Pacific Southwest Research Station

STUDY PLAN APPROVAL AND ABSTRACT SHEET

RWU: 4952 RWU Problem #: 1

Study #: 22

☒ Intramural Study
☒ Extramural Study

Study Title: Predictive Equations for Estimating Street Tree Dimensions and Leaf Area in Glendale, AZ

Author's Signature: /s/Paula Peper Date: 8/27/03

Reviewed By (Comments attached):

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Coordination: ______________________
Assistant Director

Approved by: ______________________ ______ ______________________
Project Leader Date Assistant Director[1]

Received by: ______________________ ______ Notice to FYI: ______
Assistant Director Date Date

Summary:

Objective: The objective of this study is to develop predictive equations for estimating the dimensions and leaf area of 21 predominant street tree species growing in Glendale, AZ and validate the methodology used to collect the tree data. This is the base data necessary for modeling annual benefits and costs associated with Glendale's municipal trees.

Design: Stratified random sampling, stratification by dbh class; 35-70 trees per species including validation set

Analysis: Least squares to determine best fit regression, with subsequent testing of paired parameters (slopes and intercepts)

[1] Plans for studies not in an approved problem analysis require Assistant Director approval in addition to Project Leader's approval.

Methods: Dimensional and leaf area data will be collected on 21 species in Glendale. Digital photos will be processed using previously established methodology for estimating leaf area (Peper and McPherson, 1998; Peper and McPherson, 2003). Diameter at breast height (dbh) will be regressed on age and all other dimensions and leaf area regressed on dbh. The resulting slopes and intercepts will then be compared to slopes and intercepts obtained for the same species from data collected during the previous field season.

Cooperation: Region 3 Urban and Community Forestry

Study Leader: Scott Maco/Paula Peper   Study Location: Glendale, AZ

Schedule: Study Established: 08/20/2003   Estimated Date of Completion: 08/2004

Predictive Equations for Estimating
Street Tree Dimensions and Leaf Area in Glendale, Arizona
Study Plan
August 27, 2003

Introduction The Center for Urban Forest Research has proposed preparing "Western Regional Tree Guidelines" for the 17 western states and Pacific Islands by 2006. The guidelines will be compiled for approximately six western regions, each encompassing similar climatic conditions. The intent of this proposed project is to provide a complete community forestry management "tool kit" that will not only 1) dispel the myth that the community forest is only an amenity by scientifically valuing the benefits of community forests, but also 2) provide guidelines to help communities achieve more sustainable urban forests (forests that provide residents with a continuing level of economic, social, environmental, and economic benefits today and into the future). Appendix 1 includes the complete proposal outline including intent, methodology, and description of the resources needed to realize this commitment.

The second of six western climate regions to be studied was the Northern Mountain and Prairie Region. The resulting guidelines were published in April 2003. This study plan describes the proposed continuation of research to produce an additional set of guidelines for the Desert Southwest Region. As a foundation for accurate benefit-cost analysis we will measure approximately 890 street trees in Glendale, Arizona, a representative city within the region. From these data we will develop growth curves for 21 of the most common species (trees of these species account for over 76% of all municipal trees).

The factor that limits benefit-cost assessments of urban and municipal trees remains the lack of data available on the size and growth of open-grown tree species in urban areas. This study proposes expanding upon that limited knowledge base, including many new species that were never measured in previous studies.

Literature
To date, seven studies establishing growth rates for urban trees have been conducted in the United States. Frelich collected data on 221 trees of known age representing 12 species (9-27 trees per species) in Minnesota and Nowak collected data on 54 open-grown park trees in Chicago representing five species. We have collected data on 20-22 species in Modesto, Santa Monica, and Claremont, CA (Peper et al. 2001a; Peper et al., 2001b), as well as Longview, Washington, Fort Collins, Colorado, San Francisco and Berkeley, California. Additionally, we have collected subsets of tree growth data from Cheyenne, Wyoming and Bismarck, North Dakota to examine similarities and differences in tree growth within sub-regions of the Northern Mountain and Prairie Region. Comparisons of the tree dimensions for the four California cities listed above show significantly different growth of same species (Peper, in process).

Objective
The objective of this study is to develop predictive equations for estimating the dimensions and leaf area of street trees for Glendale, Arizona, a representative city in the Desert Southwest Climate Region.

Methods

***Field Data Collection Procedures**.* Computerized street tree inventories, containing planting records for trees by dbh class, will be utilized to statistically sample the most common street tree species for Glendale. The purpose of sampling trees is to 1) establish relations between tree diameter at breast height (dbh), age, size, leaf area and biomass for important species and 2) estimate tree size (e.g., height, crown width, leaf area) using dbh or age as the predictor. Because resources are not available to sample trees belonging to every species, the sample will be designed to include 21 of the most abundant species, representing over 76% of the municipal forest.

Stratified random sampling will be conducted using dbh classes for each stratum to obtain dimensional information spanning the existing life span of each species. Trees are stratified into a minimum of 3 dbh classes for small-growing trees like crabapple and a maximum of 7 dbh classes for larger-growing trees like white birch. As close to an equal number of trees as possible will be randomly selected from each size class. The City of Glendale maintains an inventory that includes address, species and dbh class of each street tree. Random samples will be drawn from this database.

Data to be collected for each tree includes species, age, address, dbh (to nearest 0.1 cm by tape), tree and bole height (to nearest 0.5m by clinometer or range pole and 0.1m by range pole or tape, respectively), average crown diameter in two directions (nearest 0.5m by tape), and leaf area. If size of tree does not appear correlated with age of the adjacent development, we will verify age either through interviewing home or business owner or tree services personnel with the City of Glendale. Trees will be cored and rings counted when ages cannot be otherwise determined. Appendix 1 lists all measurements taken and the protocols for collecting each.

Two digital photos of each tree crown taken at perpendicular angles are used to calculate leaf area using an image processing method developed by Peper and McPherson (1998, 2003). Focal length of the camera and distance from camera to the tree is recorded (to nearest 0.1m by tape) for each photo.

All data is logged into a Cassiopeia IT-700/70 Palmtop PC and the Nikon 990 digital camera and downloaded at the end of each field day.

Data Storage. All data is stored in Excel format. The files are stored as follows:

1) The field sample tree list: Hickory:\\C:\Glendale\Sample\finalsample.xls
2) All collected dimensional, leaf area and side walk data from field sample: Hickory:\\C:\Glendale \Data\fielddata2001.xls
3) Growth coefficients: Hickory:\\C:\Glendale\Data\Glendalegro.xls
4) The above files are also backed up on a CD- RW disk and sent to the main office weekly.

