Urban Tree Crown Health Assessment System: A Tool for Communities and Citizen Foresters

Matthew F. Winn, USDA Forest Service, Southern Research Station
Sang-Mook Lee, Bradley Department of Electrical Engineering, Virginia Tech
Philip A. Araman, USDA Forest Service, Southern Research Station

Abstract

Trees are important assets to urban communities. In addition to the aesthetic values that urban trees provide, they also aid in such things as erosion control, pollution removal, and rainfall interception. The urban environment, however, can often produce stresses to these trees. Soil compaction, limited root growth, and groundwater contamination are just a few of the factors that can influence tree health. In order to preserve the health of urban trees, an effective monitoring regime is necessary. Communities often seek the help of citizen foresters (concerned volunteers from the community) to aid in data collections of this type. Unfortunately, these volunteers have limited tools and resources that an arborist or other tree professional might have. An effective urban tree monitoring regime is one that uses tools available to the average citizen and allows for minimal knowledge of urban forestry. The U.S. Forest Service Southern Research Station in Blacksburg, Virginia is in the process of constructing a web-based tool that will allow urban foresters, citizen foresters, and other concerned individuals to assess the health of urban trees using digital photographs. The assessment will be based on tree crown characteristics, which serve as good indicators of overall tree health. The tool will allow individuals to upload digital images of urban trees, have those images processed using crown analysis software, and return to the user the results of the analysis. The software developed by the Forest Service will provide estimates of tree length, crown diameter, live crown ratio, crown volume, crown density, and foliage transparency. The database driven website will allow users to monitor individual tree crown characteristics over time and assist in diagnosing declining tree health.

Introduction

The urban tree crown assessment tool is part of a website devoted to urban tree monitoring (www.srs4702.forprod.vt.edu/urbantree/). The website was created to provide urban foresters, landowners, and concerned community members information and tools relating to the health assessment of urban trees. The website is divided into three sections; site, bole, and crown characteristics, but the focus up to this point has primarily been on urban tree crowns. Within the crowns section, there is a training module and the crown evaluation software. The training module is a step-by-step tutorial for evaluating individual tree crown conditions in urban areas. Before using the crown evaluation software, it is advisable that the individual reads the tutorial in order to become familiar with the terminology and measurement techniques relating to tree crown assessment. The crown evaluation software (still in development) is a web-based tool for analyzing digital images of urban tree crowns. The tool can be used as part of a monitoring regime to detect a decline in urban tree health (Figure 1). It can also be used as a tool for urban landscape planners to examine the vitality of different tree species. This paper discusses the steps involved in analyzing urban trees using the crown evaluation software and includes guidelines for collecting field data, uploading the data to the website, and processing the image. The program output is also discussed, including output data and images.

Field Data Collection

In order for the analyzing software to provide accurate tree and crown measurements, the ratio between measurement units (feet) and camera units (pixels) needs to be determined. One way to obtain this information is to use the distance to the tree and the focal length of the camera. However, since focal length varies from camera to camera and changes when zooming, a more practical method of obtaining the conversion ratio is to place an object in the picture for scale. Therefore, before photographing the tree, flagging should be wrapped around the tree stem near breast height. A color should be chosen that contrasts with the bark of the tree and will show up clearly on the photo. Once the flagging is in place, the vertical distance from the base of the tree to the flagging should be measured and recorded.

The next step is to establish the position(s) where photographs will be taken. If multiple photos are taken, the photographer should attempt to space the photo locations at 90 degree intervals around the tree. The following guidelines should be used when establishing photo position and example photos based on these guidelines are shown in Figure 2.

• Photos should include entire tree from the stem base, to the top, to the outermost edges of the crown.

