375 kg/ha, while DMI plots averaged just 45 trees/ha and 570 kg/ha of leaf biomass. Given the size of these categories within the four-county study area (102,341 ha for DLI and 129,436 ha for DMI), it makes sense to continue to stratify between these two land cover types if time and funding permits.

Finally, some discussion on the statistical validity of these estimates is warranted. For each set of plots, a “coefficient of variation” (COV) was calculated as the ratio of the total standard error for number of trees, divided by the estimated total number of trees for the grouping. This produced COV values ranging from over 61% (Cross Timbers DMI) to as low as 17% (all developed plots). These high COV values reflect the relatively small number of plots used to calculate the estimates. As sample size increases, or stratification of the study area becomes more refined, COV values should drop into the more acceptable range of 12-15% for total number of trees. This still means that subdivisions within the class, such as species, will retain relatively high standard error values.

Difficulties/Issues/Recommendations:

Plot Selection

There were some plots that ultimately had been assigned to the wrong class. There are built-in assumptions when selecting pixels randomly within a class, so re-aligning a plot after-the-fact may have some impact on the integrity of the “randomness” of the plots where data was collected. To prevent this in the future, plot locations should be scrutinized and verified as to class before beginning fieldwork.

It was also unrealistic for field crews to properly assign a plot to either DLI or DMI upon visiting the site. In some cases, crews merely wrote on the data sheet the category based on the plot map class; in other cases, structures on the plot prevent getting a good look around. Most importantly, though, crews are simply not trained to do this sort of large-scale stratification. This work must be done during the field plot random selection process.

Permission to visit a few plots could not be obtained, forcing the crew to visit a replacement plot instead. Time constraints also prevented waiting to hear back from an owner for more than a day or two. Some of these “denials” were the result of gated subdivisions, often in the wealthiest areas. It is possible then, that since the replacement plot was not in such an area, our sample is no longer “random” within the class. In fact, under-sampling due to socio-economic conditions could affect the results of our sample. We didn’t test such stratification, and this issue will likely not be a problem in the future if a more robust sample can be obtained.

Mapping

The individual plot location maps produce by Jin Zhu were outstanding and critical to the success of the field data collection portion of the project. The only recommendation would be to add the major road network to the large-scale map of plot locations to make it easier to drive from plot to plot.

Data Collection

The original UFORE procedures call for assessing tree crown parameters in “leaf on” condition, which was not possible for this project due to time constraints related to contracting procedures between HARC, CSR, and TFS. This could produce different crown estimates from field crews, particularly the estimate of crown **dieback**. Any future contracts for fieldwork need to be in place well before full leaf-out in the spring.

Two-person crews are recommended. While it is possible to complete a plot with just one person, if trees are present in any number, two people are needed to complete the measurements in a reasonable amount of time.

A significant number of plot centers fell on a house or other structure. While the field manual gives detailed instructions for identifying the plot boundary when this occurs, field crews rarely spent the time to follow these procedures completely. Instead, the relatively small number of trees made it fairly easy in most cases to determine that a tree was “in” or “out” of the plot. But in more difficult cases, key measurements were not always documented in the field to be used back in the office to determine whether a tree was “in” or “out.” This lack of documentation does not mean the field determinations were improper, but it does mean that no double-check in the office can be performed.

In order to make such determinations in the office, additional measurements are required:

- Distance and azimuth measurements between plot center (PC) and the point from which tree measurements are taken (MP). Typically, two sets are taken, along the closest two walls of a building. Crews use the plot photo to measure or estimate the distance along each wall.
- **Distance** (DS) and **direction** (DR) from MP to each “suspect” tree *must* be recorded.
- This extra data would allow office staff to calculate PC-to-tree measurements from MP-to-tree measurements, using the geometrical formulae shown in **Exhibit 12**. It would be preferable to add the appropriate formulae to the Access database so that this tree verification could be done automatically, but this would require further study.

A few shrub **species** were encountered that were so large (Photinia spp.) as to warrant counting as trees. Perhaps providing a minimum size for a specimen would help crews know when to measure and record its crown parameters. For instance, crapemyrtles were measured in almost all cases, but waxmyrtle and yaupon were only recorded when the crew decided the specimen was “large enough” to count as a tree. Since the purpose of the study is to estimate leaf biomass for the cover type, setting minimum crown dimensions could perhaps eliminate such arbitrary decisions and improve crew effectiveness.

Foliage absent was the most difficult variable for field crews to understand and apply consistently. This variable is crucial to estimating leaf biomass, yet trying to make such field estimates in December 2005 was difficult. The description of the variable itself also caused problems for the field crews, since significant experience is needed to make the judgments required.

Data Compilation & Analysis

Dr. Nowak’s UFORE model is necessary to produce leaf biomass estimates by species. Given the competing demands for his time, it would be useful to be able to perform this analysis locally instead of depending on his staff. As the UFORE model is made more accessible and transparent, this step may become a reality.

Design Parameters for Future Studies

Based of the results of this study, the total number of field plots used to calculate leaf biomass for trees in the developed land cover classes must be increased. In a typical UFORE study for a single city, 200 plots is the desired minimum number. For large study areas even more are necessary, such as the study covering the eight-county Houston region where 332 plots were visited. Dr. Nowak has recommended that the sample size be increased to between 30 and 60 plots per strata to improve the statistical averages for each class.

If funding were not a barrier, there were enough differences between the Level 4 DLI classes to warrant continuing this stratification with additional plots. It also appears that there was a large difference between the DLI and DMI cover classes across the region, and even within the DMI classes at the Level 3 ecoregion grouping. Using the original six classes, with 60 plots per class, at $200-300/plot, the budget for data collection alone would range from $72,000 to $108,000. The next most logical stratification to fit a more austere budget would be to use the Level 3 groupings for DLI and a Level 2 grouping for DMI, making three main strata. This produces a cost estimate of between $36,000 and $54,000. A Level 2 study to differentiate solely between DLI and DMI cover types would likely cost between $24,000 and $36,000.

One potentially large consideration is the fact that only a handful of Developed Open Space (DOS) and no “forest” plots were visited in this study – too few even to analyze statistically. It is possible that these lands contain much higher densities of trees, perhaps even dwarfing the leaf biomass totals from the other developed classes. If the contribution from these lands towards biogenic emissions from trees is much greater than the other developed classes, it might make sense to use the second alternative study design described above, or even just a Level 2 analysis to differentiate between DLI and DMI cover types.

Part 2: Land Cover Map Accuracy Assessment Using FIA Dataset and TFS DOQQ’s

In Summer 2006, the TFS performed an accuracy assessment of vegetation classes for a new East Texas land cover classification map developed by CSR, using FIA data and TFS DOQQ’s. A full inventory of FIA data had been collected for a 43-county area in East Texas and TFS had just finished its five-year cycle of producing 0.5-meter, Color Infrared (CIR), GIS-ready images that cover most of East Texas.

Methodology:

FIA Plot Location Confidentiality

To comply with the confidentiality agreement between the USDA Forest Service and TFS, a Confidentiality Certification document was obtained from the USDA Forest Service Southern Research Station for each TFS staff member who worked on this part of project. TFS seasonal GIS student worker, Wesley Marcel, was certified and assigned to work on this project under the supervision of Jin Zhu, TFS senior GIS specialist.

Plot Selection and Testing

Due to time limitations, CSR and TFS decided to select a single county (Angelina) as the study area to test for accuracy using the methodology developed in this project. CSR provided the land cover map for Angelina County to be tested by overlaying FIA field plots by TFS. TFS selected the FIA field plots qualifying for this study based on the following criteria:

- Forested plots only
- Each plot comprised of a single FIA forest cover class

TFS overlaid the FIA plots with CSR land cover map. By using TFS DOQQs as the reference data, TFS interpreted each selected FIA plot to see if it was consistent with the CSR land cover map class (see Figures 1-3 in **Exhibit 13**). When interpreting the maps, image acquisition dates and field data collection dates were also a consideration: CSR developed the land cover map based on Landsat 7 images from 2003 to 2004; TFS collected FIA plots in Angelina County from 2002 to 2004 and produced corresponding DOQQ's in this county in 2003 and 2004. The accuracy assessment results using FIA plot data alone may be different than the assessment using DOQQ's simply due to the time gap between data sets.

Part 2 Study Results:

A total of 52 FIA plots in Angelina County qualified for this study. Comparing FIA plot interpretation alone with the combination method (FIA plot data plus the corresponding DOQQ), TFS produced an accuracy assessment report for the land cover map in Angelina County (**Exhibit 14**). The accuracy rate of the CSR land cover map (vegetation classes) is 27% by interpreting FIA plots alone. By interpreting both the FIA plot data and the corresponding TFS DOQQ's, the accuracy rate of land cover map increased to 56%. Thus, TFS DOQQ's could play an important role in resolving the time difference between the FIA data and the Landsat images in order to improve the accuracy of the land cover map for forested cover types.

Part 3: Estimation of Leaf Biomass for Tree Species in East Texas Using FIA Plot Data

The Texas Forest Service developed a method to estimate the mean and variation of the leaf biomass density per hectare for each observed tree genus in each land cover classification in East Texas, using FIA plot data. The information is required to model biogenic emissions in Texas, and to quantify the time and resources required to establish and update a comprehensive database for the eastern half of the State. The method was developed by TFS Principal Economist Weihuan Xu, PhD., and Lin Li, PhD. candidate in Department of Statistics, Texas A&M University.

Methodology:

Data Parameters

The estimation was based on 2003 Texas Forest Inventory and Analysis (FIA) plot and tree level data. The data was limited to all live trees on forestlands. There were a total of 1,825 plots, and 44,242 trees in 43 counties of East Texas (**Table 1**). These plots were classified into 7 land categories based on information supplied by the CSR (**Table 2**). Plots with more than one land category were excluded from the sample.

Leaf Biomass Equations

The existing leaf biomass equations in the literature were thoroughly reviewed and evaluated. Leaf biomass can be estimated using a variety of equations, but for this project leaf biomass would ultimately have to be associated with variables in the FIA database such tree diameter at breast height (DBH) and tree height. While many biomass leaf equations exist for species in North America, the existing equations do not cover each species in each geographical location. There are also quality differences in the existing equations. The selection of the equations for each species was based on three factors: species, geographical location, and equation quality. Sometimes, tradeoffs needed to be made if these three factors conflicted with each other. Species factor usually received the highest priority. If an equation exists for a species, we would usually choose to use it, even if it meant using an equation of a species that was from a location far from Texas. In situations when there was no equation available for a certain species, an equation for a similar species was used. Location factor was given the next highest priority. If there were more than one equation available for a certain species, the equation from the location that was closest to East Texas was chosen. The location factor was not simply a 'distance' concept, however; it also took into account the geographical distributions of each species. Efforts were made to choose equations from locations with similar growing conditions for each species. The last consideration was equation quality. Equations based on both DBH and height were given higher priority over equations based on DBH only. The final selection of equations is documented in **Tables 3**, **4**, and **5**.

Leaf Biomass Estimation Process

The estimation of the means and variations of leaf biomass by land cover type and species took three steps. The first step was to compute the leaf biomass for each tree in the sample. The second step was to summarize the leaf biomass by land cover type and species for each plot. The third step was to estimate the mean, standard deviation, and coefficient of variation of the leaf biomass by land cover type and species. The estimated leaf biomass results were presented in kg/hectare dry weight. Using similar steps, we also computed the means and variations of leaf biomass by land cover type and species group, by forest type and species, and by forest type and species group.

Part 3 Study Results:

The estimated mean and standard deviation of each species in each land cover type is presented in **Tables 6-9**. Many of the standard deviations and coefficient of variations were fairly high. Majority of the standard deviations were bigger than their corresponding means, which means that the coefficients of variations were bigger than 100%. The main reason for the high variation of leaf biomass was the uneven distribution of tree species across the landscape. There are dozens of tree species in each land cover type in East Texas. However, for each particular FIA plot, there are usually far fewer species, meaning that the species that are not present in each plot are treated as having zero biomass in that plot. The large number of zero values for leaf biomass (by species and by plot) substantially increased the leaf biomass variation by species and by land cover type. The second contributing factor for the high variation in leaf biomass was the age distribution of trees. Because many different private owners control the majority of forestlands in East Texas, the harvest history and subsequent age distribution is highly variable from plot to plot, causing leaf biomass to vary greatly across the landscape. The variations of leaf biomass differ from **Tables 6-9** in some small ways, showing the impact of different ways of presenting the information, but they are generally large due to the two reasons stated above.

Sample Plots - Class 6

TEXAS FOREST SERVICE
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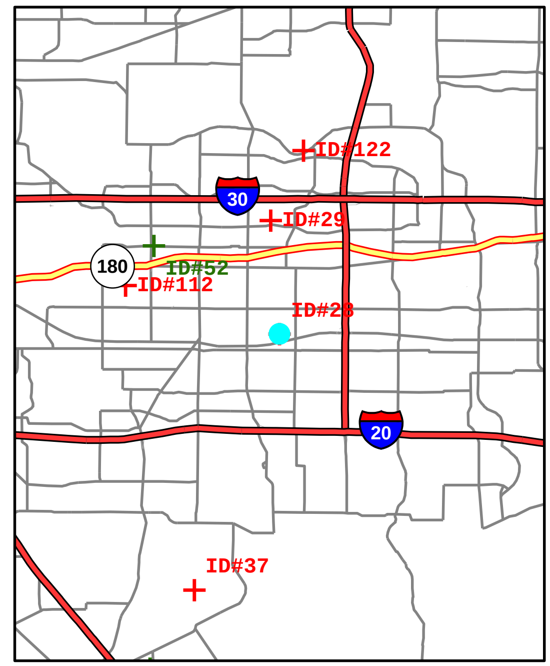
N
W E
S

1:2,500

0 200 400 Feet

Exhibit 1: Sample Plot Location Map



PLOTS - TOP PRIORITY

PLOTS - REPLACEMENT

Field Map - All Smaple Plots

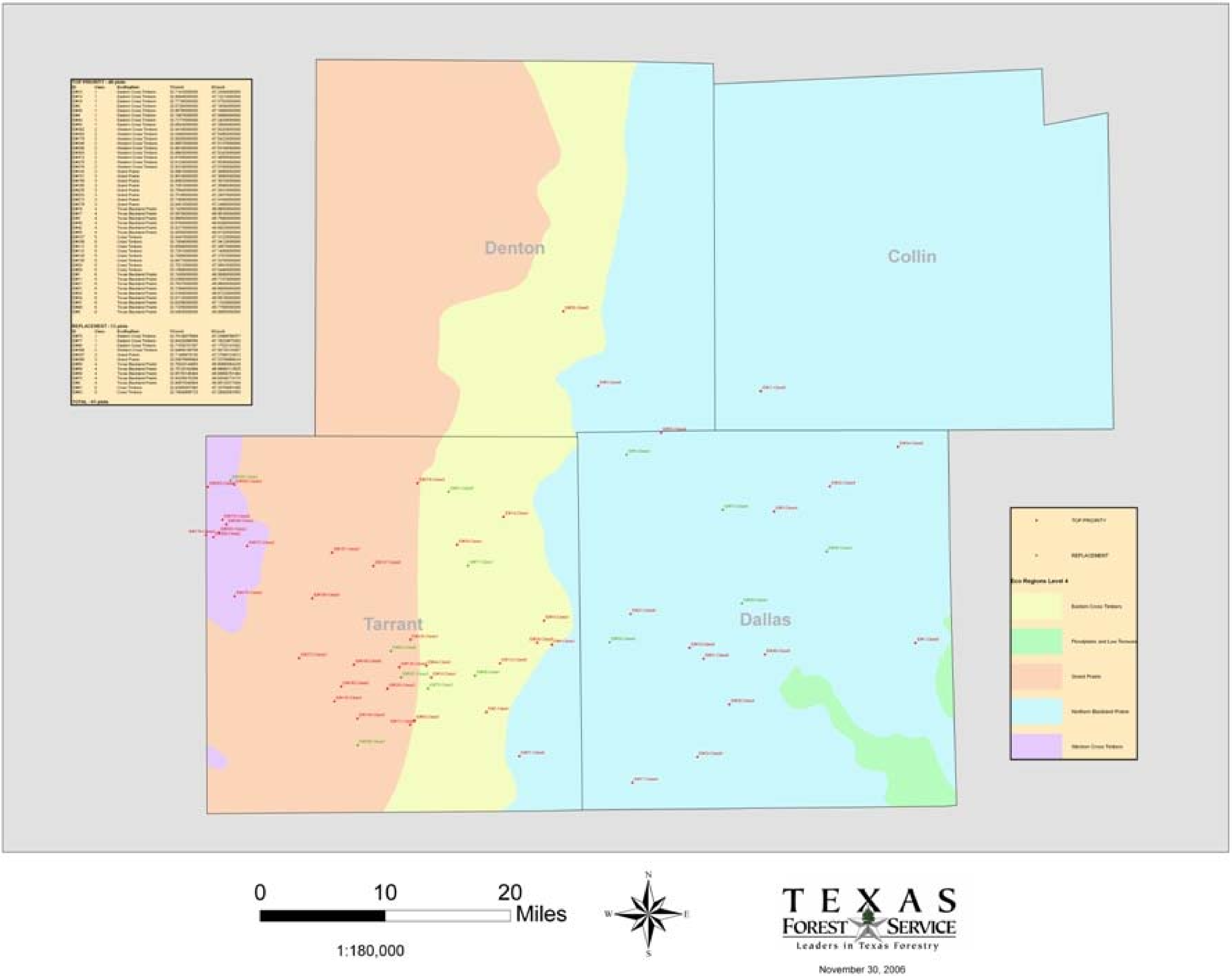


Exhibit 2: Field Plot Locations Within D/FW Study Area

The Urban Forest Effects (UFORE) Field Data Collection Procedures for the Surface Characterization Study In the Dallas/Fort Worth Metroplex

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Field Data Collection Procedures

1.0 Plot Establishment (Methods given are based on a 1/10-acre, circular field plot)

1) Locate property on the ground where plot center is located, based on evidence from map, DOQQ image, and/or photograph provided.