Training. A training manual for all phases of data collection written prior to the outset of the Glendale study, to be maintained and updated as the need arises, is available for reference to data collectors at all times in protocol binders maintained at the office and in the field. The manual also contains copies of manufacturer's operations manuals for camera, altimeter, clinometer and compass. Originals are maintained in the unit office.
The unit's biological technician is responsible for training assistants working in the field and lab portions of this study. Training includes instruction in use of field equipment (measuring tapes, clinometer, Haga altimeter, Vertex hypsometer, range pole, camera, increment bore, palmtop computer), followed by guided practice throughout the course of the first days of the study. Measurements taken by data collectors are checked for accuracy against measurements taken

by the technician. Distances measured on the ground, with clinometer or altimeter, meter and dbh tapes are randomly rechecked by the technician for accuracy.

Measurement of computer images are double-checked by technician with repeated area measures required to be within ±1% of one another. Scaled photographs also allowed for rechecking of field measurements (tree height, bole height, crown width, dbh).

Leaf Area Image Analysis*.* This method was developed for lab use with 35mm negatives (Lindsey and Bassuk, 1992). We adapted it for field use with digital cameras and image processing software. The method essentially converts digital images of tree crowns into estimates of leaf area (LA) using a unitless quantification of tree crown density called silhouette area (SA) as follows:

$$LA = SA \ x \ CFA$$

where CFA represents the Crown Frame Area (area within a rectangle drawn to frame the entire tree crown). SA is the percentage of the digital image that is composed of tree crown (Lindsey and Bassuk, 1992):

$$\mathrm{SA} = \frac{\mathrm{CrownArea}}{\mathrm{ImageFrameArea}}$$

This method has shown accuracy (± 15%) in previous studies (Peper and McPherson, 1997; Peper, in progress).

We use a Nikon 990 digital camera with the zoom/wide-angle lens set at 8 mm focal length. Images are captured at fixed distances from each tree (5 m increments, so image is taken at 5, 10, 15, 20…45 m distances keeping tree crown as large as possible in view finder. A $0.25m^2$ poster board scale is used to calibrate images taken at each distance for use during image measurement on SigmaScan Pro 4. Images are downloaded using the software supplied with the Nikon camera. Adobe Photoshop 7.0 is used for initial isolation of the tree crowns. Files are saved in JPEG format, then loaded into SigmaScan Pro 4 program for measuring. Default image size for this camera is 3:2 ratio, same as a 35mm negative. Using SigmaScan each image is calibrated and CA and IFA measured to obtain the unitless SA value. Measurements of maximum crown width and height (in pixels) are then converted to centimeters and scaled down to the size of a negative (each dimension divided by 10) to obtain the maximum dimensions of the tree crown on the negative. A negative-to-reality scale was then calculated as the representative fraction:

$$\frac{Camera\ FocalLength\,(0.8cm)}{Distance\ from\ Camera\ to\ Tree}$$

Numerator and denominator were each divided by 0.8 cm to yield the negative scale 1cm on the negative = *x* cm in reality. Crown width and height (on the negative) were multiplied by this scale to obtain the final CFA. Leaf area was obtained by multiplying CFA by SA.

Data Analysis. We will use least squares regression to fit an appropriate model. In prior studies quadratic, cubic, and log-linear models have been fitted. In addition, non-linear exponential and pseudo-Weibull models have shown best fit for leaf area data. For the last two studies, the following regression model generally was found to fit best:

$$E\left(y_i\right) = a + bx_i + \in_i \qquad (1)$$

where *E ( )* = expected value
y_i = response,
a and *b* = parameters to be estimated and
e_i = error term Subsequently we will test the four parameters: intercepts a_1 , a_2 , and slopes b_1 , b_2.

Validation Data Set. For 3 species (representative small-, medium-, and large-growing speices) 2*n* observations (70 trees each) will be chosen at random. This set will be split into two sets of *n* observations. After fitting a regression model, we will test the intercepts and slopes. For example, if we pool all of the data together and are using equation (1) for prediction we would test the model as follows:

$$E(y_{ij}) = a_i + b_i x_{ij} + 0_{ij} \qquad (2)$$

where *i* is period (*i*=1 old data, *i*=2 new data),
j=observation j.

Then we will test the four parameters: intercepts a_1, a_2 and slopes b_1, b_2. If a_1=a_2 and b_1=b_2 then it is the same equation. We can also check whether or not the variability in each period is the same (if the variability is the same then by pooling the data together one get smaller confidence intervals). If intercepts and slopes are not significantly different, the equations are the same and methodology repeatable.

Glendale Budget - Fieldwork

		Glendale, AZ	
		Quantity	Amount
Reconnaissance trip			
	Lodging, per diem, car rental, air (pp/pd)	3.5	$ 1,771.00
Field work			
	Air Travel (rt)	8	$ 1,600.00
	Fuel (gals. @1.60 to $1.90 if non-GSA)		$ -
	GSA Montlhy Lease ($236)		$ 472.00
	Lodging	2	$ 4,440.00
	Per diem	100	$ 2,900.00
	MCI longdistance (@ $0.06/min.)	1500	$ 90.00
	Misc.		$ 1,500.00
Sub total			**$ 12,773.00**
Other			
	Auto Mileage @ $0.105/mi.	3128	$ 328.44
	Cell phone ($30/mo)	2	$ 60.00
Total			**$ 13,161.44**

Total w/o personnel
= $13,161.44

Literature Cited

Council of Tree and Landscape Appraisers. 1993. Guide for Plant Appraisal, 8th Edition. International Society of Arboriculture, Savoy, Illinois.

Frelich, L.E. 1992. Predicting Dimensional Relationships for Twin Cities Shade Trees. University of Minnesota. Twin Cities, MN. Department of Forest Resources. 33 pp.

Lindsey, P. A. and N. L. Bassuk. 1992. *A nondestructive image analysis technique for estimating whole-tree leaf area.* HortTechnology. 2 (1): 66-72.

Nowak, D.J. 1996. Estimating leaf area and leaf biomass of open-grown deciduous urban trees. For. Sci. 42:504-507.

Peper, P.J. and E.G. McPherson. 1998. Comparison of five methods for estimating leaf area index of open-grown trees. J. Arbor. 24:98-111.