Figure 1. Example of Urban Tree Decline for Which the Crown Evaluation Tool Could be Used

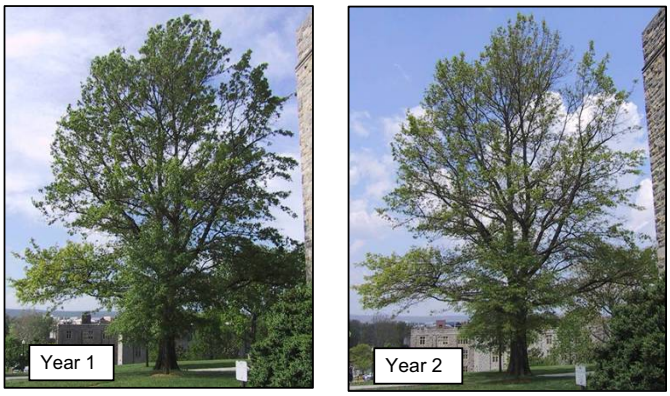


Figure 2. Good and Poor Photos Based on the Criteria for Photographing Sample Trees

• There should be no obstructions (buildings, other trees, etc…) between the camera and tree that block view of crown or tree base.
• The preferred vantage point is at grade level or upslope from tree.
• The sun should be directly overhead or at the photographer's back.
• Include as much clear sky or other contrasting background behind the crown as possible. Background vegetation can be problematic.
• Never establish photo positions in roads or other unsafe environments.

Understandably, it may not be possible to meet all of the above criteria, particularly in an urban environment where buildings, roads, and other man-made objects can limit photo vantage points. The photographer should try to meet as many of the criteria as possible for each tree while maintaining a safe working environment. Once the position has been established, the tree should be photographed using a digital camera, being sure to capture the entire tree in the photograph. Photo resolution is not critical and zooming is permissible.

For monitoring purposes, it will be necessary to photograph the tree in subsequent years from the same location. Therefore, the location where each photograph was taken needs to be recorded. First, the horizontal distance to the tree from each camera vantage point should be measured and recorded. Distances can be measured using a tape measure, laser rangefinder, or other distance measuring device. Second, the azimuth in degrees from the camera vantage point to the tree is measured. These two measurements can then be used in the future to ensure photographs are taken from the same locations. At this time, the observer should also record other information such as tree species, date, and location.

Entering Tree and Photo Information

Once the photograph has been taken and the field data recorded, proceed to the crown analysis web page to upload and process the image. (*Note:* The crown analysis web address will not be given at this time since the software is still in development. Once the software is ready for use, a link will be provided under the *Crowns* portion of the Urban Tree Monitoring website). All information submitted through the website will be stored in a database, allowing the user to retrieve input and output data at a later time. The initial page of the crown analysis website will first ask the user to enter the following information:

• ***User ID*** (required) – a unique identification tag that will be appended to all information submitted by that particular user.
• ***Tree Species*** (optional) – the species of the tree which was photographed.
• ***Photo Date*** (optional) – the month, day, and year that the photograph of the tree was taken.
• ***Tree Location*** (optional) – the location of tree that was photographed. Can be GPS coordinates, street address, or any information that will help locate the tree at a later date.
• ***Height of Flagging*** (required) – the measured height in inches from the base of the tree to the flagging. Will be used to scale the photo.
• ***Horizontal Distance*** (optional) – the distance in feet along the horizon from the photo vantage point to the pith of the tree.
• ***Azimuth*** (optional) – the angle in degrees from the photo vantage point to the tree.
• ***Comments*** (optional) – any information that the user would like appended to their data in the database (weather conditions, site conditions, etc.).