2) Obtain permission from resident/owner to access property.
   - If owner/resident is available, present TFS credentials and letter explaining the purpose of the project. Try to obtain permission to enter all properties affected by the plot. If permission is denied for the property where plot center is located, entire plot is thrown out; if adjoining owner denies access, plot location is established and plot data is recorded, even if visual estimates of trees must be made.
   - If owner/resident is unavailable or unknown, find out any name or contact information from neighbors so that contact can eventually be made. If location is a business or residence, leave business card and letter explaining the project. Follow up later once contact is made with owner or resident.
   - If no owner information is available or obvious, collect sufficient tract information so that a courthouse records check is possible to locate the landowner.

3) Locate plot center *as shown on photo image* one of two ways:
   - Move as close as possible to the target location and fine-tune using the hand-held GPS device. Final location should match the photo as closely as possible. UTM coordinates provided are to two decimal places, but location can be established with a single decimal place match for both latitude and longitude.
   - Get as near to plot center as possible, while remaining in an area with landmarks that are visible on the photo image. Obtain a stable GPS reading for the landmark closest to plot center, then enter plot center coordinates into unit to obtain distance and direction readings. Proceed to plot center using tape and compass.

4) At plot center, record actual GPS coordinates. On plot data sheet, identify location or other notes (e.g., address if available, front or back yard, etc.) and sketch plot center in reference to a few fixed objects (e.g., buildings, fences, etc). If plot is in the middle of the forest, write specific directions (distance and direction) to relocate plot center. Take four digital photos to record the location of plot center, each facing a cardinal direction (N, S, E, or W).

5) If plot center falls on a building or other surface (such as highways) where the center point cannot be accessed, the plot is not to be moved and the boundary of the plot should be determined on the ground in the plot area that is not obstructed. Distance to plot center from all edges of the obstruction should be measured from the aerial photograph in combination with the GPS unit. Use the sketch map to indicate the geometry of the plot, showing the building or obstruction and rough plot boundaries (see Appendix 1).

6) Next, determine plot boundaries on the ground. Plot radius is 37.2 ft from true plot center on flat ground. Mark the rough boundaries at this distance with flagging. All distances and directions to trees are to be measured and recorded from a building corner or other fixed point. Make notation of "plot measurement point" on sketch map and data sheet.

1.1 Measurement Units
All measured variables to be recorded in English (ft/in) units.

1.2 Plot Data Recorded (See Appendix_2.PDF for data collection forms and record this information only once per plot)

- **Plot ID** – Plot number from the aerial photograph.
- **Date –** Date of field measurements.
- **Crew** – List first and last initials of each crewmember.
- **Plot address** – Additional notes will be useful if plot is not located in area where there are no street numbers (vacant land, parks, industrial areas, etc.).
- **GPS coor** – Coordinates of global positioning system at plot center. Use UTM coordinate system (NAD 83).
- **Plot Contact Info** – If available, record contact person's name and phone number. For residential land uses, do not ask for this information. However, if name is on mailbox, record it. Owner/renter status is useful if it comes up in conversation.
- **Photo #** (four are required) – Record digital picture numbers from camera. One picture should be taken from plot center facing each cardinal direction. Photos should be re-labeled in the office with the plot number, followed by N, E, S, or W.
- **Slope through plot center** – Slope is determined by sighting the clinometer along a line parallel to the average incline (or decline) through the center of each plot, in the direction of the plot's aspect. To measure slope, Observer 1 should stand at the uphill edge of the plot and sight Observer 2, who stands at the downhill edge of the plot. Sight Observer 2 at the same height as the eye-level of Observer 1. Read the slope directly from the percent scale of the clinometer. If slope changes gradually across the plot, record an average slope. If slope changes across the plot but the slope is predominantly of one direction, code the predominant slope percentage rather than the average. *Record to nearest 1%, for slopes >=5%; for slopes <5%, record as 0%.*
- **Aspect** – Measure aspect with a hand-held compass along the same direction used to determine slope. *Record to nearest 1 degree. Values: 0 = no aspect (slope < 5 percent); 1 = 1 degree; 2 = 2 degrees; … 360 = 360 degrees, due north.*
- **Land Cover** – Record actual land cover for the plot *and its surrounding area*, as determined by the crew on the ground. *Use the definitions and codes from Appendix 10.*

2.0 Tree Data
Within each 1/10-acre plot, all *living* specimens of tree species with stem diameters >= 1-in will be measured (see Section 2.1 for diameter measurement instructions).

Data collection for trees starts with the tree to the north and then proceeds in a clockwise direction. (Note: flagging or chalking each tree as it is measured will help keep track of trees once they are measured and prevent missing or double-entering a tree*. No permanent marks, such as paint or scribe marks are allowed.*)

For plots with slopes <5%, trees are determined to be within the plot boundary if the distance from plot center to the center of the trunk at or near the ground line is 37.2 ft or less. For plots with slopes >=5%, the ground distance and actual slope to each tree should be measured.

Trees will be recorded and measured if more than ½ of its stem meets the limiting distance according to the following table:

Slope %	**5**	**7**	**10**	**12**	**15**	**17**	**20**	**22**	**25**	**27**	**30**
Slope Angle	2.9°	4.0°	5.7°	6.8°	8.5°	9.7°	11.3°	12.4°	14.0°	15.1°	16.7°
Limiting Distance	37.25′	37.3′	37.4′	37.5′	37.6′	37.7′	37.9′	38.1′	38.3′	38.5′	38.8′

If laser rangefinder is used, shoot parallel to the ground line to measure slope distance, then use limiting distance table above based on ground slope. Actual distance values recorded are for horizontal distance and may not exceed 37.2 ft. Actual slope distance and slope percent can be recorded in the Remarks section.

2.1 Basic Tree Measurements

For each *live* tree within the plot with greater than ½ of its stem in the plot and stem diameter >= 1-in, the following data are recorded:

- **DR** – Azimuth direction from plot center to the tree in degrees. *Record to nearest 1 degree. Values: 1 = 1 degree; 2 = 2 degrees; … 360 = 360 degrees, due north.*
- **DS** – Horizontal distance from plot center to the pith of the tree at its base, measured in ft. Rangefinder values to front of tree are acceptable, except for trees at the edge of the plot radius; these trees must conform to the limiting distance table in Section 2.0. *Record to nearest 0.1 ft. Values may not exceed 37.2 ft!*
- **SPECIES** – *Species must be recorded for all live trees*. If species is not known, take sample and record on datasheet as SAMPLE_1, etc. Each unknown tree with a number is unique to a specific species, so every time that same unknown is encountered it will be recorded as SAMPLE_1. Sequentially number unknowns in notebook, identify later, and correct data to proper species code. If identification of individual species is difficult (e.g., due to hybridization) or individual species is not known, then record genus if possible. *Record using codes given in Appendix 3.*
- **DIAMETER –** In general, measure stem diameter at 4.5 ft above the ground line (DBH) on the uphill side of the tree. For forked or multi-stemmed trees, determine the point at which the pith of the stems converge: if pith union is below the ground line, each fork or stem is treated as a separate tree; if pith union is above ground, measure stem diameter at the narrowest point below the fork. For trees that fork close to the ground, included bark down to the ground line is a good indicator that the pith union is below ground. If tree forks above DBH, measure diameter at the narrowest point between DBH and the ground. See Appendix 4 for other special circumstances. *Record values to the next lowest 0.1-in (e.g. -- a reading of 3.68 inches is recorded as 3.6 inches).*
- **HEIGHT TO DIAMETER** – Distance along the stem from the ground line on the uphill side to the point where diameter was measured. *Record to the nearest 0.1-in.*
- **TOT HEIGHT** – Height to top of tree, measured in ft. For downed living trees or severely leaning trees, height is considered the distance along the main stem from ground to treetop. *Record to the nearest 1-ft.*
- **HEIGHT TO CROWN BASE** – Height to base of live crown, in ft (see Appendix 7). *Record to the nearest 1-ft.*

2.2 Tree Crown Measurements

- **CROWN WIDTH** – Crown width measured in ft. Crown width is recorded by two measurements: widest and then at a right angle to the first measurement. If tree is downed or leaning, take width measurements perpendicular to the tree bole. *Record to the nearest 1-ft; dead trees = 0.*
- **FOLIAGE ABSENT** – Within the "typical crown outline," estimate the percent foliage missing due to pruning, dieback, defoliation, uneven crown, or dwarf or sparse leaves. The typical crown outline is defined as a symmetrical silhouette created by the live crown width, height, and height to base of live crown measurements (see Appendix 5). It is assumed to be symmetrical around the center point of the measured width of the tree and filled with leaves as if it were a healthy tree in excellent condition. This measure estimates the percent of leaf mass that is missing from the outline as compared to a healthy tree with a full symmetrical crown. Take into account the natural crown shape for the particular species. Two perpendicular measures of missing leaf mass are made and the average result is recorded. *Record to nearest 5% (<2.5% = 0; 2.5-<7.5% = 5; 7.5-<12.5% = 10; etc.; record dead trees as 99).*
- **DB (DIEBACK)** – Percent crown dieback in live crown area. This dieback does not include natural branch dieback due to crown competition/shading in the lower portion of the crown. However, branch dieback on side(s) of crown area due to shading from a building or another tree would be included. *Record to nearest 5% (<2.5% = 0; 2.5-<7.5% = 5; 7.5-<12.5% = 10; etc.; record dead trees as 99). See Appendix 6.*
- **CLE** – Crown Light Exposure: Number of sides of the tree receiving sunlight from above. Top of tree is counted as one side. Divide the crown vertically into four equal sides. Count the number of sides that would receive direct light if the sun were directly above the tree. Add one if the tree receives any direct light from the top. **Note: One-third of the live crown must be receiving full light in order for a side to qualify. A sliver of a side receiving light does not qualify.** *Record values from 0 – 5.*

Crown Light Exposure Codes.

Code	Definition
0	The tree receives no full light because it is shaded by buildings, trees, vines, or other vegetation. (Suppressed)
1	The tree receives full light from the top or 1 side. (Suppressed or intermediate)
2	The tree receives full light from the top and 1 side (or 2 sides without the top). (Intermediate)
3	The tree receives full light from the top and 2 sides (or 3 sides without the top). (Intermediate or Co-dominant)
4	The tree receives full light from the top and 3 sides. (Co-dominant or Dominant)
5	The tree receives full light from the top and 4 sides. (Dominant)

3. Equipment

The following are field equipment that are needed for UFORE plot measurements:

- Aerial photographs and street map to locate plot
- GPS unit
- Clinometer, or other tree height measuring device
- Diameter tape
- Clipboard; data sheets, pens/pencils (or digital recorders-PDA)
- 50/100 ft tape measure (or electronic measuring device)
- Species ID guide
- Notebook, clippers, and tape (to store unknown samples)
- First Aid Kit
- Calculator
- Compass (Suunto or other "see-through" brand)
- Binoculars (for estimating crown dieback)
- Dazer (to ward off dogs)
- Digital Camera
- Chalk/Flagging (to mark trees that have been measured)
- Electronic rangefinder (optional)

4. Safety

Safety is a critical component of any field operation. In cities, differing neighborhood condition can cause potential safety hazards. Be aware of the surrounding environments and use caution at all times. Discuss with local project managers specific conditions that may be encountered within the city. Also contact local police for more information, if necessary, and to let the police know that the field operation is occurring. Leave daily itineraries with the project manager regarding the area of the city to be sampled. See Tallent-Halsell, N.G. (ed.) 1994. Forest Health Monitoring 1994 Field Methods Guide. EPA/620/R-94/027. U.S. Environmental Protection Agency, Washington, DC for more information on safety procedures.

Appendices

Appendix 1 – Plot Center on Building

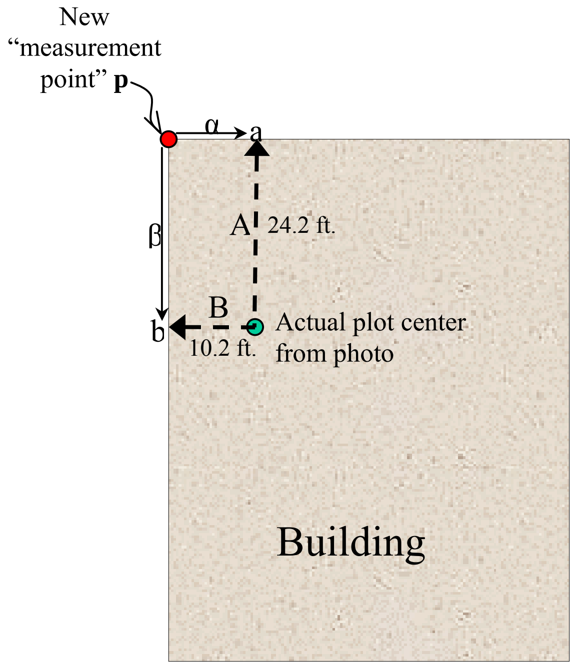

Figure 1-1. Plot center located as per TFS sketch map

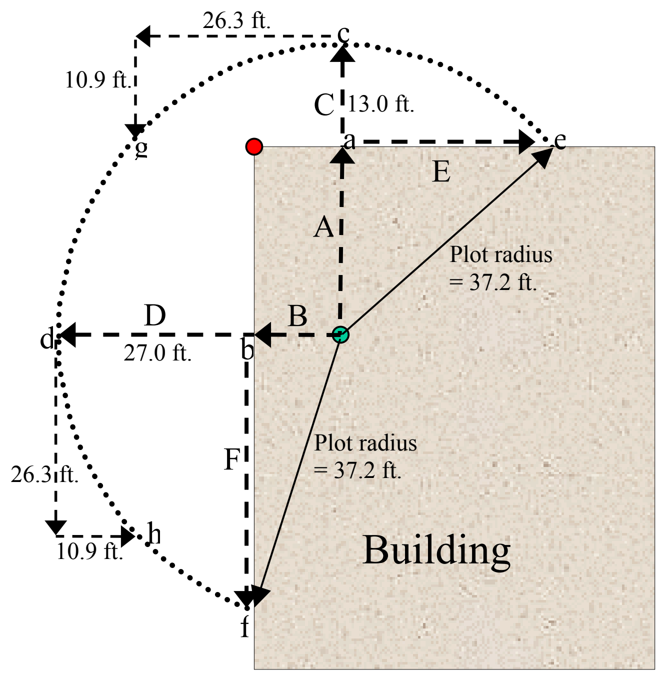

Figure 1-2. Establishing points along plot perimeter.

Step 1: Measure azimuths **α** and **β** along building walls using compass and locate points **a** and **b**.
Ex. -- Point **a** is 10.2 ft. from corner; point **b** is 24.2 ft. from corner.

Step 2: Find points **c**, **d**, **e,** and **f** on plot perimeter: Example --
Distance **C** = (plot radius - A) = (37.2-24.2) = 13 ft.; direction = **β** + 180º.
Distance **D** = (plot radius - B) = (37.2-10.2) = 27 ft.; direction = **α** + 180º.
Distance **E** = $(radius^2-A^2)^{-1}$ = $(1383.8-585.6)^{-1}$ = 28.3 ft.
Distance **F** = $(radius^2-B^2)^{-1}$ = $(1383.8-104.0)^{-1}$ = 35.8 ft.

Step 3: Find points **g** and **h** on plot perimeter: Example --
From point **c**, go 26.3 ft. on azimuth **α** + 180º, then 10.9 ft. on azimuth **β** to point **g**.
From point **d**, go 26.3 ft. on azimuth **β**, then 10.9 ft. on azimuth **α** to point **h**.

Appendix 2. – Field Data Sheets

Sheets are available as Appendix_2.PDF

Appendix 3. – Species Codes

Species codes are available as Appendix_3.PDF

Appendix 4. DBH Measurement

From: Forest Inventory and Analysis National Core Field Guide. Volume 1: Field Data Collection Procedures for Phase 2 Plots. Version 1.4

Special DBH situations:

1. Tree with butt-swell or bottleneck: Measure these trees 1.5 ft above the end of the swell or bottleneck if the swell or bottleneck extends 3.0 ft or more above the ground (Figure 4-1).