Peper, P.J. (In Review). Evaluation of four methods for estimating leaf area of isolated deciduous trees. Agric. For. Meteor.

APPENDIX 1
MUNICIPAL BENEFIT-COST ANALYSIS DATA COLLECTION: FIELD DATA COLLECTION PROTOCOLS FOR PALMTOP PC

The following data will be recorded for each tree (tailor the sections following highlighted numbers to relate to each city inventory):

1) MgtZone – this comes from the original city inventory. This is the number of the management area or zone that the tree is located in within a city. If included in that inventory, incorporate it into the data sheet.
Use: For pre-planning. For example, we may find it easier to sort and collect the data daily by management area because it enables the shortest driving distance between sample trees. Final reports also may present data by management area or zone within a city.

2) TreeID – unique number assigned to each tree by city in inventory
Use: individual tree identification and running tally by city of number of trees city maintains

3) SpCode (species code, confirmed from inventory) – a 4 to 6 letter code consisting of the first two letters of the genus name and the first two letters of the species name followed by two optional letters to distinguish two species with the same four-letter code.
Use: abbreviated genus and species for use in graph and analysis legends

4) AddressNum – street number of building where tree is located– from inventory
Use: locating tree

5) Street – the name of the street the tree is located on – from inventory
Use: locating tree

6) Side – tree location from inventory, gives side of building or lot tree is located on -- see Figure 1. F = Front, M = median, S= side, P = park.
7) Cell – the cell number where the tree is located (1,2,3, etc). Obtain city inventory protocols to determine what order the trees are numbered in (e.g., sometimes they are assigned in driving direction or, alternatively, as street number increases, depending upon city.)
Use: locating tree

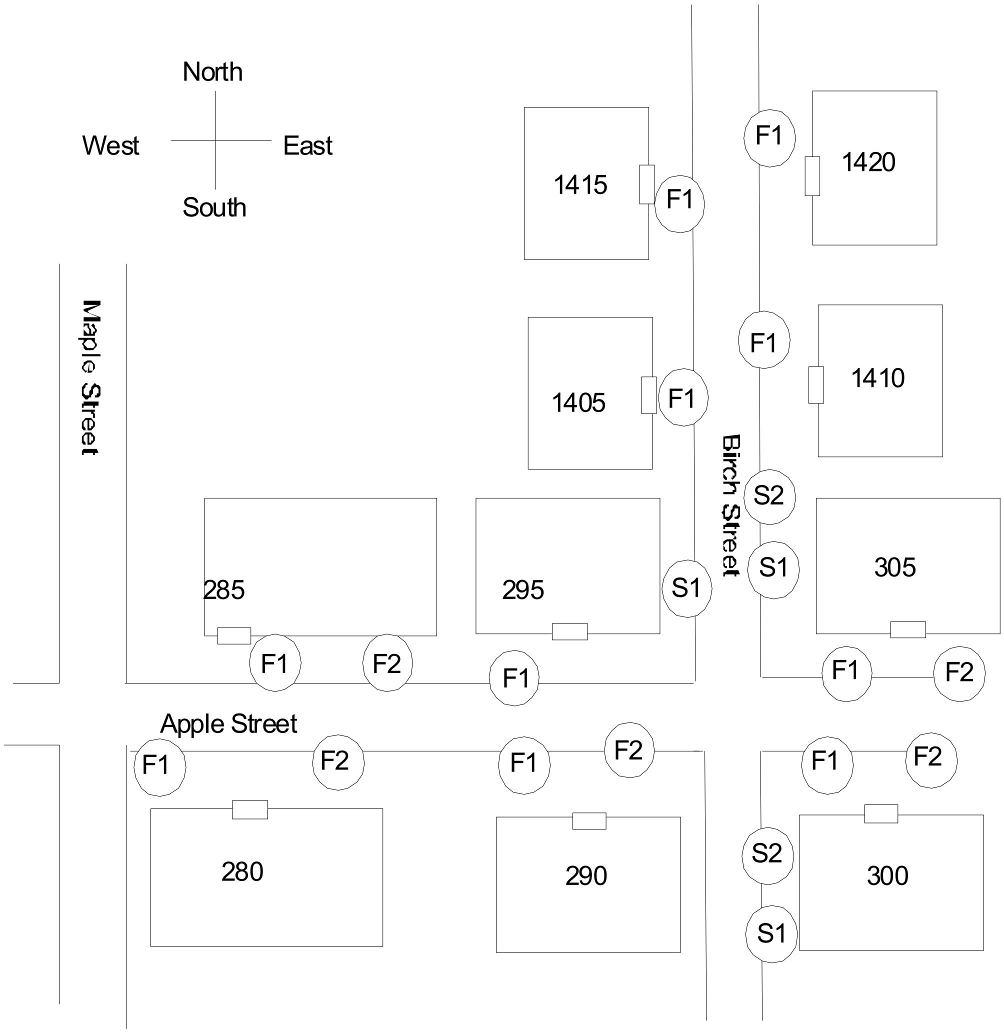

Figure 1. Treeloc tree 295 Apple S1 is actually the first tree (in driving direction) on Birch Street side of house

8) Onstreet – from inventory (omit if not included as a field in city's inventory) – this is for trees at corner addresses when tree is actually on cross street rather than the addressed street (see Figure 1). Also see if this entry is necessary for the city being studied.
Use: locating trees

9) From Street, To Street – from inventory – the names of the cross streets that form boundaries for trees lining un-addressed boulevards. For example, on boulevards that have no development adjacent to them, therefore no obvious parcel addressing, trees are typically numbered in order. By including closest

cross streets in the inventory, one will not have to begin counting trees from #1 in order to locate #333 which is 10 blocks up the boulevard from #1.
Use: for locating trees on un-addressed boulevards.

10) DBHmetric – measure the diameter at breast height (1.37m) to nearest 0.1 cm (tape). Where possible for multi-stemmed trees forking below 1.37 m measure above the butt flare and below the point where the stem begins forking. When this is not possible, measure DRC as described below. Saplings (DBH/DRC 2.54 - 12.5 cm) will be measured at 1.37 m unless falling under multi-stemmed/unusual stem categories requiring DRC measurements (per FHM Field Methods Guide).
Use: development of size prediction equations, carbon sequestration, annualization and management costs.

DIAMETER AT ROOT COLLAR (DRC) – adapted from FHM Field Methods Guide:
For species requiring diameter at the root collar, measure the diameter at the ground line or at the stem root collar, whichever is higher. For these trees, treat clumps of stems having a unified crown and common root stock as a single tree; examples include mesquite, juniper, and mountain mahogany. For multi-stemmed trees, compute and record a cumulative DRC (see below); record individual stem diameters and a stem status (live or dead) on a separate form or menu as required.

1 <u>Measuring DRC</u>: Before measuring DRC, remove the loose material on the ground (e.g., litter) but not mineral soil. Measure just above any swells present, and in a location so that the diameter measurements are reflective of the volume above the stems (especially when trees are extremely deformed at the base).

Stems must be at least 1.0 ft in length and 1.0 inch in diameter to qualify for measurement; stems that are missing due to cutting or damage must have previously been at least 1.0 ft in length (estimate by checking diameter of wound and compare with diameter and length of other stems – checking taper.
Whenever DRC is impossible or extremely difficult to measure with a diameter tape (e.g., due to thorns, extreme number of limbs), stems may be estimated and recorded to the nearest 1.0-in class.

Additional instructions for DRC measurements are illustrated in Figure 2.

2 <u>Computing and Recording DRC</u>: For all tally trees requiring DRC, with at least one stem 1.0 inch in diameter or larger at the root collar, DRC is computed as the square root of the sum of the squared stem diameters. For a single-stemmed DRC tree, the computed DRC is equal to the single diameter measured.

Use the following formula to compute DRC:

$$DRC = SQRT\ [SUM\ (stem\ diameter^2)]$$

Round the result to the nearest 0.1 in. For example, a multi-stemmed woodland tree with stems of 12.2, 13.2, 3.8, and 22.1 would be calculated as:

$$\begin{aligned} DRC &= SQRT\ (12.2^2 + 13.2^2 + 3.8^2 + 22.1^2) \\ &= SQRT\ (825.93) \\ &= 28.74 \\ &= 28.7 \end{aligned}$$

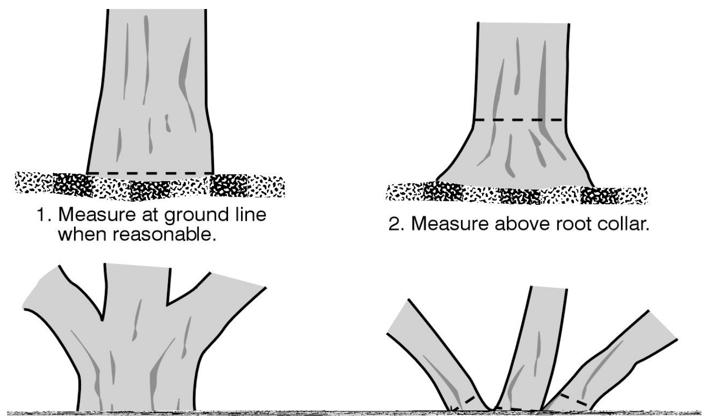

Figure 2. How to measure DRC in a variety of situations.

11) DBHinv – the DBH from the city inventory, usually expressed as classes from 1 to 9, but class system specific to city. Sometimes expressed as DBH to nearest inch.

12) flareDia – flare diameter measurement along with flareht and flaremax to be taken on trees with dbh of 30.5 cm (>12 in.) or greater. Measure the diameter of the bole at start of flare (a in Figure 3a and b) taken to the nearest 1.0 cm with dbh tape. If tree shows no buttressing or root flare enter zero (0). If tree dbh less than 30.5 cm, enter NA.
Use: to determine whether there is a consistent relationship between dbh, flaredia and flaremax for given species.

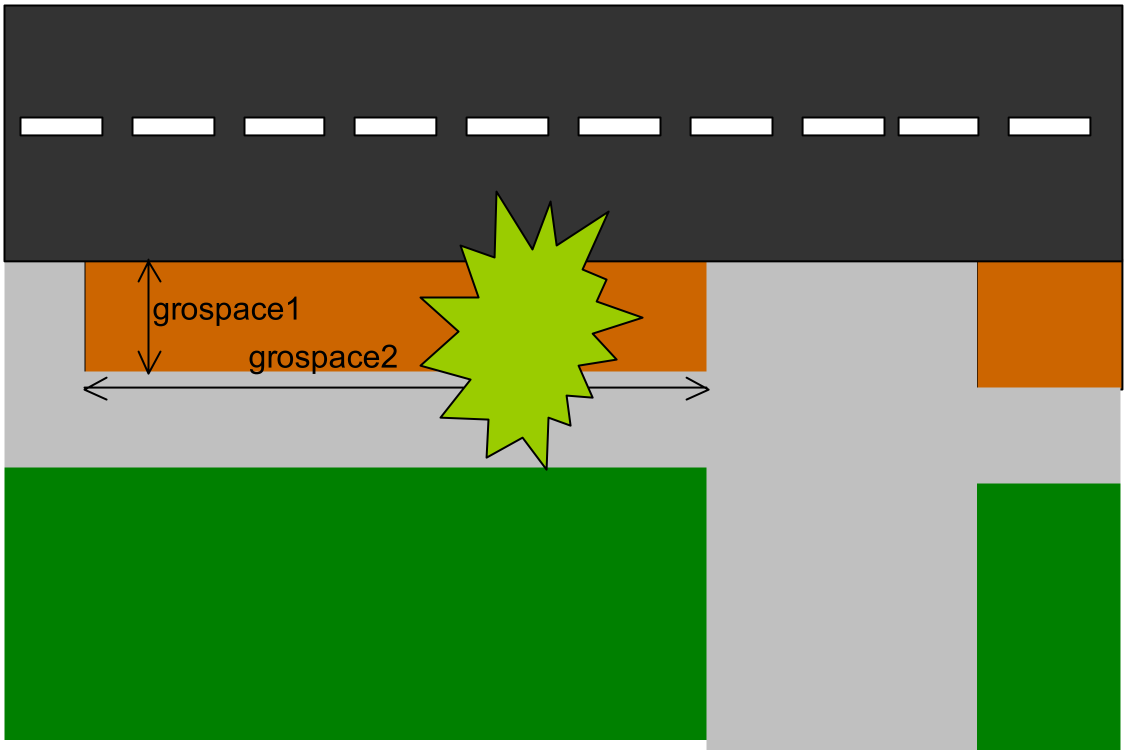

Figure 4. Grospace 2 for this tree would be recorded as NA because crown width (parallel to road) is unimpeded by hardscape.