2. Forked tree: If the tree forks, determine the point at which the pith of each fork meets. If that point is below the ground line (included bark at the ground line is evidence of separation), treat each fork as a separate tree (Figure 4-3); if the pith intersection is above the ground line, measure diameter at the narrowest point between 4.5 ft and the ground (Figure 4-2).

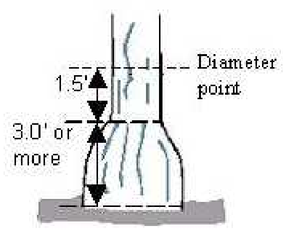

Figure 4-1: Tree with swelled butt (1)

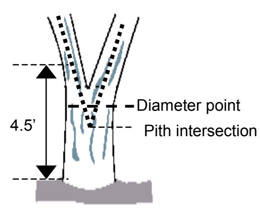

Figure 4-2: One tree (2)

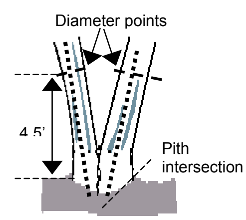

Figure 4-3: Two trees (2)

3. Tree with irregularities at DBH: On trees with swellings (Figure 4-4), bumps, depressions, branches (Figure 4-5), etc. at DBH, diameter will be measured immediately above the irregularity at the place it ceases to affect normal stem form.

4. Tree on slope: Measure diameter at 4.5 ft from the ground along the bole on the uphill side of the tree (Figure 4-6).

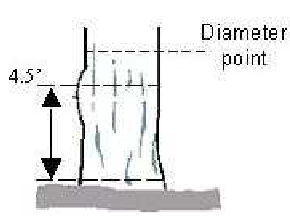

Figure 4-4: Tree with swelling (3)

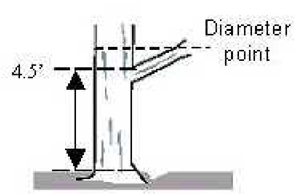

Figure 4-5: Tree with branch (3)

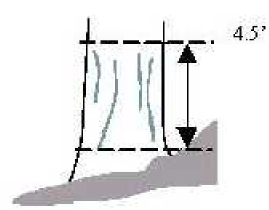

Figure 4-6: Tree on a slope (4)

5. Leaning tree: Measure diameter at 4.5 ft from the ground along the bole. The 4.5 ft distance is measured along the underside face of the bole (Figure 4-7).

6. Independent trees that grow together: Continue to treat them as two trees.

7. Diameter on trees missing a portion of bark or bole at the point of diameter measurement is measured and recorded to the nearest 0.1 in as the tree actually exists (e.g., do not "reconstruct" the bole) (Figure 4-8).

8. Live windthrown tree: Measure from the top of the root collar along the length to 4.5 ft (Figure 4-9).

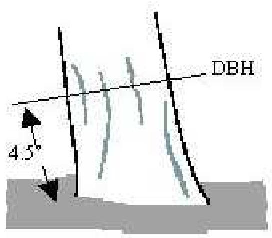

Figure 4-7: Leaning tree (5)

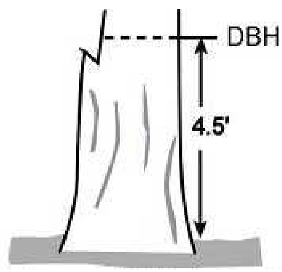

Figure 4-8: Tree with broken stem (7)

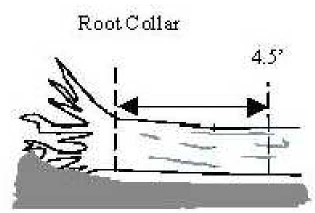

Figure 4-9: Tree on the ground (8)

Appendix 5. Foliage Absent

Foliage absent is the percent of the typical crown outline (for the measured tree's height and width) that is missing compared to the actual crown outline. The typical crown outline is defined as a symmetrical silhouette created by the crown width, height, and height to base of live crown measurements. It is assumed to be symmetrical around the center point of the measured width of the tree and filled with leaves as if it were a healthy tree in excellent condition. See illustrations in the upper right corner of Figures 5-1 and 5-2. The actual crown outline is illustrated in lower right corner of Figures 5-1 and 5-2.

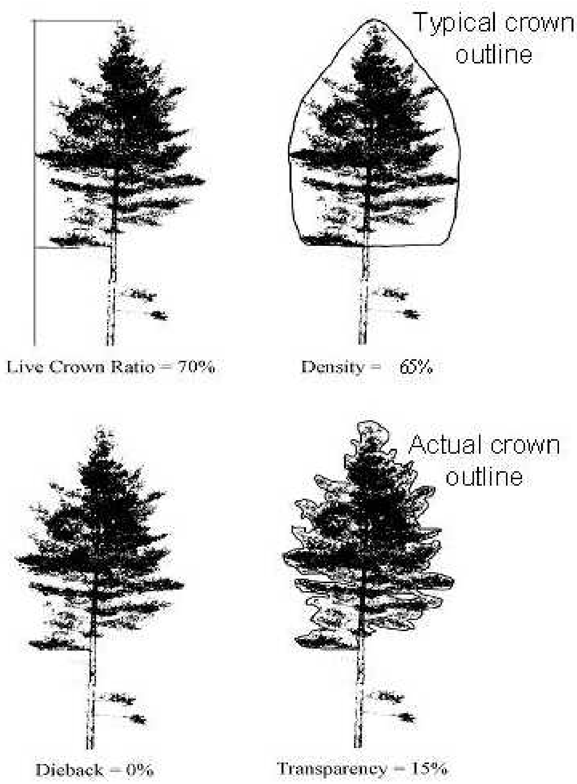

Figure 5-1. Examples of a conifer with crown measurement outlines.

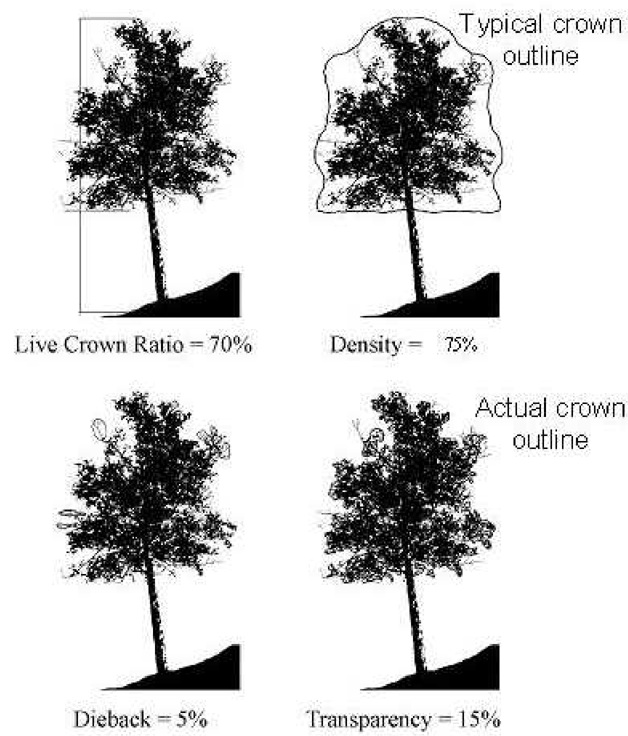

Figure 5-2. Examples of a deciduous tree with crown measurement outlines.

Foliage absent assumes the actual crown outline is totally filled and no light passes through. Light passing through the actual crown outline is assessed using foliage transparency.

Foliage absent is measured by two people standing perpendicular angles to the tree (Figure 5-3). Typical and actual crown shape is determined by the measurements made for crown width, tree height, and height to base of live crown.

When two individuals disagree with their estimates, follow the guidelines listed in Appendix 8. The estimate is placed into one of 21 percentage classes.

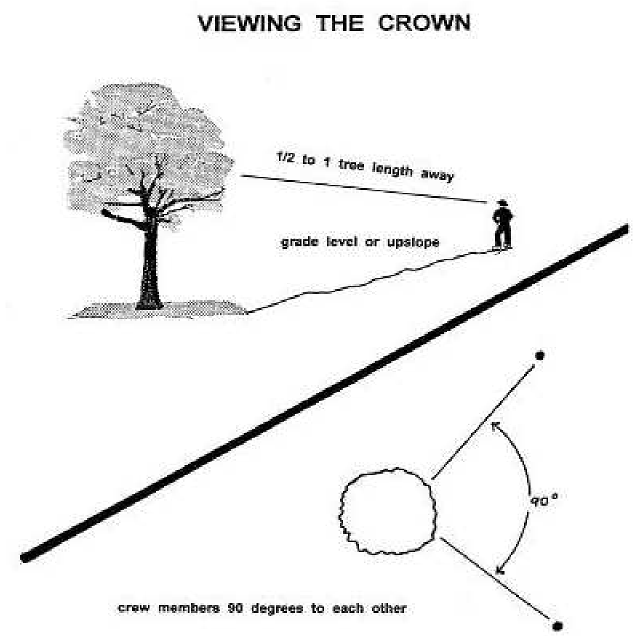

Figure 5-3. Crew positions for viewing crowns.

Appendix 6. Crown Dieback

From: Forest Inventory and Analysis National Core Field Guide. Volume 1: Field Data Collection Procedures for Phase 2 Plots. Version 1.4

Crown dieback is defined as recent mortality of branches with fine twigs, which begins at the terminal portion of a branch and proceeds toward the trunk. Dieback should occur from the top of the crown down and from the outside in toward the main stem. Dieback is only considered when it occurs in the upper and outer portions of the tree. When whole branches are dead in the upper crown, without obvious signs of damage such as breaks or animal injury, assume that the branches died from the terminal portion of the branch. Dead branches in the lower portion of the live crown are assumed to have died from competition and shading. Dead branches in the lower live crown are not considered as part of crown dieback, unless there is continuous dieback from the upper and outer crown down to those branches.

Crown dieback estimates reflect the severity of recent stresses on a tree. Estimate crown dieback as a percentage of the live crown area, including the dieback area. The crown base should be the same as that used for the live crown ratio estimate. Assume the perimeter of the crown is a two-dimensional outline from branch-tip to branch-tip, excluding snag branches and large holes or gaps in the crown (Figure 6-1).

Crown dieback is obtained by two people (Figure 5-3). Binoculars can be used to assist in the data collection. Observers should be conscious of lighting conditions and how light affects the day's observations. Under limited-light conditions, observers should take extra time. Poor lighting can make the measurement more difficult.

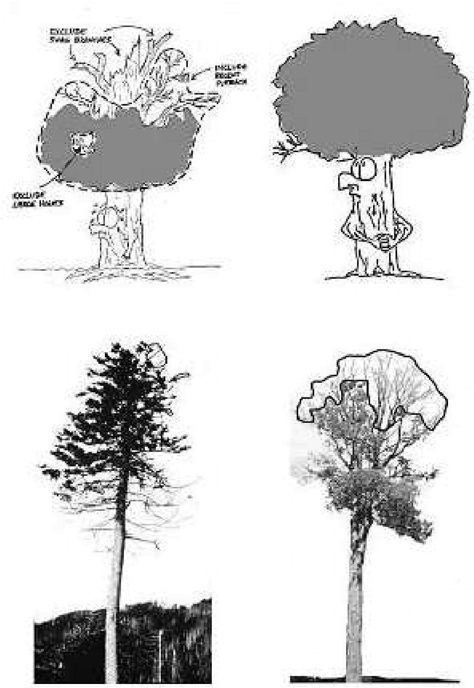

Figure 6-1. Dieback rating examples

Each individual should mentally draw a two-dimensional crown outline, block in the dieback and estimate the dieback area.

When two individuals disagree with their estimates, follow the guidelines listed in Appendix 8. The estimate is placed into one of 21 percentage classes.

Training for crown variables (crown dieback, foliage transparency) can be aided by using the Forest Health Monitoring – Crown Indicator 2000 CD by Mike Schomaker of the USDA Forest Service.

Appendix 7. Base of Live Crown

From: Forest Inventory and Analysis National Core Field Guide. Volume 1: Field Data Collection Procedures for Phase 2 Plots. Version 1.4

Live crown length is determined from the last live foliage at the crown top (dieback in the upper portion of the crown is not part of the live crown) to the "base of live crown". Many times there are additional live branches below the "base of live crown". These branches are only included if they have a basal diameter greater than 1 in and are within 5 ft of the base of the obvious live crown. The live crown base becomes that point on the main bole perpendicular to the lowest live foliage on the last branch that is included in the live crown. The live crown base is determined by the live foliage and not by the point where a branch intersects with the main bole.

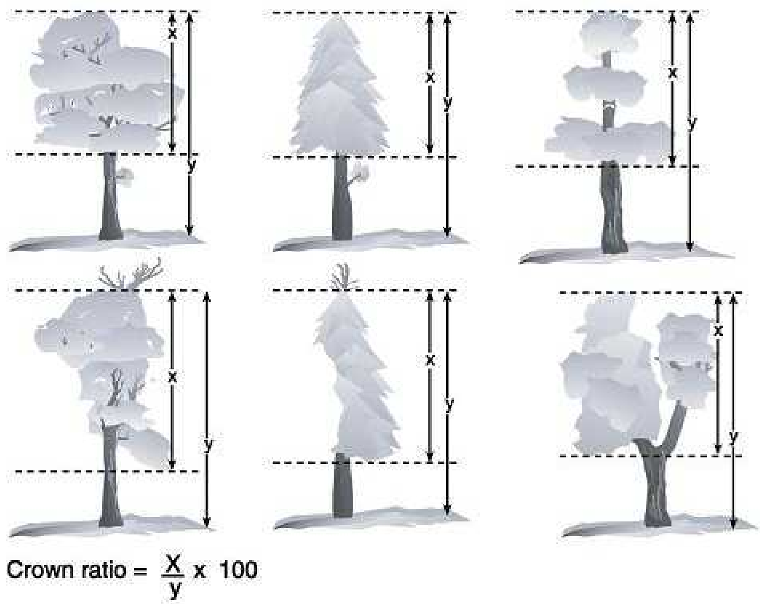

Figure 9-1 Example of base of live crown.

Appendix 8. Crown Rating Precautions

From: Forest Inventory and Analysis National Core Field Guide. Volume 1: Field Data Collection Procedures for Phase 2 Plots. Version 1.4

Crews must be especially careful when making evaluations under certain conditions and follow these procedures:

Distance from the tree

Crews must attempt to stay at least 1/2 to 1 tree length from the tree being evaluated. Some ratings change with proximity to the tree. In some situations, it is impossible to satisfy this step, but the crew should do the best it can in each case. All evaluations are made at grade (same elevation as base of the tree) or up slope from the tree. This may not be possible in all cases but never get in the habit of evaluating trees from the down slope side.

View of the crown

Crewmembers should evaluate trees when standing at an angle to each other, striving to obtain the best view of the crown. The ideal positions are at 90 degrees to each other on flat terrain (Figure 8-1). If possible, never evaluate the tree from the same position or at 180 degrees. In a forest, getting a good perspective of the crown becomes difficult. Overlapping branches, background trees and lack of a good viewing area can cause problems when rating some trees. Crews need to move laterally to search for a good view. Take special care when rating such trees.

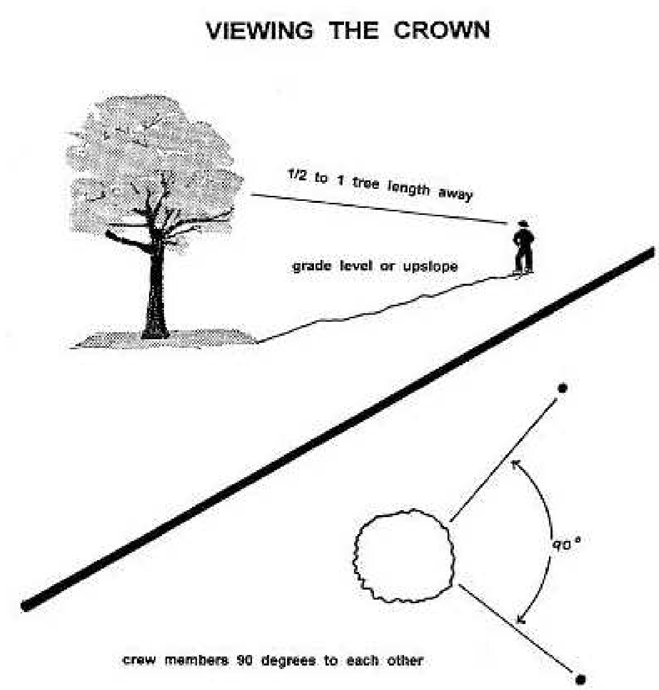

Figure 8-1. Crew positions for viewing crowns.