16) CrDiaPar- (crown diameter) Widest crown diameter measurement taken to the nearest 0.5 m (tape) parallel to the street. The occasional erratic branch should not be included (see Fig 5).
Use: equations predicting tree size, energy, air quality.

17) CrDiaPerp- (crown diameter) Widest crown measurement taken to the nearest 0.5 m (tape) perpendicular to street. The occasional erratic branch should not be included.
Use: equations predicting tree size, energy, air quality.

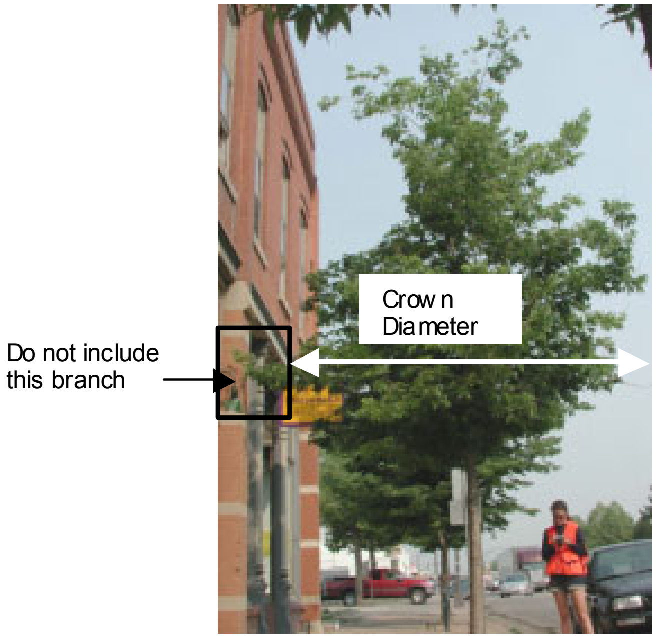

Figure 5. Erratic branch (in box at left) is omitted from crown diameter measurement . Area measured is represented by white line.

18) Setback – distance from tree to <u>nearest</u> air-conditioned/heated space (be aware that this may not be same address as tree location).
Evaluate as:

1 = 0-8 m
2 = 8.1-12 m
3 = 12.1-18 m
4 = >18 m

Use: assess effects of shade on energy use.

19) LMtce – Level (1-5) of landscaped area where tree is growing. Assess area extending from tree bole to 1.5 x drip line. Evaluate as:

1 = no obvious irrigation/maintenance (e.g. no sprinkler system, no other green vegetation beneath tree drip line, may be median tree with cobble surface or asphalt except for cutout, sidewalk cutout with no irrigation, vacant lot, compacted soils).
2 = minimal or sporadic irrigation/maintenance (usually cutouts, vacant lots, or median trees as above but may receive some irrigation from nearby sources; sometimes rental properties that are not consistently maintained; could be planting strip without active sprinkler system but homeowner may occasionally water area – strip obviously not as well maintained as nearby yard. One example would be front yard that has poorly irrigated lawn – large brown areas, partially dead; young trees would show stress as would shrubs)
3 = average maintenance/irrigation – enough care to maintain but no special treatment (e.g. minimally landscaped residential area.

4 = well-landscaped front yard tree, well-irrigated, high maintenance (all nearby plants and vegetation healthy, pruned, lawns appear fertilized, irrigated, maintained very regularly.

5 = like 4 above plus mulched or other special treatments. This would equate with a demonstration garden setting.

Use: potential explanatory variable for growth, condition.

20) MtceRec – maintenance recommended -- the recommended maintenance on the tree

0 = none
1 = young tree (general)
2 = young tree (immediate)
3 = mature tree (general)
4 = mature tree (immediate)
5 = hazard tree (public safety)

Use: provide city with info on needed management

21) MtceTask – maintenance task -- the highest priority task to perform on the tree

1 = stake/train
2 = clean
3 = raise
4 = reduce
5 = remove
6 = treat pest/disease

Use: provide city with info on needed management

22) DoorOr – Door Orientation --Taken with compass, the direction that the front door of the nearest conditioned space faces (heated or air-conditioned space may not be same address as tree location –see Figure 6). Prior to taking this data you must set the declination on the compass for the city you are working in. Then take door orientation reading and record as follows:

1 = N = North (337.5-22.5°)
2 = NE = Northeast (22.5-67.5°)
3 = E = East (67.5-112.5°)
4 = SE = Southeast (112.5-157.5°)
5 = S = South (157.5-202.5°)
6 = SW = Southwest (202.5-247.5°)
7 = W = West (247.5-292.5°)
8 = NW = Northwest (292.5-337.5°)

Use: assess effects of shade on energy use

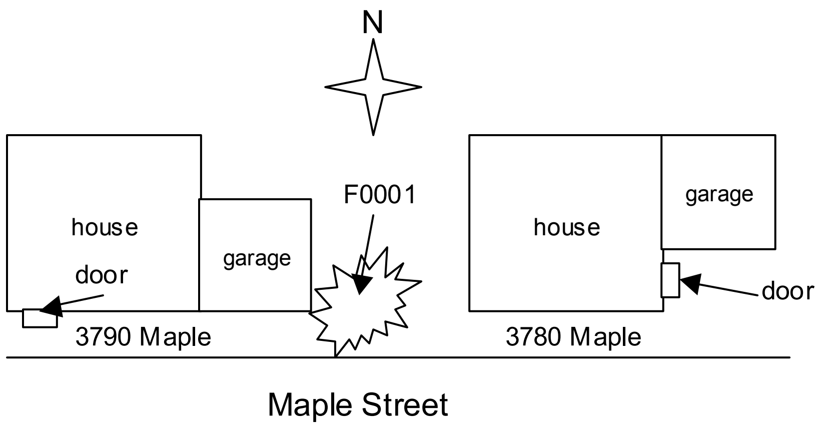

Fig. 6. Example: You are asked to obtain door orientation of tree F0001 at 3790 Maple Street. Correct orientation would be 3 (East) because closest conditioned space is 3780 Maple NOT 3790 Maple.