Climatic conditions

Cloudy or overcast skies, fog, rain and poor sun angles may affect estimates. Live crown ratio and crown diameters may be affected but to a lesser degree than other crown indicators. Crown density tends to be overestimated or underestimated because light does not project well through the foliage or, in some cases, the light may be too bright for a good estimate. Crown dieback may be underestimated, because it is difficult to see dead twigs and/or to differentiate defoliated twigs from dead twigs. The data quality expectation standard helps, because crews can normally be within 10 percent, even in poor weather conditions. However, crews need to be especially careful during poor lighting conditions. Crews should move around a tree to get another view, even if the view appears adequate at a specific location.

Heavy defoliation

During heavy defoliation, crown dieback may be overestimated and foliage transparency may be underestimated due to the difficulty in differentiating dead twigs from defoliated twigs. The use of binoculars may help in separating dead twigs from defoliated twigs.

Trees with no crown after application of definitions (epicormics or sprigs only)

After a sudden release or damage, a tree may have very dense foliage, but no crown. These situations are coded as follows: live crown ratio - 00, crown light exposure - 0, crown position - 3, crown density - 00, crown dieback - 99, foliage transparency - 99.

Epicormics remain epicormics until they regain the size of previous branches for trees with no branches 1 in or larger in diameter at the base above the swelling. For trees that had 1 in or larger branches when the epicormics formed, epicormics become branches once they reach 1 inch in diameter.

Measurement differences resolution

If the numbers for a crown measurement estimate by two crewmembers do not match, arrive at the final value by:

- Taking an average, if the numbers differ by 10% (2 classes) or less.
- Changing positions, if the numbers differ by 15 % or more and attempt to narrow the range to 10% or less.
- Averaging the two estimates for those trees that actually have different ratings from the two viewing areas (ratings of 30 and 70 would be recorded as 50)

Appendix 9. Quality Control Standards

The accuracy and precision of the data collected through this study is critical to the validity of any statistical measures or conclusions concerning tree cover. Therefore the following standards for data precision will be in effect for this study:

Table 1. -- Tolerances for UFORE field variables.

VARIABLE	TOLERANCE
PLOT LOCATION	
Plot Number	None
Date	None
Crew ID	None
GPS Coordinates	+/- 0.1 UTM unit
Photos	Min. 2 photos
Slope	+/- 1 percent
Aspect	+/- 5 degrees
Land Cover Class	None
TREE DATA VARIABLES	
Tree missed or added	None
Azimuth	+/- 3 degrees
Distance	+/- 1 foot
Species	Within genus
Diameter	+/- 0.2 inch
Height to diameter	+/- 0.2 inch
Total height	+/- 10 feet
Height to crown base	+/- 5 feet
Crown width (wide)	+/- 5 feet
Crown width (perpendicular)	+/- 5 feet
Foliage absent	+/- 10 percent
Dieback	+/- 10 percent
Crown light exposure	None

Appendix 10. Eastern Texas Land Cover Class Descriptions

Class 1 – Open Water (OW): All areas of open water, generally with less than 25 percent cover of vegetation or soil. Characteristic land cover features for this class include lakes, rivers, reservoirs, streams, ponds, and ocean.

Class 2 – Developed Open Space (DOS): Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.

Class 3 – Developed Low Intensity (DLI): Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49 percent of total cover. These areas most commonly include significantly spaced single-family housing units, farm outbuildings, and large sheds. Streets and roads, or portions of roads, with associated trees and grasses are also included in this class.

Class 4 – Developed Medium Intensity (DMI): Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50-79 percent of total cover. These areas most commonly include single-family housing units, farm outbuilings, and large sheds.

Class 5 – Developed High Intensity (DHI): Includes highly developed areas where people reside or work in high numbers. Impervious surfaces account for 80-100 percent of the total cover. Characteristic land cover features include apartment and commercial/industrial complexes and associated parking, row houses, commercial strip development, large barns, hangars, interstate highways, and runways.

Class 6 – Barren Land (Rock/Sand/Clay/Unconsolidated Shore) (BL): Includes barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15 percent of total cover. Additionally, unconsolidated material such as silt, sand, or gravel that is subject to inundation and redistribution due to the action of water. Characterized by substrates lacking vegetation except for pioneering plants that become established during brief periods when growing conditions are favorable. Erosion and deposition by waves and currents produce a number of landforms representing this class. Other characteristic land cover features include quarries, desert and arid riverbeds, exposed rock, beaches and other sandy areas, bars, and flats.

The following are VEGETATED classes: Areas having generally 25 percent or more of the land or water with vegetation. Arid or semi-arid areas may have as little as 5 percent vegetation cover.

Herbaceous Vegetation: Areas dominated by non-woody plants such as grasses, forbs, ferns and weeds, either native, naturalized, or planted. Trees must account for less than 25 percent canopy cover while herbaceous plants dominate all existing vegetation.

Class 7 – Herbaceous Natural (HN): Includes areas dominated by native or naturalized grasses, forbs, ferns and weeds. It can be managed, maintained, or improved for ecological purposes such as weed/brush control or soil erosion. Includes vegetated vacant lots and areas where it cannot be determined whether the vegetation was planted or cultivated such as in areas of dispersed grazing by feral or domesticated animals. Includes landscapes dominated by grass-like plants such as bunch grasses, palouse grass, palmetto prairie areas, as well as true prairie grasses. Characteristic land cover features include prairies, meadows, clear-cuts with natural grasses, and undeveloped lands with naturally occurring grasses.

Class 8 – Herbaceous Cultivated (HC): Includes areas of herbaceous vegetation planted and/or cultivated by humans for agronomic purposes in developed settings. The majority of vegetation in these areas is planted and/or maintained for the production of food, feed, fiber, pasture, or seed. Temporarily flooded are included in this category. This class does not include harvested areas of naturally occurring plants such as wild rice and cattails.
Note: This class is a land use class and cannot be identified with spectral information alone. GIS information helps to identify this class.

Vegetated Wetland: Areas where the water table is at, near, or above the land surface for a significant part of most years. Vegetation covers more than 25 percent of the land surface. Wetlands can include marshes, swamps situated on the shallow margins of bays, lakes, ponds, streams, or reservoirs; wet meadows or perched bogs in high mountain valleys, or seasonally wet or flooded low spots or basins. These classes do not include agricultural land which is flooded for cultivation purposes.

Woody Wetland: Areas dominated by woody vegetation, and includes seasonally flooded bottomland, mangrove swamps, shrub swamps, and wooded swamps including those around bogs. Wooded swamps and southern flood plains contain primarily cypress, tupelo, oaks, and red maple. Central and northern flood plains are dominated by cottonwoods, ash, alder, and willow. Flood plains of the Southwest may be dominated by mesquite, saltcedar, seepwillow, and arrowweed. Northern bogs typically contain tamarack or larch, black spruce, and heath shrubs. Shrub swamp vegetation includes alder, willow, and buttonbush.

Forested Wetland: Areas with tree canopy greater than 25 percent, surface water present or saturated soils present for variable periods that may or may not have detectable seasonality.

Class 9 - Riparian Forested Wetland (WFR): Includes tree dominated wetlands along river or stream courses that are seasonally or temporarily flooded. Example species include: *Quercus laurifolia, fraxinus pennsylvanica, Nyssa sp., Acer rubrum, Liquidambar* *styraciflua, Ulmas Americana, Quercus virginiana, Celtis laevigata, Carya illinoinensis, Ulmas crassifolia, and Platanus occidentalis.*

Class 10 – Swamp Forested Wetland (WFS): Includes tree dominated areas on which surface water persists throughout the growing season, except during drought years. Example species include: *Nyssa aquatica and Taxodium distichum.*

Class 11 – Shrub Wetland (WS): Wetlands with shrub canopy cover greater than 25 percent. This class includes tidal and non-tidal shrub dominated wetlands. Example species include: *Tamarix Sp., Bacharis halimifolia, Avicennia germinans, Arundinaria gigantea, Bacharis salicifolia, and Salix Sp.*

Class 12 – Herbaceous Emergent Wetland (WHE): Areas dominated by wetland herbaceous vegetation which is present for most of the growing season. Includes fresh-water, brackish-water, and salt-water marshes, tidal marshes, mountain meadows, wet prairies, and open bogs.

<u>Woody Vegetation:</u> Land with at least 25 percent tree and (or) shrub canopy cover.

<u>Forested:</u> Trees with crowns overlapping (generally 60-100 percent cover).

<u>Deciduous Forest:</u> Areas dominated by trees where 75 percent or more of the canopy cover can be determined to be trees which lose all their leaves for a specific season of the year.

Class 13 - Cold Deciduous Forest (FDC): Areas dominated by trees that shed their leaves as a strategy to avoid seasonal periods of low temperature. Example species include: *Quercus stellata and Quercus marilandica.*

<u>Evergreen Forest:</u> Areas dominated by trees where 75 percent or more of the canopy cover can be determined to be trees which maintain their leaves all year.

Class 14 – Broad-leafed Evergreen Forest (FEB): Areas dominated by evergreen trees that have well-defined leaf blades and are relatively wide in shape. Example species include: *Quercus virginicus and Quercus fusiformis*.

Class 15 - Needle-leafed Evergreen Forest (FEN): Areas dominated by evergreen trees with slender elongated leaves. Example species include: *Pinus echinata, Pinus palustris, Pinus taeda, and Juniperus virginiana.*

Class 16 - Mixed Forest (FM): Areas dominated by trees where neither deciduous nor evergreen species represent more than 75 percent of the canopy cover.

Class 17 – Cultivated Woody Vegetation (Orchards/Vineyards/Groves) (CWV): Areas containing plantings of evenly spaced trees, shrubs, bushes, or other cultivated climbing plants usually supported and arranged evenly in rows. This class includes orchards, groves, vineyards, cranberry bogs, berry vines, and hops, as well as tree plantations planted for the production of fruit, nuts, Christmas tree farms, and commercial tree nurseries. This class excludes pine plantations and other lumber or pulp wood plantings, which are classified as Forested. Note: This class is a land use class and cannot be identified with spectral information alone.

Woodland: Areas of open stands of trees with crowns not usually touching (25- 59 percent cover).

Deciduous Woodland: Areas dominated by trees where 75 percent or more of the canopy cover can be determined to be trees which lose all their leaves for a specific season of the year.

Class 18 - Cold Deciduous Woodland (WDC): Areas dominated by trees that shed their leaves as a strategy to avoid seasonal periods of low temperature. Example species include: *Quercus stellata , Quercus marilandica, Juglans nigra, and Quercus alba.*

Evergreen Woodland: Areas dominated by trees where 75 percent or more of the canopy cover can be determined to be trees which maintain their leaves all year.

Class 19 - Broad-leafed Evergreen Woodland (WEB): Areas dominated by evergreen trees that have well-defined leaf blades and are relatively wide in shape. Example species include: *Quercus virginicus and Quercus fusiformis*.

Class 20 - Needle-leafed Evergreen Woodland (WEN): Areas dominated by evergreen trees with slender elongated leaves. Example species include: *Pinus palustris, Pinus taeda, and Juniperus virginiana.*

Class 21 - Mixed Woodland (WM): Areas dominated by trees where neither deciduous nor evergreen species represent more than 75 percent of the canopy cover.

Shrub land: Areas where trees have less than 25 percent canopy cover and the existing vegetation is dominated by plants that have persistent woody stems, a relatively low growth habit (generally less than 4m), and which generally produce several basal shoots instead of a single shoot. These classes include true shrubs, trees that are small or stunted because of environmental condition, desert scrub, and chaparral. In the eastern U.S., these classes include former cropland or pasture lands which are now covered by brush to the extent that they are no longer identifiable or usable as cropland or pasture. Clear-cut areas will exhibit a stage of shrub cover during the regrowth cycle. Some common species which would be classified as shrub land are mountain mahogany, sagebrush, and scrub oaks.

Deciduous Shrub: Areas where 75 percent or more of the land cover can be determined to be shrubs which lose all their leaves for a specific season of the year.

Class 22 - Cold Deciduous Shrub (SDC): Areas dominated by shrubs that shed their leaves as a strategy to avoid seasonal periods of low temperature. Example species include: *Quercus sinuata, Rubas sp., and Smilax Sp.*

Evergreen Shrub: Areas where 75 percent or more of the land cover can be determined to be shrubs that keep their leaves year round.

Class 23 - Broad-leafed Evergreen Shrub (SEB): Areas dominated by evergreen shrubs that have well-defined leaf blades and are relatively wide in shape. Example species include: *Quercus havardii and Quercus fusiformis.*

Class 24 - Needle-leafed Evergreen Shrub (SEN): Areas dominated by evergreen shrubs with slender elongated leaves. Example species include: *Juniperus ashei and Juniperus virginiana*.

Class 25 - Mixed Shrub (SM): Areas dominated by shrubs where neither deciduous nor evergreen species represent more than 75 percent of the land cover.

Class 26 – Desert Scrub (DS): Areas predominantly in arid and semi-arid portions of the southwestern U.S. Existing vegetation is sparse and often covers only 5-25 percent of the land. Example species include sagebrush, creosote, saltbush, greasewood, and cacti.

Exhibit 4:

UFORE Urban Inventory Plot Data Sheet

PLOT ID:		DATE:		CREW:	

PLOT SKETCH AND NOTES FOR PLOT LOCATION

PLOT ADDRESS (if applicable):	GPS COORDINATES (UTM-NAD 83, Zone 14)
	Northing:
	Easting:

PLOT CONTACT INFO (if available):

Name & Title:

Phone #:

PHOTOS:

N:	
E:	
S:	
W:	
SLOPE (%):	
ASPECT (degrees):	
LAND COVER CLASS (code):	

NOTES OR REMARKS:

SKETCH MAP

Limiting Distance		Class	Code	Cover Type Name	Class	Code	Cover Type Name
Slope %	Distance	2	DOS	Dev.-Open Space	14	FEB	BL Evergreen Forest
5	37.25'	3	DLI	Dev.-Low Intensity	15	FEN	NL Evergreen Forest
7	37.3'	4	DMI	Dev.-Medium Intensity	16	FM	Mixed Forest
10	37.4'	5	DHI	Dev.-High Intensity	17	CWV	Cult. Woody Veg. (Orchards)
12	37.5'	6	BL	Barren (Rock, etc.)	18	WDC	Cold Deciduous Woodland
15	37.6'	7	HN	Herbaceous-Natural	19	WEB	BL Evergreen Woodland
17	37.7'	8	HP	Herbaceous-Cultivated	20	WEN	NL Evergreen Woodland
20	37.9'	9	WFR	Riparian Forested Wetland	21	WM	Mixed Woodland
22	38.1'	10	WFS	Swamp Forested Wetland	22	SDC	Cold Deciduous Shrubland
25	38.3'	11	WS	Shrub Wetland	23	SEB	BL Evergreen Shrubland
27	38.5'	12	WHE	Herb. Emergent Wetland	24	SEN	NL Evergreen Shrubland
30	38.8'	13	FDC	Cold Deciduous Forest	25	SM	Mixed Shrubland

UFORE Urban Inventory Plot Data Sheet - Tree Info

Plot ID =				SPECIES	DIAMETER	HEIGHT TO DIAMETER	HEIGHT		CROWN WIDTH		FOL ABS	DB	CLE	REMARKS
	#	DR	DS				TOT	CROWN BASE	WIDE	90°				
TREES	1													
	2													
	3													
	4													
	5													
	6													
	7													
	8													
	9													
	10													
	11													
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	35													

**Tree Notes:

Exhibit 5:

Field Data Collection Procedures—[Field Adjustments Noted]

1.0 Plot Establishment (Methods given are based on a 1/10-acre, circular field plot)

1) Locate property on the ground where plot center is located, based on evidence from map, DOQQ image, and/or photograph provided.

2) Obtain permission from resident/owner to access property.
   - If owner/resident is available, present TFS credentials and letter explaining the purpose of the project. Try to obtain permission to enter all properties affected by the plot. If permission is denied for the property where plot center is located, entire plot is thrown out; if adjoining owner denies access, plot location is established and plot data is recorded, even if visual estimates of trees must be made.
   - If owner/resident is unavailable or unknown, find out any name or contact information from neighbors so that contact can eventually be made. If location is a business or residence, leave business card and letter explaining the project. Follow up later once contact is made with owner or resident.
   - If no owner information is available or obvious, collect sufficient tract information so that a courthouse records check is possible to locate the landowner.
   - *[Time constraints may force crews to drop a plot for which access is either denied or cannot be obtained. Use list of replacement plots and select the first available plot in the same map class.]*

3) Locate plot center *as shown on photo image* one of two ways:
   - Move as close as possible to the target location and fine-tune using the hand-held GPS device. Final location should match the photo as closely as possible. UTM coordinates provided are to two decimal places, but location can be established with a single decimal place match for both latitude and longitude.
   - Get as near to plot center as possible, while remaining in an area with landmarks that are visible on the photo image. Obtain a stable GPS reading for the landmark closest to plot center, then enter plot center coordinates into unit to obtain distance and direction readings. Proceed to plot center using tape and compass.

4) ~~At plot center, record actual GPS coordinates.~~ On plot data sheet, identify location or other notes (e.g., address if available, front or back yard, etc.) and sketch plot center in reference to a few fixed objects (e.g., buildings, fences, etc). If plot is in the middle of the forest, write specific directions (distance and direction) to relocate plot center. Take four digital photos to record the location of plot center, each facing a cardinal direction (N, S, E, or W). *[There is no need to record actual coordinates since original coordinates and plot photo are used to identify plot center location.]*

5) If plot center falls on a building or other surface (such as highways) where the center point cannot be accessed, the plot is not to be moved and the boundary of the plot should be determined on the ground in the plot area that is not obstructed. Distance to plot center from all edges of the obstruction should be measured from the aerial photograph in combination with the GPS unit. Use the sketch map to indicate the geometry of the plot, showing the building or obstruction and rough plot boundaries (see Appendix 1).

6) Next, determine plot boundaries on the ground. Plot radius is 37.2 ft from true plot center on flat ground. Mark the rough boundaries at this distance with flagging. All distances and

directions to trees are to be measured and recorded from a building corner or other fixed point. Make notation of "plot measurement point" on sketch map and data sheet.

1.2 Plot Data Recorded (See Appendix_2.PDF for data collection forms and record this information only once per plot)

- **Plot ID** – Plot number from the aerial photograph.
- **Date –** Date of field measurements.
- **Crew** – List first and last initials of each crewmember.
- **Plot address** – Additional notes will be useful if plot is not located in area where there are no street numbers (vacant land, parks, industrial areas, etc.).
- ~~**GPS coor**~~ – Coordinates of global positioning system at plot center. Use UTM coordinate system (NAD 83). *[Not necessary to record since coordinates are already provided.]*
- **Plot Contact Info** – If available, record contact person's name and phone number. For residential land uses, do not ask for this information. However, if name is on mailbox, record it. Owner/renter status is useful if it comes up in conversation.
- **Photo #** (four are required) – Record digital picture numbers from camera. One picture should be taken from plot center facing each cardinal direction. Photos should be re-labeled in the office with the plot number, followed by N, E, S, or W.
- ~~**Slope through plot center**~~ – Slope is determined by sighting the clinometer along a line parallel to the average incline (or decline) through the center of each plot, in the direction of the plot's aspect. To measure slope, Observer 1 should stand at the uphill edge of the plot and sight Observer 2, who stands at the downhill edge of the plot. Sight Observer 2 at the same height as the eye-level of Observer 1. Read the slope directly from the percent scale of the clinometer. If slope changes gradually across the plot, record an average slope. If slope changes across the plot but the slope is predominantly of one direction, code the predominant slope percentage rather than the average. *Record to nearest 1%, for slopes >=5%; for slopes <5%, record as 0%.* *[Not necessary since UFORE model does not use this for leaf biomass.]*
- ~~**Aspect**~~ – Measure aspect with a hand-held compass along the same direction used to determine slope. *Record to nearest 1 degree. Values: 0 = no aspect (slope < 5 percent); 1 = 1 degree; 2 = 2 degrees; … 360 = 360 degrees, due north.* *[Not necessary since UFORE model does not use this for leaf biomass.]*
- **Land Cover** – Record actual land cover for the plot *and its surrounding area*, as determined by the crew on the ground. *Use the definitions and codes from Appendix 10.*

2.0 Tree Data

Within each 1/10-acre plot, all *living* specimens of tree species with stem diameters >= 1-in will be measured (see Section 2.1 for diameter measurement instructions).

Data collection for trees starts with the tree to the north and then proceeds in a clockwise direction. (Note: flagging or chalking each tree as it is measured will help keep track of trees once they are measured and prevent missing or double-entering a tree*. No permanent marks, such as paint or scribe marks are allowed.*)

For plots with slopes <5%, trees are determined to be within the plot boundary if the distance from plot center to the center of the trunk at or near the ground line is 37.2 ft or less. For plots with slopes >=5%, the ground distance and actual slope to each tree should be measured.

Trees will be recorded and measured if more than ½ of its stem meets the limiting distance according to the following table:

Slope %	**5**	**7**	**10**	**12**	**15**	**17**	**20**	**22**	**25**	**27**	**30**
Slope Angle	2.9°	4.0°	5.7°	6.8°	8.5°	9.7°	11.3°	12.4°	14.0°	15.1°	16.7°
Limiting Distance	37.25′	37.3′	37.4′	37.5′	37.6′	37.7′	37.9′	38.1′	38.3′	38.5′	38.8′

If laser rangefinder is used, shoot parallel to the ground line to measure slope distance, then use limiting distance table above based on ground slope. Actual distance values recorded are for horizontal distance and may not exceed 37.2 ft. Actual slope distance and slope percent can be recorded in the Remarks section.

2.1 Basic Tree Measurements

For each *live* tree within the plot with greater than ½ of its stem in the plot and stem diameter >= 1-in, the following data are recorded:

- **DR** – Azimuth direction from plot center to the tree in degrees. *Record to nearest 1 degree. Values: 1 = 1 degree; 2 = 2 degrees; … 360 = 360 degrees, due north.* *[Required only in situations where PC is on building and limiting distance will have to be calculated from plot geometry in the office.]*
- **DS** – Horizontal distance from plot center to the pith of the tree at its base, measured in ft. Rangefinder values to front of tree are acceptable, except for trees at the edge of the plot radius; these trees must conform to the limiting distance table in Section 2.0. *Record to nearest 0.1 ft. Values may not exceed 37.2 ft!* *[Required only in situations where PC is on building and limiting distance will have to be calculated from plot geometry in the office. Values could exceed 37.2 ft. under these circumstances.]*
- **SPECIES** – *Species must be recorded for all live trees*. If species is not known, take sample and record on datasheet as SAMPLE_1, etc. Each unknown tree with a number is unique to a specific species, so every time that same unknown is encountered it will be recorded as SAMPLE_1. Sequentially number unknowns in notebook, identify later, and correct data to proper species code. If identification of individual species is difficult (e.g., due to hybridization) or individual species is not known, then record genus if possible. *Record using codes given in Appendix 3.*
- **~~DIAMETER~~ –** In general, measure stem diameter at 4.5 ft above the ground line (DBH) on the uphill side of the tree. For forked or multi-stemmed trees, determine the point at which the pith of the stems converge: if pith union is below the ground line, each fork or stem is treated as a separate tree; if pith union is above ground, measure stem diameter at the narrowest point below the fork. For trees that fork close to the ground, included bark down to the ground line is a good indicator that the pith union is below ground. If tree forks above DBH, measure diameter at the narrowest point between DBH and the ground. See Appendix 4 for other special circumstances. *Record values to the next lowest 0.1-in (e.g. -- a reading of 3.68 inches is recorded as 3.6 inches).* *[Not necessary since UFORE model does not use this for leaf biomass.]*
- **~~HEIGHT TO DIAMETER~~** – Distance along the stem from the ground line on the uphill side to the point where diameter was measured. *Record to the nearest 0.1-in.* *[Not necessary since UFORE model does not use this for leaf biomass.]*
- **TOT HEIGHT** – Height to top of tree, measured in ft. For downed living trees or severely leaning trees, height is considered the distance along the main stem from ground to treetop. *Record to the nearest 1-ft.*

- **HEIGHT TO CROWN BASE** – Height to base of live crown, in ft (see Appendix 7). *Record to the nearest 1-ft.*

2.2 Tree Crown Measurements

- **CROWN WIDTH** – Crown width measured in ft. Crown width is recorded by two measurements: widest and then at a right angle to the first measurement. If tree is downed or leaning, take width measurements perpendicular to the tree bole. *Record to the nearest 1-ft; ~~dead trees = 0~~.* *[Dead trees are not included in the study.]*
- **FOLIAGE ABSENT** – Within the "typical crown outline," estimate the percent foliage missing due to pruning, dieback, defoliation, uneven crown, or dwarf or sparse leaves. The typical crown outline is defined as a symmetrical silhouette created by the live crown width, height, and height to base of live crown measurements (see Appendix 5). It is assumed to be symmetrical around the center point of the measured width of the tree and filled with leaves as if it were a healthy tree in excellent condition. This measure estimates the percent of leaf mass that is missing from the outline as compared to a healthy tree with a full symmetrical crown. Take into account the natural crown shape for the particular species. Two perpendicular measures of missing leaf mass are made and the average result is recorded. *Record to nearest 5% (<2.5% = 0; 2.5-<7.5% = 5; 7.5-<12.5% = 10; etc.; ~~record dead trees as 99~~).* *[Dead trees are not included in the study.]*
- **DB (DIEBACK)** – Percent crown dieback in live crown area. This dieback does not include natural branch dieback due to crown competition/shading in the lower portion of the crown. However, branch dieback on side(s) of crown area due to shading from a building or another tree would be included. *Record to nearest 5% (<2.5% = 0; 2.5-<7.5% = 5; 7.5-<12.5% = 10; etc.; ~~record dead trees as 99~~). See Appendix 6.* *[Dead trees are not included in the study.]*
- **CLE** – Crown Light Exposure: Number of sides of the tree receiving sunlight from above. Top of tree is counted as one side. Divide the crown vertically into four equal sides. Count the number of sides that would receive direct light if the sun were directly above the tree. Add one if the tree receives any direct light from the top. **Note: One-third of the live crown must be receiving full light in order for a side to qualify. A sliver of a side receiving light does not qualify.** *Record values from 0 – 5.*

Crown Light Exposure Codes.

Code	Definition
0	The tree receives no full light because it is shaded by buildings, trees, vines, or other vegetation. (Suppressed)
1	The tree receives full light from the top or 1 side. (Suppressed or intermediate)
2	The tree receives full light from the top and 1 side (or 2 sides without the top). (Intermediate)
3	The tree receives full light from the top and 2 sides (or 3 sides without the top). (Intermediate or Co-dominant)
4	The tree receives full light from the top and 3 sides. (Co-dominant or Dominant)
5	The tree receives full light from the top and 4 sides. (Dominant)

Exhibit 6: # Tree Species Codes for Dallas/Fort Worth Metroplex

Code	Scientific Name	Common Name
ACSP2	ACACIA SPECIES	ACACIA
ACBAC	ACER BARBATUM 'CADDO'	CADDO MAPLE
ACBU	ACER BUERGERIANUM	TRIDENT MAPLE
ACGR3	ACER GRANDIDENTATUM	BIGTOOTH MAPLE
ACNE	ACER NEGUNDO	BOXELDER
ACPA	ACER PALMATUM	JAPANESE MAPLE
ACRU	ACER RUBRUM	RED MAPLE
ACSA1	ACER SACCHARINUM	SILVER MAPLE
AIAL	AILANTHUS ALTISSIMA	TREE OF HEAVEN
ALJU	ALBIZIA JULIBRISSIN	MIMOSA
BENI	BETULA NIGRA	RIVER BIRCH
BRPA	BROUSSONETIA PAPYRIFERA	PAPER MULBERRY
BULA	BUMELIA LANUGINOSA	CHITTAMWOOD
CACA	CARPINUS CAROLINIANA	AMERICAN HORNBEAM
CAIL	CARYA ILLINOENSIS	PECAN
CA1	CARYA SPECIES	HICKORY
CATE	CARYA TEXANA	BLACK HICKORY
CA3	CATALPA SPECIES	CATALPA
CEAT	CEDRUS ATLANTICA	ATLAS CEDAR
CEDE	CEDRUS DEODARA	DEODAR CEDAR
CELA	CELTIS LAEVIGATA	SUGARBERRY
CELAR	CELTIS LAEVIGATA VAR. RETICULAT	NETLEAF HACKBERRY
CEOC	CELTIS OCCIDENTALIS	NORTHERN HACKBERRY
CECA	CERCIS CANADENSIS	EASTERN REDBUD
CECAM	CERCIS CANADENSIS VAR. MEXICA	MEXICAN REDBUD
CECAT	CERCIS CANADENSIS VAR. TEXENSI	TEXAS REDBUD
CHLI	CHILOPSIS LINEARIS	DESERT-WILLOW
CHTA	CHITALPA X TASKENTENSIS	CHITALPA
CISP	CITRUS SPECIES	CITRUS
COFL	CORNUS FLORIDA	FLOWERING DOGWOOD
COKO	CORNUS KOUSA	KOUSA DOGWOOD
COOB	COTINUS OBOVATUS	AMERICAN SMOKETREE
CR	CRATAEGUS SPECIES	HAWTHORN
CULE	CUPRESSOCYPARIS X LEYLANDII	LEYLAND CYPRESS
CUAR	CUPRESSUS ARIZONICA	ARIZONA CYPRESS
CUSE	CUPRESSUS SEMPERVIRENS	ITALIAN CYPRESS
DITE	DIOSPYROS TEXANA	TEXAS PERSIMMON
DIVI	DIOSPYROS VIRGINIANA	COMMON PERSIMMON
ERJA	ERIOBOTRYA JAPONICA	LOQUAT TREE
EU1	EUCALYPTUS SPECIES	EUCALYPTUS
FISI	FIRMIANA SIMPLEX	CHINESE PARASOLTREE
FRAM	FRAXINUS AMERICANA	WHITE ASH
FRBE	FRAXINUS BERLANDIERIANA	BERLANDIER ASH
FRPE	FRAXINUS PENNSYLVANICA	GREEN ASH
FRTE	FRAXINUS TEXENSIS	TEXAS ASH
GIBI	GINKGO BILOBA	GINKGO
GLTR	GLEDITSIA TRIACANTHOS	HONEYLOCUST
GYDI	GYMNOCLADUS DIOICUS	KENTUCKY COFFEETREE
ILDE	ILEX DECIDUA	POSSUMHAW
ILOP	ILEX OPACA	AMERICAN HOLLY
ILVO	ILEX VOMITORIA	YAUPON
JUMI	JUGLANS MICROCARPA	LITTLE WALNUT
JUNI	JUGLANS NIGRA	BLACK WALNUT
JUAS	JUNIPERUS ASHEI	ASHE JUNIPER
JU	JUNIPERUS SPECIES	JUNIPER
JUVI	JUNIPERUS VIRGINIANA	EASTERN REDCEDAR
KOPA	KOELREUTERIA PANICULATA	GOLDENRAIN TREE
LAIN	LAGERSTROEMIA INDICA	COMMON CRAPEMYRTLE
LIST	LIQUIDAMBAR STYRACIFLUA	SWEETGUM
LITU	LIRIODENDRON TULIPIFERA	TULIPTREE
MAPO	MACLURA POMIFERA	OSAGE ORANGE
MAGR	MAGNOLIA GRANDIFLORA	SOUTHERN MAGNOLIA
MASO	MAGNOLIA X SOULANGEANA	SAUCER MAGNOLIA
MA2	MALUS SPECIES	CRABAPPLE
MEAZ	MELIA AZEDARACH	CHINABERRY
MEGL	METASEQUOIA GLYPTOSTROBOIDE	DAWN REDWOOD
MORU	MORUS RUBRA	RED MULBERRY
MO	MORUS SPECIES	MULBERRY
NYSY	NYSSA SYLVATICA	BLACK TUPELO
OSVI	OSTRYA VIRGINIANA	EASTERN HOPHORNBEAM
PAAC	PARKINSONIA ACULEATA	JERUSALEM THORN
PATO	PAULOWNIA TOMENTOSA	ROYAL PAULOWNIA
PIED	PINUS EDULIS	PINYON PINE
PIEL2	PINUS ELDARICA	AFGHAN PINE
PIEL	PINUS ELLIOTTII	SLASH PINE