23) TreeOr – Tree Orientation – taken with compass, as in Figure 7 the coordinate of tree taken from imaginary lines extending from walls of the nearest conditioned space (heated or air-conditioned space -- may not be same address as tree location):

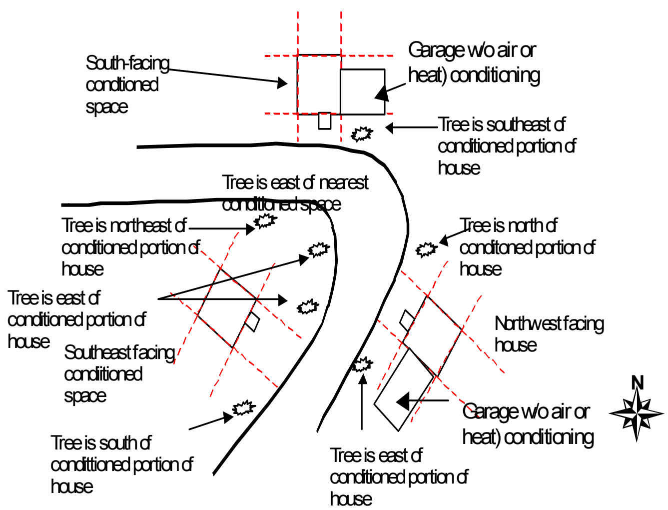

Figure 7. Shows imaginary lines extending from walls and associated tree orientation.

Use: energy analysis

24) NumCarShaded – Number of autos where any portion of any parked automotive vehicle is under the tree's drip line. Car must be present:

0 = no autos

1 = 1 auto
2 = 2 autos, etc…

Use : vehicle hydrocarbon emissions reduction

25) Image 1 – select position for best possible photo of tree crown, keeping in mind that you must try to obtain two perpendicular views of the tree that are as free of background noise as possible. Try to position yourself so the tree crown is as isolated as possible from neighboring tree crowns and other crowns in background:

a) distance from tree that photo is taken from should be at increments of 5m (5,10,15, 20 meters, etc) and accurate within 0.05 meter
b) camera zoom should be set to full wide angle
c) first image must include entire tree (bole and crown) for backup measurements and should fill as much of viewfinder as possible
d) kneel to take images so more sky is included in background

Use: leaf area estimation, field measurement correction or validation

26) Dist 1 – Measure distance from camera back (the point where image is actually recorded) to point equivalent to center of tree bole (Figure 8). Measure accurately within 0.05 meter.

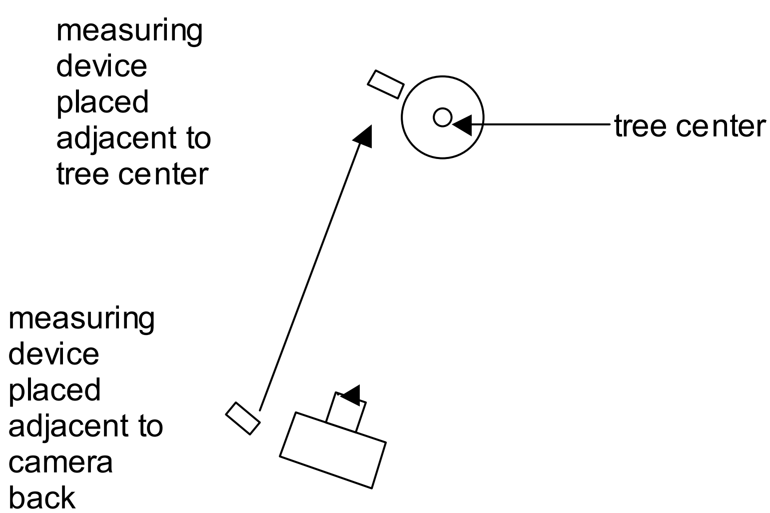

Figure 8. Showing how to measure distance (in 5 m increments) between camera back and tree center).

Use: distance measurement is key component to calculation (and resulting level of accuracy) of leaf area equations.

27) Image 2 – taken as perpendicularly (90°) as possible to image 1.

Use: average leaf area calculated from image 1 plus image 2 for total leaf area

28) Dist 2 – distance as per #26 for Image 2.
Use: distance measurement is key component to calculation (and resulting level of accuracy) of leaf area equations.

29) Land use – Area where tree is growing:
- 1 = single family residential
- 2 = multi-family residential (duplex, apartments, condos)
- 3 = industrial/institutional/large commercial (schools, gov't, hospitals)
- 4 = vacant/other (agric., unmanaged riparian areas of greenbelts)
- 5 = small commercial

Use: energy, property value

30) LocType – location type:
- 1 = Front yard
- 2 = Planting strip
- 3 = Cutout (tree root growth restricted on all four sides by hardscape
- 4 = Median
- 5 = Other maintained locations
- 6 = Other un-maintained locations

Use: BCA, management considerations, narrative reports, explanatory variable during data analysis (to assist in explaining variance)

31) Tree Height – from ground level to top to nearest 0.5m (omit erratic leader as shown in Fig. 9) with range pole, altimeter or clinometer
Use: size equations, carbon, energy, hydrology

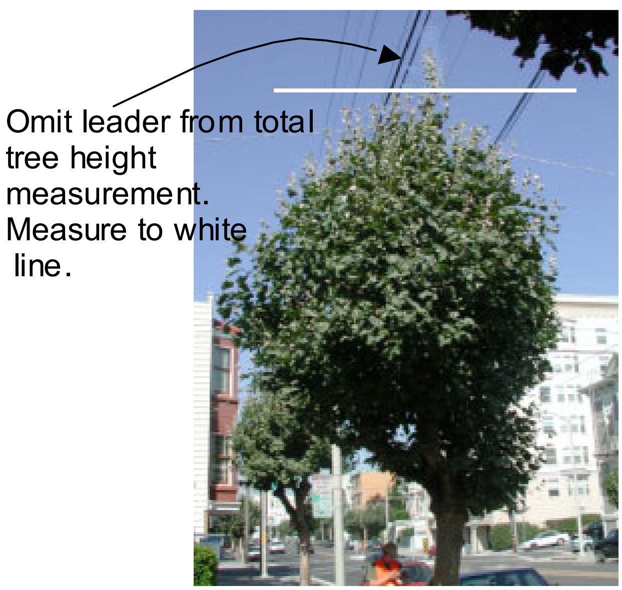

Figure 9. Showing tree with erratic leader that should not be included in height measurement.

32) CrnBase – with altimeter, average distance between ground and lowest foliage layer (omitting erratic branch) to nearest 0.5m.
Use: energy crown definition

33) BoleHt – with altimeter, distance between ground and location at bole where first set of branches connect. This is generally higher up the bole than the crnbase measurement.
Use: hydrology model

34) Shape – visual estimate of crown shape verified when different from each side with actual measured dimensions of crown height and average crown diameter. If in doubt, determine shape using average crown diameter and crown height measurements. See Figure 10.
Use: energy (shadow patterns)

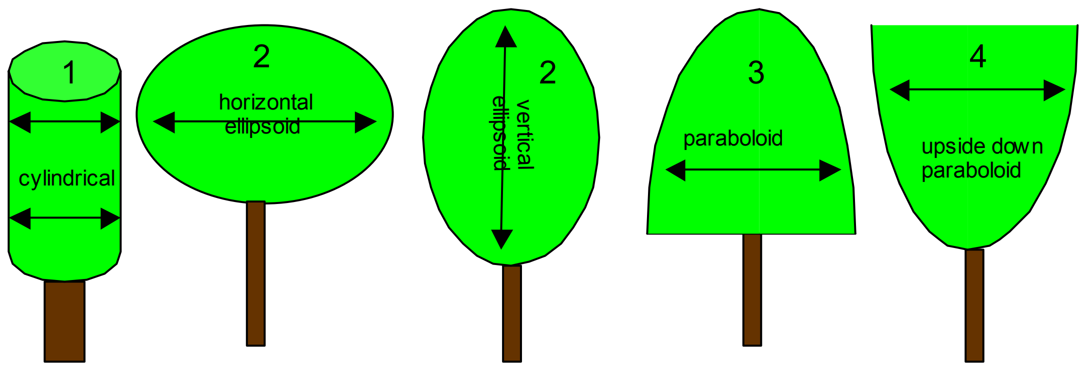

Figure 10. Showing shapes of trees.

1 = cylinder = maintains same crown diameter in top and bottom thirds of tree
2 = ellipsoid (horizontal or vertical; also includes spherical) – for ellipse the tree's center (whether vertical or horizontal) should be the widest)
3 = paraboloid – widest in bottom third of crown
4 = upside down paraboloid – widest in top third of crown

Pruning Entries:
During preparations for starting fieldwork, photos of the sample species should be taken with the city forester in order to establish crown and condition norms for the city for each tree type.
Pruning should be evaluated on the basis of the average form and shape that a tree of that species and age should have if in good health according to the city forester.
Pruning history should be considered only if it has contributed to reducing the crown beyond what the city-established norm. Crown height prune, crown diameter prune estimates are used to identify trees that deviate from the city-wide norm for crown raising and crown reduction. They may deviate, for example, due to utility or sign clearance, storm damage, private pruning, topping, and disease.

For all pruning categories, data collectors need to evaluate the tree's pruning from both below and away from the crown.

Use: may assist in explaining variation in height, crown height or leaf area for trees of similar ages or dbh; info used descriptively in final reports.

35) CrnHt. Prune – percentage missing from top of tree compared to norm:
- 0 = none
- 1 = 1-10%
- 2 = 11-25%
- 3 = 26-50%
- 4 = 51-75%
- 5 = >75%

35) CrnDiaPrune – percentage missing from width of tree compared to norm
- 0 = none
- 1 = 1-10%
- 2 = 11-25%
- 3 = 26-50%
- 4 = 51-75%
- 5 = >75%

36) CrnDens – essentially an estimate of foliar density, not solely leaf pruning – compared to the species norm supplied by city forester. CROWN DENSITY is the amount of crown branches, foliage and reproductive structures that blocks light visibility through the crown
Use the CROWN DENSITY-FOLIAGE TRANSPARENCY CARD to estimate percentage of crown present, from 5 to 95% as on card below.

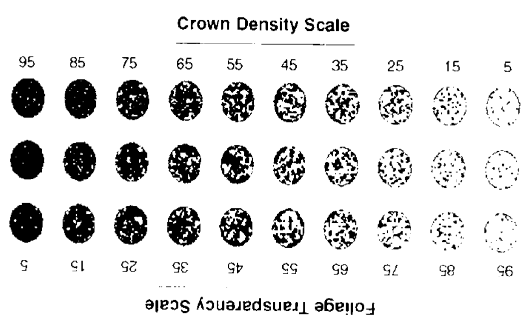

Figure 11. Crown Density Foliage Transparency card

The Crown Density - Foliage Transparency card (Figure 11) should be used. White areas of the card represent skylight visible through the crown area and black areas represent a portion of the tree that is blocking skylight. Hold the card so that "Crown Density" is up ("Foliage Transparency" should be upside down).

View the crown as shown in Figure 12. Both members should view from different angles (never 180 degrees apart) and average their findings.

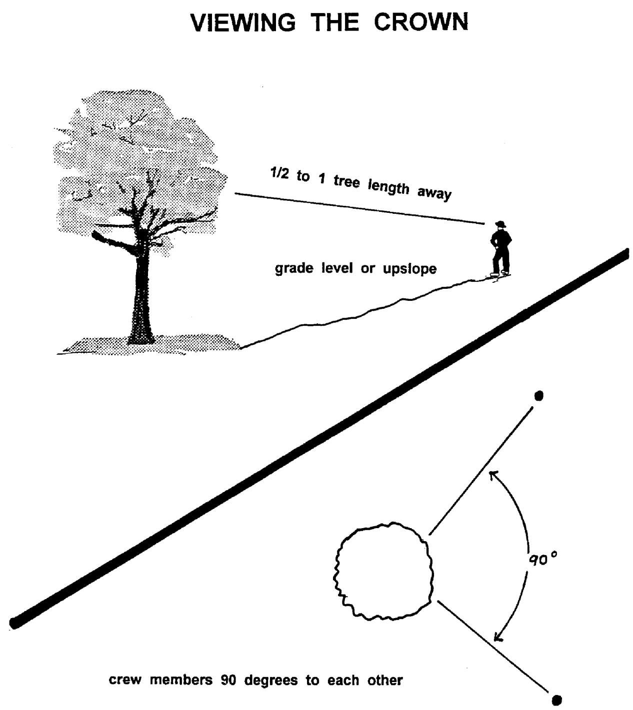

Figure 12. Crew positions for viewing crowns.

CROWN DENSITY estimates crown condition in relation to a typical tree for the site where it is found. CROWN DENSITY is the amount of crown branches, foliage and reproductive structures that blocks light visibility through the crown.
Both data collectors measure CROWN DENSITY (Figure 12). To determine the crown shape, project a full "mirror image" crown based on that tree's shape where it is growing to the crown top (missing, dead or live). Foliage below the crown base is not included. If the top is broken or missing, mentally re-establish that portion of the tree before estimating DENSITY. Mentally project half-sided trees as full crowns by using the "mirror image" of the existing half of the crown. Include CROWN DIEBACK and open areas in this outline (Figures 13 and 14).