Code	Scientific Name	Common Name
PINI	PINUS NIGRA	AUSTRIAN PINE
PIPI2	PINUS PINEA	ITALIAN STONE PINE
PITA	PINUS TAEDA	LOBLOLLY PINE
PITH	PINUS THUNBERGII	JAPANESE BLACK PINE
PICH	PISTACIA CHINENSIS	CHINESE PISTACHE
PLAQ	PLANERA AQUATICA	WATER ELM
PLME	PLATANUS MEXICANA	MEXICAN SYCAMORE
PLOC	PLATANUS OCCIDENTALIS	AMERICAN SYCAMORE
POMA	PODOCARPUS MACROPHYLLUS	YEW PODOCARPUS
PODE	POPULUS DELTOIDES	EASTERN COTTONWOOD
PO	POPULUS SPECIES	POPLAR
PRGL2	PROSOPIS GLANDULOSA	HONEY MESQUITE
PRCA	PRUNUS CAROLINIANA	CAROLINA LAURELCHERRY
PRME	PRUNUS MEXICANA	MEXICAN PLUM
PRSE1	PRUNUS SEROTINA	BLACK CHERRY
PR	PRUNUS SPECIES	CHERRY
PTTR	PTELEA TRIFOLIATA	COMMON HOPTREE
PYCA	PYRUS CALLERYANA	CALLERY PEAR
QUAC	QUERCUS ACUTISSIMA	SAWTOOTH OAK
QUAL	QUERCUS ALBA	WHITE OAK
QUBI	QUERCUS BICOLOR	SWAMP WHITE OAK
QUBU2	QUERCUS BUCKLEYI	TEXAS RED OAK
QUCA1	QUERCUS CANBYI	CANBY OAK
QUDU1	QUERCUS DURANDII	DURAND OAK
QUFA	QUERCUS FALCATA	SOUTHERN RED OAK
QUGR2	QUERCUS GRAVESII	CHISOS RED OAK
QULA	QUERCUS LACEYI	LACEY OAK
QULA2	QUERCUS LAURIFOLIA	LAUREL OAK
QULY	QUERCUS LYRATA	OVERCUP OAK
QUMA1	QUERCUS MACROCARPA	BUR OAK
QUMA3	QUERCUS MARGARETTA	SAND POST OAK
QUMA2	QUERCUS MARILANDICA	BLACKJACK OAK
QUMI	QUERCUS MICHAUXII	SWAMP CHESTNUT OAK
QUMU	QUERCUS MUEHLENBERGII	CHINKAPIN OAK
QUNI	QUERCUS NIGRA	WATER OAK
QUPA2	QUERCUS PAGODA	CHERRYBARK OAK
QUPA	QUERCUS PALUSTRIS	PIN OAK
QUPH	QUERCUS PHELLOS	WILLOW OAK
QUPO2	QUERCUS POLYMORPHA	MEXICAN WHITE OAK
QUSH	QUERCUS SHUMARDII	SHUMARD OAK
QUSIB	QUERCUS SINUATA VAR. BREVILOB	BIGELOW OAK
QU	QUERCUS SPECIES	OAK
QUST	QUERCUS STELLATA	POST OAK
QUVE	QUERCUS VELUTINA	BLACK OAK
QUVI	QUERCUS VIRGINIANA	LIVE OAK
RHCA2	RHAMNUS CAROLINIANA	CAROLINA BUCKTHORN
RHLA3	RHUS LANCEOLATA	PRAIRIE SUMAC
ROPS	ROBINIA PSEUDOACACIA	BLACK LOCUST
SATE	SABAL TEXANA	TEXAS SABAL PALM
SABA	SALIX BABYLONICA	WEEPING WILLOW
SANI	SALIX NIGRA	BLACK WILLOW
SA	SALIX SPECIES	WILLOW
SADR	SAPINDUS DRUMMONDII	WESTERN SOAPBERRY
SASE	SAPIUM SEBIFERUM	CHINESE TALLOWTREE
SAAL	SASSAFRAS ALBIDUM	SASSAFRAS
SOAF	SOPHORA AFFINIS	TEXAS SOPHORA
SOJA	SOPHORA JAPONICA	JAPANESE PAGODA TREE
SOSE	SOPHORA SECUNDIFLORA	MESCALBEAN
TA2	TAMARIX SPECIES	TAMARISK
TAAS	TAXODIUM ASCENDENS	PONDCYPRESS
TADI	TAXODIUM DISTICHUM	BALDCYPRESS
THOR	THUJA ORIENTALIS	ORIENTAL ARBORVITAE
TICA	TILIA CAROLINIANA	CAROLINA BASSWOOD
ULAL	ULMUS ALATA	WINGED ELM
ULAM	ULMUS AMERICANA	AMERICAN ELM
ULCR	ULMUS CRASSIFOLIA	CEDAR ELM
ULPA	ULMUS PARVIFOLIA	CHINESE ELM
ULPU	ULMUS PUMILA	SIBERIAN ELM
ULRU	ULMUS RUBRA	SLIPPERY ELM
ULS	ULMUS SPECIES	ELM
UNKN	UNKNOWN SPECIES	UNKNOWN SPECIES
VIRU	VIBURNUM RUFIDULUM	RUSTY BLACKHAW
VIAG	VITEX AGNUS-CASTUS	CHASTE TREE
ZACL	ZANTHOXYLUM CLAVA-HERCULIS	HERCULES CLUB
ZESE	ZELKOVA SERRATA	JAPANESE ZELKOVA

3.313

County:

Plot #:

Dear Landowner or Resident:

The Texas Forest Service, a member of the Texas A&M University System, is currently conducting a study of trees in the four-county Dallas/Fort Worth Metropolitan region. This study is funded by the Texas Environmental Research Consortium under the direction of the Texas Commission on Environmental Quality (TCEQ) and uses data gathered from field plots to answer questions about the role trees play in the region's air pollution problem.

Texas Forest Service foresters have been assigned the task of collecting tree data at approximately 160 sample points across the region. One of those field plots has been determined to fall on your property and we are asking for your permission to locate that point on the ground and to take the measurements for our study.

Each plot is typically completed in an hour or so and the data collected will include the species, diameter, height, and crown dimensions for each tree within a 1/10th-acre circular plot. There will be no damage to the trees or any of your property and all property ownership information remains strictly confidential.

On behalf of the Texas Forest Service—and all the residents of the Metroplex that will one day benefit from this research—I want to thank you for your cooperation. For more information about the study or your particular situation, contact me at the number below and reference the plot number at the top of the page.

Pete Smith
Staff Forester III
(979) 458-6650

Exhibit 8: Plot Photo Example, Plot #28-N

CSR LAND SURFACE CHARACTERIZATION PROJECT FOR EASTERN TEXAS (H-55)

Exhibit 10: **Plot Groupings for Leaf Biomass Analysis**

Level 4 **Eastern Cross Timbers** **Dev. Low Intensity (DLI)** **23,404.9 ha** **Map Group 1**	**Level 4** **Western Cross Timbers** **Dev. Low Intensity (DLI)** **1,095.84 ha** **Map Group 2**	**Level 4** **Grand Prairie** **Dev. Low Intensity (DLI)** **27,780.9 ha** **Map Group 3**	**Level 4** **Texas Blackland Prairie** **Dev. Low Intensity (DLI)** **77,152.3 ha** **Map Group 4**	**Level 3** **Cross Timbers** **Dev. Med. Intensity (DMI)** **25,329.4 ha** **Map Group 5**	**Level 3** **Texas Blackland Prairie** **Dev. Med. Intensity (DMI)** **57,184.6 ha** **Map Group 6**	**Level 3** **Cross Timbers** **Dev. Low Intensity (DLI)** **52,281.6 ha** **Map Groups 1, 2, & 3**	**Level 3** **Cross Timbers** **All Developed** **77,611 ha** **Map Groups 1, 2, 3, & 5**	**Level 3** **Texas Blackland Prairie** **All Developed** **134,336.9 ha** **Map Groups 4 & 6**	**Level 3** **Cross Timbers** **Dev. Open Space (DOS)** **420,044.4 ha**	**Level 2** **All DLI** **102,341 ha** **Map Groups 1, 2, 3, & 4**	**Level 2** **All DMI** **129,436 ha** **Map Groups 5 & 6**	**Level 2** **all Developed Plots** **314,291.2 ha** **All Map Groups**	
2	178	107	3	4	1	2	2	1	44	2	1	1	
10	349	111	9	29	5	10	4	3	75	3	4	2	
14	363	126	16	35	11	14	10	5	359	9	5	3	
19	372	143	17	61	31	19	14	9	398	10	11	4	
36	375	151	21	63	34	36	19	11		14	29	5	
50	376	158	32	109	37	50	29	16	Do Not Run	16	31	9	
77	382	185	39	136	55	77	35	17	UFORE	17	34	10	
96	383	235	42		58	96	36	21	Analysis	19	35	11	
112		253	48			107	50	31		21	37	14	
		272	59			111	61	32		32	55	16	
		279	69			112	63	34		36	58	17	
		287	70			126	77	37		39	61	19	
		289				143	96	39		42	63	21	
						151	107	42		48	109	29	
						158	109	48		50	136	31	
						178	111	55		59		32	
						185	112	58		69		34	
						235	126	59		70		35	
						253	136	69		77		36	
						272	143	70		96		37	
						279	151			107		39	
						287	158			111		42	
						289	178			112		44	
						349	185			126		48	
						363	235			143		50	
						372	253			151		55	
						375	272			158		58	
						376	279			178		59	
						382	287			185		61	
						383	289			235		63	
							349			253		69	
							363			272		70	
							372			279		75	
							375			287		77	
							376			289		96	
							382			349		107	
							383			363		109	
										372		111	
										375		112	
										376		126	
										382		136	
										383		143	
												151	
												158	
												178	
												185	
												235	
												253	
												272	
												279	
												287	
												289	
												349	
												359	
												363	
												372	
												375	
												376	
												382	
												383	
												398	
9	8	13	12	7	8	30	37	20	4	42	15	61	**Counts**

Cover Type	Species	Number of Trees (trees/ha)	SE	Leaf Area (m^2/ha)	SE	Leaf Biomass (kg/ha)	SE
East cross timbers (DLI)	Post oak	38.4	22.6	5063.8	2860.75	431	243.47
	Silver maple	5.5	3.63	2764.8	1946.82	145.5	117.78
	Sugarberry	13.7	13.73	1732.4	1732.37	117.8	102.46
	Honey mesquite	2.7	2.75	650.3	650.29	48.5	10.35
	Callery pear	2.7	2.75	459.6	459.58	34.3	12.41
	Eastern red cedar	2.7	2.75	67	66.98	18.6	18.6
	Cherry	5.5	3.63	232.3	160.35	18	48.5
	Elm	2.7	2.75	190.4	190.4	13	34.28
	Common crapemyrtle	5.5	3.63	164.3	138.73	12.3	12.97
	Total	79.6	32.11	11324.9	4134.31	838.8	317.13
	Coefficient of Variation:	40.34%					

Cover Type	Species	Number of Trees (trees/ha)	SE	Leaf Area (m^2/ha)	SE	Leaf Biomass (kg/ha)	SE
West cross timbers (DLI)	Post oak	108.1	31.99	13336.8	3317.54	1135	282.34
	Cedar elm	108.1	108.09	6223.4	6222.48	423.9	423.81
	Southern magnolia	6.2	6.18	2394	2393.66	323.3	323.25
	Sugarberry	6.2	4.04	1740.8	1152.9	118.4	78.39
	Blackjack oak	6.2	6.18	601.9	601.84	55.2	55.23
	Mexican plum	3.1	3.09	177.8	177.73	13.8	13.75
	Texas ash	3.1	3.09	87.8	87.83	7	7.04
	Ligustro	3.1	3.09	40.3	40.29	3.7	3.66
	Cherry	3.1	3.09	33.1	33.12	2.6	2.56
	Hawthorn	3.1	3.09	25.2	25.21	0.9	0.91
	Total	250.2	102.98	24661.2	6719.21	2083.7	502.63
	Coefficient of Variation:	41.16%					

Cover Type	Species	Number of Trees (trees/ha)	SE	Leaf Area (m^2/ha)	SE	Leaf Biomass (kg/ha)	SE
Grand prairie (DLI)	Live oak	3.8	2.57	1324.7	897.34	278.1	188.38
	Sugarberry	36.1	18.69	3626.1	2024.97	246.5	137.68
	Boxelder	3.8	2.57	1178	865.67	107.8	79.19
	Silver maple	3.8	3.8	1373.1	1373.04	72.3	72.27
	Slash pine	1.9	1.9	689.8	689.77	66.5	66.48
	Cedar elm	5.7	4.11	862.9	761.4	58.8	51.86
	Oriental arbor vitae	1.9	1.9	295.4	295.41	56.8	56.81
	Pecan	15.2	9.91	721.7	464.48	50.2	32.3
	Callery pear	5.7	5.7	641.3	641.33	47.8	47.83
	Tree of heaven	1.9	1.9	335.7	335.72	25	25.04
	Cherry	3.8	3.8	192.6	192.63	14.9	14.9
	Common crapemyrtle	9.5	5.96	161.6	92.12	12.1	6.87
	White mulberry	1.9	1.9	144.7	144.7	10.6	10.58
	Ligustro	3.8	3.8	95.3	95.26	8.7	8.66
	Carolina laurelcherry	3.8	2.57	105	90.86	8.1	7.03
	American elm	3.8	3.8	78.7	78.69	5.7	5.72
	Photinia	1.9	1.9	41.3	41.26	4.2	4.21
	Chinaberry	1.9	1.9	53.1	53.07	4	3.96
	Eastern red cedar	1.9	1.9	13.6	13.6	3.8	3.78
	Eastern redbud	5.7	4.11	49.9	37.48	3.2	2.4
	Honeylocust	5.7	5.7	28.6	28.6	3	2.99
	Chittamwood	1.9	1.9	24.2	24.17	1.8	1.8
	Baldcypress	1.9	1.9	8.4	8.43	0.9	0.93
	Total	127.3	36.46	12045.7	3283.01	1090.7	301.81
	Coefficient of Variation:	28.64%					

Cover Type	Species	Number of Trees (trees/ha)	SE	Leaf Area (m^2/ha)	SE	Leaf Biomass (kg/ha)	SE
Blackland prairie (DLI)	Sugarberry	68	29.66	6596.1	2367.25	448.5	160.95
	Eastern red cedar	6.2	3.23	915.5	569.15	254.3	158.1
	Shumard oak	6.2	3.23	1856.1	1096.83	170.3	100.65
	Pecan	6.2	3.23	1620.3	1029.85	112.7	71.62
	Oriental arbor vitae	6.2	6.18	480.5	480.49	92.4	92.4
	Cedar elm	6.2	6.18	1247.2	1247.21	84.9	84.95
	Boxelder	8.2	6.33	881.3	764.22	80.6	69.91
	Red mulberry	2.1	2.06	762	761.98	75.7	75.68
	Texas oak	4.1	2.78	761.3	580.44	69.9	53.26
	Chinaberry	6.2	3.23	644.9	532.76	48.1	39.74
	Ligustro	2.1	2.06	491.5	491.5	44.7	44.68
	Photinia	6.2	4.43	366.8	310.28	37.4	31.66
	Chinese tallowtree	2.1	2.06	432.5	432.55	28.1	28.14
	Silver maple	2.1	2.06	486.6	486.55	25.6	25.61
	Yaupon	4.1	4.12	170.9	170.91	22.8	22.85
	American elm	2.1	2.06	123.9	123.86	9	9.01
	Common crapemyrtle	2.1	2.06	38.9	38.87	2.9	2.9
	Cherry	2.1	2.06	24.6	24.59	1.9	1.9
	Live oak	2.1	2.06	8.3	8.31	1.7	1.74
	Total	144.1	39.05	17909.3	4146.25	1611.7	384.28
	Coefficient of Variation:	27.10%					

Cover Type	Species	Number of Trees (trees/ha)	SE	Leaf Area (m^2/ha)	SE	Leaf Biomass (kg/ha)	SE
Cross timbers (DMI)	Pecan	10.6	7.35	5304.1	3908.09	368.9	271.78
	Eastern red cedar	21.2	17.41	657	610.78	182.5	169.66
	Post oak	10.6	10.59	891	890.99	75.8	75.83
	Oriental arbor vitae	3.5	3.53	184.8	184.76	35.5	35.53
	Cedar elm	7.1	7.06	507.7	507.65	34.6	34.58
	Blackjack oak	3.5	3.53	74.6	74.61	6.8	6.85
	Holly	3.5	3.53	34	34.03	4.5	4.55
	Total	60	36.91	7653.1	4012.61	708.7	351.08
	Coefficient of Variation:	61.52%					

Cover Type	Species	Number of Trees (trees/ha)	SE	Leaf Area (m^2/ha)	SE	Leaf Biomass (kg/ha)	SE
Blackland prairie (DMI)	Live oak	6.2	4.04	918.9	872.16	192.9	183.09
	Red mulberry	3.1	3.09	1064.5	1064.48	105.7	105.72
	Silver maple	3.1	3.09	1253.2	1253.16	66	65.96
	Callery pear	6.2	4.04	431.7	295.47	32.2	22.04
	Pecan	3.1	3.09	370.4	370.44	25.8	25.76
	Southern bayberry	3.1	3.09	56.2	56.18	19.3	19.33
	Bur oak	3.1	3.09	41.7	41.72	3.8	3.83
	Chinese pistache	3.1	3.09	30.8	30.76	2.3	2.35
	Total	30.9	9.04	4167.3	2380.29	448.1	225.26
	Coefficient of Variation:	29.26%					

Cover Type	Species	Number of Trees (trees/ha)	SE	Leaf Area (m^2/ha)	SE	Leaf Biomass (kg/ha)	SE
Cross timbers DLI plots	Post oak	40.4	13.22	5075.6	1548.67	432	131.8
	Cedar elm	31.3	28.8	2033.5	1679.76	138.5	114.41
	Sugarberry	21.4	9.23	2555.3	1048.54	173.7	71.29
	Pecan	6.6	4.42	312.8	207.6	21.7	14.44
	Common crapemyrtle	5.8	2.82	119.3	57.38	8.9	4.28
	Cherry	4.1	2.08	162	95.24	12.5	7.37
	Silver maple	3.3	1.96	1424.4	830.05	75	43.69
	Callery pear	3.3	2.58	415.8	305.94	31	22.82
	Eastern redbud	2.5	1.82	21.6	16.52	1.4	1.06
	Honeylocust	2.5	2.47	12.4	12.39	1.3	1.3
	Ligustro	2.5	1.82	52	42.29	4.7	3.84
	Boxelder	1.6	1.14	510.4	382.26	46.7	34.97
	Eastern red cedar	1.6	1.14	26	20.74	7.2	5.76
	Southern magnolia	1.6	1.65	638.4	638.4	86.2	86.21
	Carolina laurelcherry	1.6	1.14	45.5	39.67	3.5	3.07
	Blackjack oak	1.6	1.65	160.5	160.51	14.7	14.73
	Live oak	1.6	1.14	574	399.05	120.5	83.77
	American elm	1.6	1.65	34.1	34.1	2.5	2.48
	Tree of heaven	0.8	0.82	145.5	145.48	10.9	10.85
	Chittamwood	0.8	0.82	10.5	10.48	0.8	0.78
	Hawthorn	0.8	0.82	6.7	6.72	0.2	0.24
	Texas ash	0.8	0.82	23.4	23.42	1.9	1.88
	Chinaberry	0.8	0.82	23	23	1.7	1.72
	White mulberry	0.8	0.82	62.7	62.7	4.6	4.59
	Photinia	0.8	0.82	17.9	17.88	1.8	1.82
	Slash pine	0.8	0.82	298.9	298.9	28.8	28.81
	Honey mesquite	0.8	0.82	195.1	195.09	14.6	14.55
	Mexican plum	0.8	0.82	47.4	47.4	3.7	3.67
	Baldcypress	0.8	0.82	3.7	3.65	0.4	0.4
	Oriental arbor vitae	0.8	0.82	128	128.01	24.6	24.62
	Elm	0.8	0.82	57.1	57.12	3.9	3.89
	Total	145.8	34.02	15193.6	2716.82	1280	222.29
	Coefficient of Variation:	23.33%					

Cover Type	Species	Number of Trees (trees/ha)	SE	Leaf Area (m^2/ha)	SE	Leaf Biomass (kg/ha)	SE
Cross timbers developed plots	Post oak	34.7	11.02	4283.9	1290.8	364.6	109.86
	Sugarberry	17.4	7.59	2071.8	863.67	140.9	58.72
	Cedar elm	26.7	23.36	1744.8	1364.18	118.8	92.91
	Live oak	1.3	0.93	465.4	324.68	97.7	68.16
	Pecan	7.3	3.81	1257.1	784.78	87.4	54.58
	Southern magnolia	1.3	1.34	517.6	517.62	69.9	69.9
	Silver maple	2.7	1.6	1155	677.25	60.8	35.64
	Eastern red cedar	5.3	3.47	145.4	117.22	40.4	32.56
	Boxelder	1.3	0.93	413.9	310.73	37.9	28.43
	Oriental arbor vitae	1.3	0.93	138.8	108.6	26.7	20.88
	Callery pear	2.7	2.09	337.1	248.74	25.1	18.55
	Slash pine	0.7	0.67	242.4	242.35	23.4	23.36
	Blackjack oak	2	1.48	144.3	130.52	13.2	11.98
	Honey mesquite	0.7	0.67	158.2	158.18	11.8	11.8
	Cherry	3.3	1.7	131.4	77.69	10.2	6.01
	Tree of heaven	0.7	0.67	118	117.96	8.8	8.8
	Common crapemyrtle	4.7	2.31	96.7	47.03	7.2	3.51
	Ligustro	2	1.48	42.2	34.35	3.8	3.12
	White mulberry	0.7	0.67	50.8	50.84	3.7	3.72
	Elm	0.7	0.67	46.3	46.31	3.2	3.15
	Mexican plum	0.7	0.67	38.4	38.43	3	2.97
	Carolina laurelcherry	1.3	0.93	36.9	32.2	2.9	2.49
	American elm	1.3	1.34	27.6	27.65	2	2.01
	Texas ash	0.7	0.67	19	18.99	1.5	1.52
	Photinia	0.7	0.67	14.5	14.5	1.5	1.48
	Chinaberry	0.7	0.67	18.6	18.65	1.4	1.39
	Eastern redbud	2	1.48	17.5	13.43	1.1	0.86
	Honeylocust	2	2	10	10.05	1.1	1.05
	Holly	0.7	0.67	6.4	6.44	0.9	0.86
	Chittamwood	0.7	0.67	8.5	8.49	0.6	0.63
	Baldcypress	0.7	0.67	3	2.96	0.3	0.33
	Hawthorn	0.7	0.67	5.5	5.45	0.2	0.2
	Total	129.6	28.81	13767	2360.29	1171.9	193.78
	Coefficient of Variation:	22.23%					

Exhibit 11: Statistical Analysis of Plots, by EPA Level 3 and 4 Ecoregions and Development Intensity

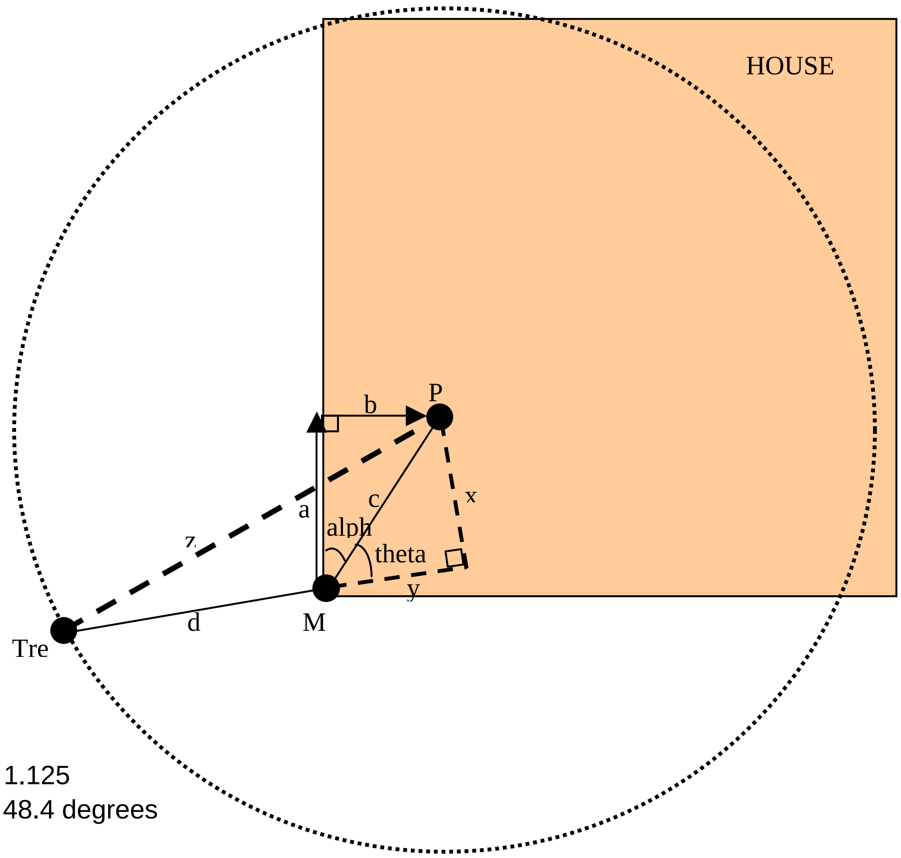
Cover Type	Species	Number of Trees (trees/ha)	SE	Leaf Area (m^2/ha)	SE	Leaf Biomass (kg/ha)	SE
Blackland Prairie developed plots	Sugarberry	40.8	19.08	3957.7	1579.93	269.1	107.42
	Eastern red cedar	3.7	2.02	549.3	350.87	152.6	97.46
	Shumard oak	3.7	2.02	1113.7	679.27	102.2	62.33
	Red mulberry	2.5	1.7	883	608.13	87.7	60.4
	Live oak	3.7	2.02	372.6	350.14	78.2	73.5
	Pecan	4.9	2.27	1120.4	639.04	77.9	44.44
	Oriental arbor vitae	3.7	3.71	288.3	288.29	55.4	55.44
	Cedar elm	3.7	3.71	748.3	748.33	51	50.97
	Boxelder	4.9	3.84	528.8	461.18	48.4	42.19
	Texas oak	2.5	1.7	456.8	352.64	41.9	32.36
	Silver maple	2.5	1.7	793.2	566.64	41.7	29.82
	Chinaberry	3.7	2.02	387	322.25	28.9	24.04
	Ligustro	1.2	1.24	294.9	294.9	26.8	26.81
	Photinia	3.7	2.7	220.1	187.46	22.5	19.13
	Chinese tallowtree	1.2	1.24	259.5	259.53	16.9	16.88
	Yaupon	2.5	2.47	102.5	102.54	13.7	13.71
	Callery pear	2.5	1.7	172.7	123.37	12.9	9.2
	Southern bayberry	1.2	1.24	22.5	22.47	7.7	7.73
	American elm	1.2	1.24	74.3	74.32	5.4	5.4
	Common crapemyrtle	1.2	1.24	23.3	23.32	1.7	1.74
	Bur oak	1.2	1.24	16.7	16.69	1.5	1.53
	Cherry	1.2	1.24	14.8	14.76	1.1	1.14
	Chinese pistache	1.2	1.24	12.3	12.3	0.9	0.94
	Total	98.8	26.53	12412.5	3031.84	1146.2	275.46
	Coefficient of Variation:	26.85%					

Cover Type	Species	Number of Trees (trees/ha)	SE	Leaf Area (m^2/ha)	SE	Leaf Biomass (kg/ha)	SE
all DLI plots map groups 1-4	Post oak	28.8	9.82	3625.4	1157.57	308.5	98.52
	Sugarberry	34.7	11.01	3709.8	1032.62	252.2	70.21
	Cedar elm	24.1	20.62	1808.8	1244.13	123.2	84.74
	Live oak	1.8	0.99	412.4	286.45	86.6	60.13
	Eastern red cedar	2.9	1.25	280.1	170.26	77.8	47.29
	Southern magnolia	1.2	1.18	456	456	61.6	61.58
	Silver maple	2.9	1.51	1156.5	608.79	60.9	32.04
	Boxelder	3.5	1.99	616.4	345.37	56.4	31.59
	Shumard oak	1.8	0.99	530.3	330.7	48.7	30.35
	Pecan	6.5	3.27	686.3	334.04	47.7	23.23
	Oriental arbor vitae	2.4	1.85	228.7	163.08	44	31.36
	Callery pear	2.4	1.85	297	219.43	22.2	16.37
	Red mulberry	0.6	0.59	217.7	217.71	21.6	21.62
	Slash pine	0.6	0.59	213.5	213.5	20.6	20.58
	Texas oak	1.2	0.82	217.5	169.44	20	15.55
	Ligustro	2.4	1.41	177.6	142.77	16.1	12.98
	Chinaberry	2.4	1.13	200.7	154.76	15	11.54
	Photinia	2.4	1.41	117.6	90.26	12	9.21
	Blackjack oak	1.2	1.18	114.7	114.65	10.5	10.52
	Honey mesquite	0.6	0.59	139.3	139.35	10.4	10.39
	Cherry	3.5	1.59	122.7	68.72	9.5	5.32
	Chinese tallowtree	0.6	0.59	123.6	123.58	8	8.04
	Tree of heaven	0.6	0.59	103.9	103.91	7.8	7.75
	Common crapemyrtle	4.7	2.1	96.3	42.56	7.2	3.17
	Yaupon	1.2	1.18	48.8	48.83	6.5	6.53
	American elm	1.8	1.3	59.7	42.47	4.3	3.09
	White mulberry	0.6	0.59	44.8	44.79	3.3	3.28
	Elm	0.6	0.59	40.8	40.8	2.8	2.78
	Mexican plum	0.6	0.59	33.9	33.86	2.6	2.62
	Carolina laurelcherry	1.2	0.82	32.5	28.38	2.5	2.2
	Texas ash	0.6	0.59	16.7	16.73	1.3	1.34
	Eastern redbud	1.8	1.3	15.5	11.84	1	0.76
	Honeylocust	1.8	1.76	8.9	8.85	0.9	0.93
	Chittamwood	0.6	0.59	7.5	7.48	0.6	0.56
	Baldcypress	0.6	0.59	2.6	2.61	0.3	0.29
	Hawthorn	0.6	0.59	4.8	4.8	0.2	0.17
	Total	145.3	26.49	15969.5	2254.7	1374.7	191.91
	Coefficient of Variation:	18.23%					

Cover Type	Species	Number of Trees (trees/ha)	SE	Leaf Area (m^2/ha)	SE	Leaf Biomass (kg/ha)	SE
all DMI plots map groups 5-6	Pecan	6.6	3.79	2672.8	1877.23	185.9	130.55
	Live oak	3.3	2.24	490.1	466.75	102.9	97.99
	Eastern red cedar	9.9	8.28	306.6	286.85	85.2	79.68
	Red mulberry	1.6	1.65	567.7	567.73	56.4	56.39
	Post oak	4.9	4.94	415.8	415.8	35.4	35.39
	Silver maple	1.6	1.65	668.4	668.35	35.2	35.18
	Oriental arbor vitae	1.6	1.65	86.2	86.22	16.6	16.58
	Cedar elm	3.3	3.29	236.9	236.9	16.1	16.14
	Callery pear	3.3	2.24	230.2	163.08	17.2	12.16
	Southern bayberry	1.6	1.65	30	29.96	10.3	10.31
	Blackjack oak	1.6	1.65	34.8	34.82	3.2	3.2
	Holly	1.6	1.65	15.9	15.88	2.1	2.12
	Bur oak	1.6	1.65	22.3	22.25	2	2.04
	Chinese pistache	1.6	1.65	16.4	16.4	1.3	1.25
	Total	44.5	17.59	5794	2224.21	569.7	198.47
	Coefficient of Variation:	39.53%					

Cover Type	Species	Number of Trees (trees/ha)	SE	Leaf Area (m^2/ha)	SE	Leaf Biomass (kg/ha)	SE
All developed plots	Post oak	21.1	7	2598.4	824.24	221.1	70.15
	Sugarberry	32.8	10.68	3116.8	815.48	211.9	55.44
	Cedar elm	17.8	14.22	1306	860.72	89	58.62
	Live oak	2	0.88	404.5	226.53	84.9	47.56
	Pecan	6.5	2.44	1130.9	517.75	78.6	36.01
	Eastern red cedar	4.5	2.2	268.3	135.81	74.5	37.73
	Boxelder	12.2	9.78	658.2	329.86	60.2	30.18
	Shumard oak	2.8	1.43	614.3	331.1	56.4	30.38
	Silver maple	2.4	1.11	960.6	449.23	50.6	23.64
	Southern magnolia	0.8	0.81	314	313.97	42.4	42.4
	Oriental arbor vitae	2	1.33	178.7	114.18	34.4	21.96
	Red mulberry	1.2	0.69	297.8	203.1	29.6	20.17
	Eastern cottonwood	0.8	0.81	408.6	408.58	29.5	29.48
	Callery pear	2.4	1.38	261.1	155.8	19.5	11.62
	Slash pine	0.4	0.41	147	147	14.2	14.17
	Texas oak	0.8	0.57	149.8	116.95	13.7	10.73
	Ligustro	1.6	0.98	122.3	98.5	11.1	8.95
	Chinaberry	1.6	0.79	138.2	106.83	10.3	7.97
	Photinia	1.6	0.98	81	62.31	8.3	6.36
	Blackjack oak	1.2	0.9	87.5	79.26	8	7.27
	Honey mesquite	0.4	0.41	95.9	95.94	7.2	7.16
	Cherry	2.4	1.11	84.5	47.71	6.5	3.69
	Chinese tallowtree	0.4	0.41	85.1	85.09	5.5	5.54
	Tree of heaven	0.4	0.41	71.5	71.55	5.3	5.34
	Common crapemyrtle	3.2	1.47	66.3	29.76	4.9	2.22
	American elm	2	1.2	64.7	37.21	4.7	2.71
	Yaupon	0.8	0.81	33.6	33.62	4.5	4.49
	Southern bayberry	0.4	0.41	7.4	7.37	2.5	2.54
	White mulberry	0.4	0.41	30.8	30.84	2.3	2.26
	Elm	0.4	0.41	28.1	28.09	1.9	1.91
	Mexican plum	0.4	0.41	23.3	23.31	1.8	1.8
	Carolina laurelcherry	0.8	0.57	22.4	19.56	1.7	1.51
	Texas ash	0.4	0.41	11.5	11.52	0.9	0.92
	Eastern redbud	1.2	0.9	10.6	8.18	0.7	0.52
	Honeylocust	1.2	1.22	6.1	6.1	0.6	0.64
	Holly	0.4	0.41	3.9	3.91	0.5	0.52
	Bur oak	0.4	0.41	5.5	5.47	0.5	0.5
	Chittamwood	0.4	0.41	5.2	5.15	0.4	0.38
	Chinese pistache	0.4	0.41	4	4.03	0.3	0.31
	Baldcypress	0.4	0.41	1.8	1.8	0.2	0.2
	Hercules club	0.4	0.41	3.1	3.13	0.2	0.23
	Hawthorn	0.4	0.41	3.3	3.31	0.1	0.12
	Total	134.5	23.19	13912.6	1797.37	1201.6	151.22
	Coefficient of Variation:	17.24%					