After determining the crown shape, each person should use the crown density - foliage transparency card (Figure 11). Along the line of sight, estimate what percentage of the outlined area is blocking

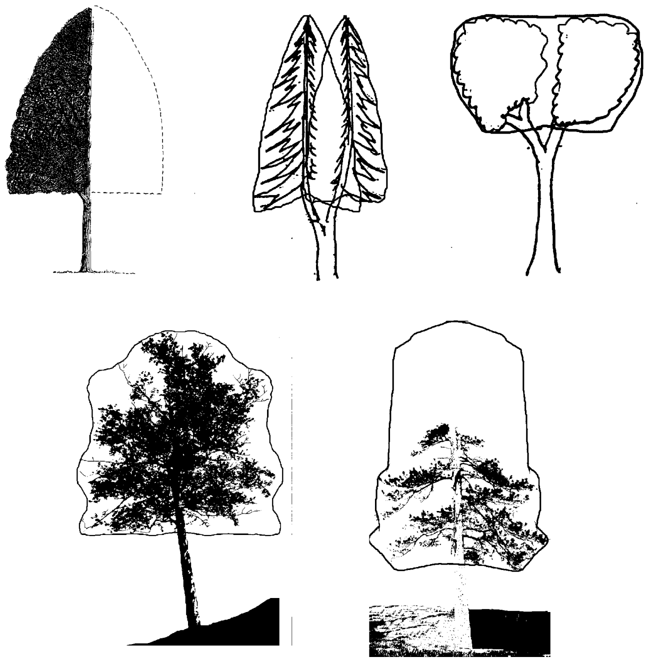

Fig. 13

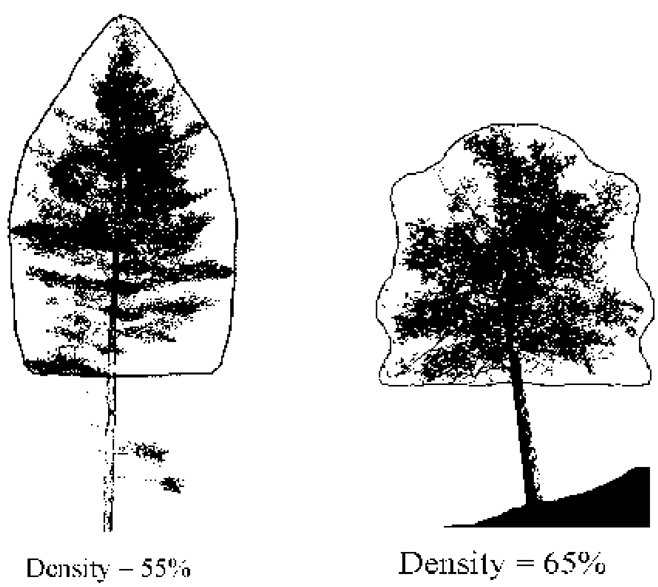

Fig. 14

sunlight. In cases where portions of the tree may be missing, i.e., half-sided trees, it may be easier to determine the percent of the crown shape missing and the actual density of the tree's remaining portion. Then use the table on the back of the crown density - foliage transparency card to arrive at the final CROWN DENSITY. When estimates made by two individuals disagree, they should discuss the reasons for their ratings until an agreement is reached, or use the methods below to resolve the situation.

If the numbers for a crown measurement estimated by two crew members do not match, arrive at the final value by:

- 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).
- 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.

Use: assist in explaining variation in leaf area and shading by same-aged or same-dbh trees. Assists in explaining variations in leaf area estimates. Provides info for descriptive reports.

37) OvhdLines – lines that interfere with or appear above tree
0 = no lines
1 = present and no potential conflict
2 = present and conflicting
3 = present and potential for conflicting

Use: comparison of city-maintained vs. utility contract pruned trees.

38) SW Damage – sidewalk damage categories (see Appendix 1 photos) will be determined for each city during study preparation. City forester will be asked 1) dimensional measurement at which sidewalk is heaved enough to grind or ramp and 2) at what degree of damage does city move from temporary to permanent repair. Example:
0 = heaved <1.90 cm (3/4 inch) = no repair
1 = heaved 1.90 to 3.8cm (3/4-1.5 inch) = ramp/grind
2 = heaved > 3.8 cm (1.5 inch) = replace/permanent repair.

Be careful NOT to assess damage adjacent to newly planted trees as damage associated with that tree.
Use: costs, size and species associated with damage by growspace size

39) Repair – is there evidence of previous sidewalk repair at this site (sections of sidewalk adjacent to tree only):
0 = No
1 = Yes
Use: costs, history of repair with species

40) Cond -- Condition – tree condition as per adaptation of CTLA tree appraisal and FHA guidelines to nearest 5%

1. Rate each of 5 factors using 0-5 scale, add points
Roots
Trunk
Scaffold Branches
Smaller Branches and Twigs
Foliage
5 = No problem = Excellent
4 = No apparent problems = Good
3 = Minor problems = Fair
2 = Major problems = Poor
1 or 0 = Extreme problems = Dead/dying

Total Points	Condition	Rating
23-25	Excellent	90-100 = 5
19-22	Good	70-89 = 4
15-18	Fair	50-69 = 3
11-14	Poor	25-49 = 2
05-10	Dead/dying	05-24 = 1

Use: asset value, structure

41) PlantDate – Date tree was planted (for data analysis, assumptions of age at planting will be obtained from city forester for 1.5” caliper trees).

42) Accuracy -- aging trees –when trees are being aged by city:

1. remind city forester to record planting date, not tree age. City should provide CUFR with info on typical age for each species at planting.
2. Provide city with list of trees to be aged –list should be sorted for aging by management area, street, and address (in this order) to simplify locating them
3. You should convert dbh metric into dbh inches for the city’s use
4. Add 2 columns to the data sheet – planting date and accuracy. Forester should then specify accuracy of estimated planting date using classes:
    1 = within a year
    2 = within 2-3 years
    3 = within 4-5 years
    4 = within 6-10 years
    5 = over 10 years.

Use: relate age of trees to dimensions of tree

43) Notes: any pertinent notes that help explain something that is unusual about the tree that may affect growth of the tree.

44) dbh1, dbh2, dbh 3, etc., are for individual stem diameter entries for multi-stemmed trees being recorded using DRC methods. These cells are linked to the formula in the DBHmetric column calculating the final DBH.