Exhibit 12: Converting MP-to-tree measurements to PC-to-tree measurements to apply limiting distance



tan(alpha) = b/a = 9/8 = 1.125
arctan(1.125) = alpha = 48.4 degrees

C = A+alpha+180-360

a	b	c	d	A	B	C	D	alpha	theta	x	y	z
8	9	12.04	35.4	355	85	223	312	48.4	88.6	7.1	9.7	45.7
8	9	12.04	22	355	85	223	281	48.4	57.6	10.5	6.0	29.9

Exhibit 13: Map and Imagery Interpretation for Angelina County, Texas

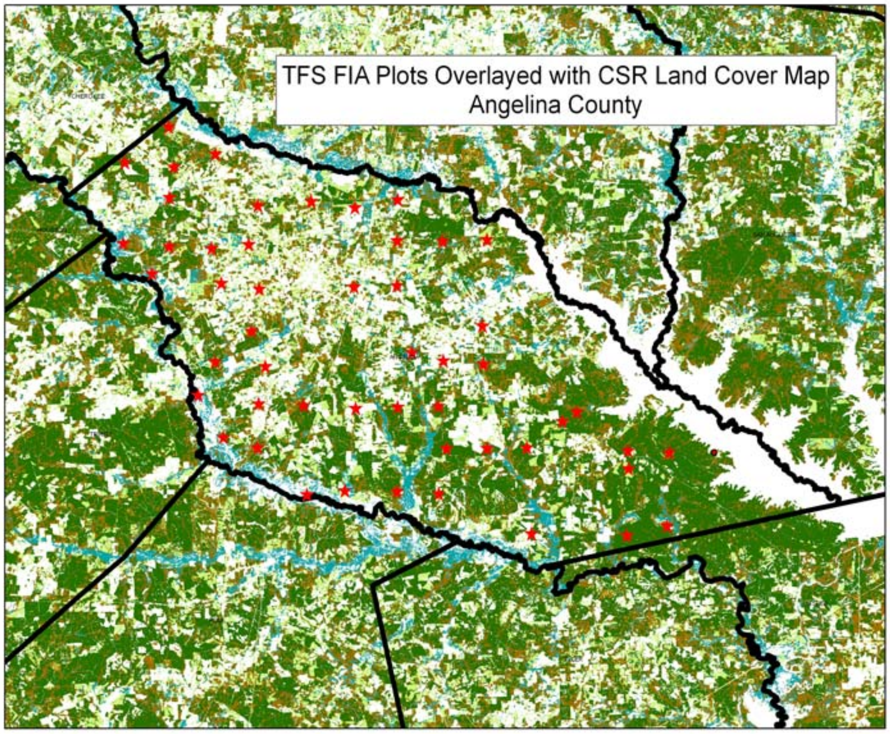


Figure 1

Figure 2

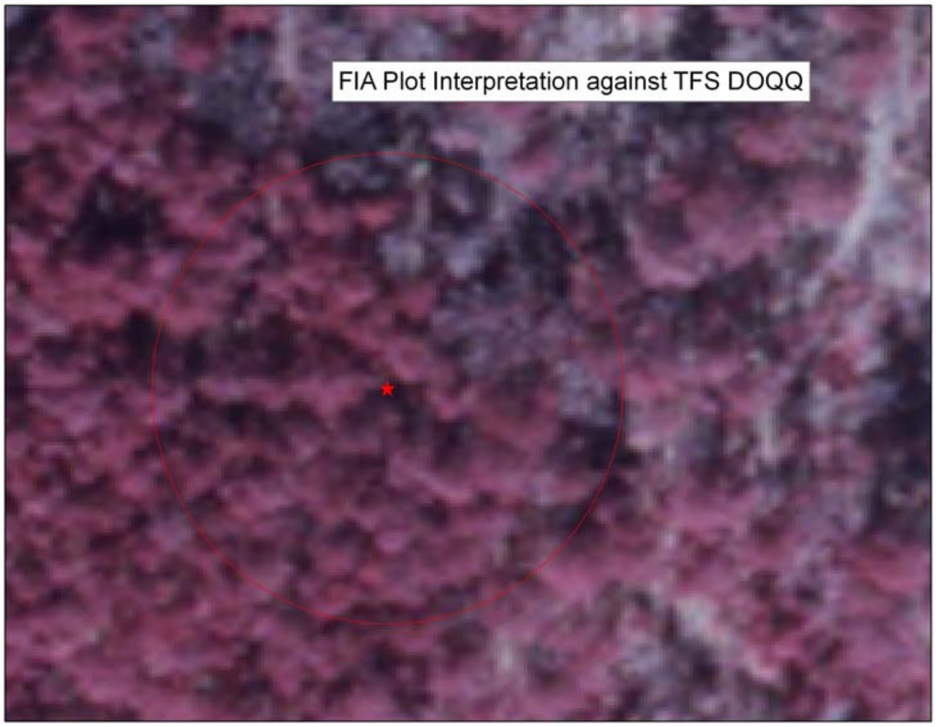


Figure 3

CSR LAND SURFACE CHARACTERIZATION PROJECT FOR EASTERN TEXAS (H-55)
Exhibit 14: Accuracy Assessment of CSR Land Cover Map Using FIA Plots and DOQQ's

Plot #	FORESTTYPE	CSRTYPENAM	Score (FIA Only)	PineForest	PineShrub	HWForest	MixForest	DevelopedLow	DevelopedOpen	Rip_f_wetl	swap_fwetl	herb_culti
1	Loblolly Pine	Needle-leaved Evergreen Forest	0	5	0	0	2	0	0	0	0	0
2	Loblolly Pine	Needle-leaved Evergreen Forest	1	8	0	0	0	0	0	0	0	0
3	Loblolly Pine	Needle-leaved Evergreen Forest	1	8	0	0	0	0	0	0	0	0
4	Shortleaf Pine	Needle-leaved Evergreen Forest	1	8	0	0	0	0	0	0	0	0
5	Loblolly Pine	Needle-leaved Evergreen Forest	1	8	0	0	0	0	0	0	0	0
6	Loblolly Pine	Needle-leaved Evergreen Forest	1	8	0	0	0	0	0	0	0	0
7	Loblolly Pine	Needle-leaved Evergreen Forest	1	8	0	0	0	0	0	0	0	0
8	Loblolly Pine	Needle-leaved Evergreen Forest	0	0	0	0	0	0	0	0	0	0
9	Loblolly Pine / Hardwood	Mixed Forest	0	8	0	0	0	0	0	0	0	0
10	Loblolly Pine	Needle-leaved Evergreen Forest	1	8	0	0	0	0	0	0	0	0
11	Post Oak / Blackjack Oak	Cold Deciduous Forest	0	0	8	0	0	0	0	0	0	0
12	Loblolly Pine	Needle-leaved Evergreen Forest	0	0	8	0	0	0	0	0	0	0
13	Loblolly Pine	Needle-leaved Evergreen Forest	1	8	0	0	0	0	0	0	0	0
14	Loblolly Pine / Hardwood	Mixed Forest	0	0	2	0	0	0	0	0	0	4
15	Loblolly Pine	Needle-leaved Evergreen Forest	1	8	0	0	0	0	0	0	0	0
16	Loblolly Pine	Needle-leaved Evergreen Forest	0	2	0	0	6	0	0	0	0	0
17	Loblolly Pine	Needle-leaved Evergreen Forest	0	0	0	0	0	0	0	0	0	0
18	Loblolly Pine	Needle-leaved Evergreen Forest	0	3	0	0	5	0	0	0	0	0
19	Loblolly Pine	Needle-leaved Evergreen Forest	0	3	3	0	1	0	0	0	0	1
20	White Oak / Red Oak / Hickory	Cold Deciduous Forest	0	0	1	0	7	0	0	0	0	0
21	Loblolly Pine	Needle-leaved Evergreen Forest	0	0	1	0	0	0	0	0	0	0
22	Loblolly Pine	Needle-leaved Evergreen Forest	0	0	0	6	1	0	0	0	0	0
23	Loblolly Pine	Needle-leaved Evergreen Forest	0	0	0	0	0	0	0	0	0	8
24	Mixed Upland Hardwoods	Cold Deciduous Forest	0	0	0	0	8	0	0	0	0	0
25	Loblolly Pine	Needle-leaved Evergreen Forest	0	0	1	0	0	0	0	0	0	7
26	Sugarberry / Hackberry / Elm / Green Ash	Cold Deciduous Forest	0	1	3	0	4	0	0	0	0	0
27	Sweetgum / Nuttall Oak / Willow Oak	Cold Deciduous Forest	0	0	0	2	0	0	0	0	6	0
28	Loblolly Pine	Needle-leaved Evergreen Forest	1	8	0	0	0	0	0	0	0	0
29	Loblolly Pine	Needle-leaved Evergreen Forest	0	0	3	0	0	0	0	0	0	5
30	Post Oak / Blackjack Oak	Cold Deciduous Forest	0	0	0	0	3	1	0	0	0	3
31	Loblolly Pine	Needle-leaved Evergreen Forest	0	0	0	4	2	0	0	0	0	2
32	Loblolly Pine / Hardwood	Mixed Forest	0	0	6	0	0	0	0	0	0	0
33	Loblolly Pine	Needle-leaved Evergreen Forest	0	3	0	0	5	0	0	0	0	0
34	Loblolly Pine	Needle-leaved Evergreen Forest	0	0	2	0	4	0	0	0	0	0
35	Loblolly Pine	Needle-leaved Evergreen Forest	0	0	1	0	0	0	0	0	0	7
36	Loblolly Pine	Needle-leaved Evergreen Forest	0	3	0	0	4	0	0	0	0	0
37	Swamp Chestnut Oak / Cherrybark Oak	Cold Deciduous Forest	1	0	0	8	0	0	0	0	0	0
38	Loblolly Pine	Needle-leaved Evergreen Forest	0	3	3	0	1	0	0	0	0	0
39	Loblolly Pine	Needle-leaved Evergreen Forest	0	0	1	1	0	0	0	0	0	6
40	Loblolly Pine	Needle-leaved Evergreen Forest	0	0	1	0	6	0	0	0	0	0
41	Loblolly Pine	Needle-leaved Evergreen Forest	0	0	8	0	0	0	0	0	0	0
42	Loblolly Pine	Needle-leaved Evergreen Forest	0	0	0	0	8	0	0	0	0	0
43	Loblolly Pine	Needle-leaved Evergreen Forest	0	2	6	0	0	0	0	0	0	0
44	Loblolly Pine	Needle-leaved Evergreen Forest	1	8	0	0	0	0	0	0	0	0
45	Loblolly Pine	Needle-leaved Evergreen Forest	1	6	0	0	0	0	0	0	0	2
46	Swamp Chestnut Oak / Cherrybark Oak	Cold Deciduous Forest	0	0	0	2	0	0	0	5	1	0
47	Loblolly Pine	Needle-leaved Evergreen Forest	1	8	0	0	0	0	0	0	0	0
48	Loblolly Pine / Hardwood	Mixed Forest	0	0	3	0	0	0	0	0	0	4
49	Sassafras / Persimmon	Cold Deciduous Forest	0	0	6	0	0	0	2	0	0	0
50	Loblolly Pine	Needle-leaved Evergreen Forest	0	0	0	0	8	0	0	0	0	0
51	White Oak / Red Oak / Hickory	Cold Deciduous Forest	0	0	0	0	8	0	0	0	0	0
52	Sassafras / Persimmon	Cold Deciduous Forest	0	0	0	0	0	0	0	0	8	0

herb_natur	Total	Comments	DOQQScore	DOQComment
0	7		1	Very close to Development and large lake a few HW
0	8		1	
0	8		1	
0	8		1	Right next to open area that matches with classification
0	8		1	
0	8		1	
0	8		1	Half of the plot is on a pine stand. Other half is recently harvested and has been replanted with pine
8	8	Near evergreen stand	0	Looks like a recently harvested pine stand that has been replanted with seedlings
0	8		1	
0	8		1	Looks to have been recently harvested and replanted
0	8		0	This looks to be a stand of either hardwood or possibly mixed forest
0	8		0	This stand looks to be a pine forest
0	8		1	
2	8		0	This plot is a small patch of mixed forest surrounded by pine.
0	8		1	
0	8	plot in a small mixed area of pine stand	0	Appears to be a few HW but pine dominates this stand
8	8		0	A recently harvested stand that has been replanted
0	8	Near Riparian area	1	Stand appears to be fairly mixed. Slightly more pine than hardwood
0	8		0	Entire plot seems is a developed pine stand
0	8		0	This plot looks to be part of a large hardwood stand
6	7		0	This plot is near a road and a few houses. It appears to be dominated by pine
0	7	Very Close to Pine Stand	1	The DOQQ appears to have mostly hardwood on this plot
0	8		1	This plot is definately not pine. It looks like there is no major vegetation other than grass on this plot
0	8		1	This stand appears to be mixed pretty well. The surrounding forest is mainly hardwood but there is pine mixed in at this plot
0	8		0	About 1/3 of this plot appears to be mixed forest. The rest is grass. This area is off a road and is being developed.
0	8		0	This stand appears to be mostly hardwood. It is likely a beetle spot because it is a small HW patch surrounded by pine forest
0	8	Appears to be in or near Riparian Area	1	Obviously in a pure hardwood Riperian zone.There a river nearby and standing water like it is in the floodplain of the river
0	8		1	This plot is recently harvested (on DOQQ) but has been replanted. The provided CIR look to be preharvest images
0	8		0	This area may have formerly been a pine stand. It was recently harvested and apparantly not replanted
0	7		0	This plot is in a recently harvested area. Looks to have been replanted
0	8		0	This stand is a mixed stand. There is no open ares near this plot so not sure why there were any herbacious pixels identified
2	8	Right off a Roadway	0	Off a major roadway near deveolpment. Definitely a mix stand of trees
0	8		0	Plot appears to be solid pine
1	7		0	This is a young pine stand near a residentail area
0	8		1	This site is in a developed residential area. Most of the plot seems to be herbacious and there are a few small pines on the site
0	7		0	This plot is all pine. It is stocked very low with less than 50% crown coverage
0	8		1	Clearly a hardwood stand. Very close to wetlands.
0	7		0	This is a pure pine stand
0	8		0	This plot is in a residental area. 1/4 of the plot is herbacious. The rest of the plot is hardwood
0	7		1	This plot does look to be mixed forest. It has a pine forest on one side and hardwood on the other. This plot falls where the two forest types are both present
0	8		0	This is definately an established pine forest.
0	8		1	This plot is mixed forest. There are some pine forest arround this plot however this looks pretty mixed.
0	8		0	This plot is near a residential area. 75% of the plot is pine forest. The rest is herbacious growth
0	8		1	
0	8		1	Near a residential development. There is a small amout of herbacious groth but it is bout 90% pine
0	8	Fairly Close to River	1	The classification matches the DOQQ image. The stand is pure hardwood and there appears to be some water on the site. Looks like it could be flood zone of a river
0	8		1	
1	8		0	Looks to be along a SMZ left during a recent cut.
0	8		1	A road runs through the middle of this plot. Looks to be mostly herbacious growth
0	8	Small mixed Patch surrounded by pine	1	This plot looks mixed. It is pretty small so it may not have met the criteria of the FIA data to be considered a stand. Area around this plot is mostly pine
0	8		1	This area is clearly mixed. It is surronded by pine
0	8	Appears along Riparian Zone	1	This area has standing water and is pure hardwood. Looks like a rivers flood plain.

CSR LAND SURFACE CHARACTERIZATION PROJECT FOR EASTERN TEXAS (H-55)
Exhibit 14: Accuracy Assessment of CSR Land Cover Map Using FIA Plots and DOQQ's

COLUMN HEADING DEFINITIONS

Plot #	Plot Number assigned to FIA plots	
FORESTTYPE	Forest Type as defined by FIA guidelines	
CSRTYPENAM	CSR Land Cover Class Description. Based on FIA Forest Type plots were defined using the same guidelines as classified image	
Score (FIA Only)	Score (0 or 1) given to each FIA plot. Plot given a 1 if entire plots CSR type in classified image matches CSR type of FIA plots	
PineForest	Needle-leafed Evergreen Forest pixel count within each plot	Class 15
PineShrub	Needle-leafed Evergreen Shrub pixel count within each plot	Class 24
HWForest	Cold Deciduous Forest pixel count within each plot	Class 13
MixForest	Mixed Forest pixel count within each plot	Class 16
DevelopedLow	Developed Low Intensity pixel count within each plot	Class 3
DevelopedOpen	Developed Open Space pixel count within each plot	Class 2
Rip_f_wetl	Riparian Forested Wetland pixel count within each plot	Class 9
swap_fwetl	Swamp Forested Wetland pixel count within each plot	Class 10
herb_culti	Herbaceous Cultivated pixel count within each plot	Class 8
herb_natur	Herbaceous Natural pixel count within each plot	Class 7
Total	Total pixels within each plot (Summation of above pixel counts)	
Comments	Comments made based only on classified image	
DOQQScore	Score (0 or 1) given to each FIA plot based on TFS DOQQ. Plot is given a 1 if classified image matches DOQQ	
DOQComment	Comments made at each plot. These comments are made based on DOQQ comparing visual interpretations to the Classified Image	