Photo Upload and Measurements

After the preliminary information has been collected, the user can upload the tree image to the web server and rotate it if necessary. The user will then be asked to draw several reference lines on the tree image (Figure 3). The first is a line from the base of the tree to the flagging. This information will be used along with the height measurement taken in the field to scale the photo. Next, the user will be asked to draw a line from the base to the top of the tree, following the main stem. Total tree length will be calculated from this information. In order to calculate the crown dimensions, lines will then be drawn from the top to the bottom of the live crown (following the main stem) and from the left edge to the right edge of the crown (perpendicular to the main stem). This information will also be used along with the total tree length to calculate the live crown ratio. Finally, the user is asked to draw a rectangle around the portion of the crown with no background interference in order to calculate crown density and foliage transparency. If this is a tree that was analyzed in a previous year, the user will have the option to retrieve the rectangle used in the prior analysis and resize if necessary. For all analyses of the same tree, the rectangle should cover the same area in order to reliably compare the results from year to year.

Output Data

Once the image has been processed, the user will be presented with a summary page containing the results of the analysis along with the input data. Included in the summary page will be estimates of tree length, crown ratio, crown diameter, crown

volume, crown density, and foliage transparency. Each of the output parameters is defined below.

• ***Tree Length*** – the straight-line distance along the stem from the ground level of the tree to the apical meristem. Tree length differs from tree height in that height implies a vertical distance and does not account for tree lean.
• ***Crown Ratio*** – a percentage determined by dividing the live crown length by the total live tree length. Along with crown diameter and volume, crown ratio provides an estimate of the photosynthetic capacity of a tree.
• ***Crown Diameter*** – the width of the live crown measured perpendicular to the tree bole.
• ***Crown Volume*** – the volume of the space occupied by live foliage and branches in the crown. Typically, crown volume is calculated using area estimates from perpendicular views of the tree. However, since the crown software only analyzes one tree at a time, volume will be estimated by calculating the visible crown area and rotating that area around the axis of the tree.
• ***Crown Density*** – the amount of crown stem, branches, twigs, shoots, buds, foliage and reproductive structures that block light penetration through the visible crown. Crown density is expressed as a percentage of the crown area and provides an estimate of crown condition in relation to a typical tree for the site where it is found.
• ***Foliage Transparency*** – the percentage of the live, normally foliated portion of the crown in which skylight is visible. Figure 4 shows examples of foliage transparency ratings for urban tree crowns.

Figure 3. Reference Lines Drawn on the Tree Image Used to Calculate Tree and Crown Metrics

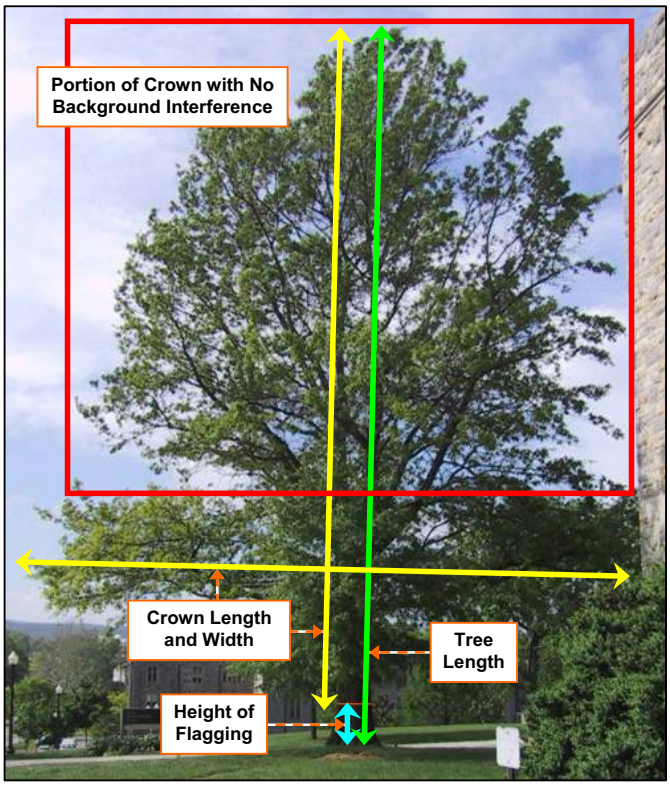
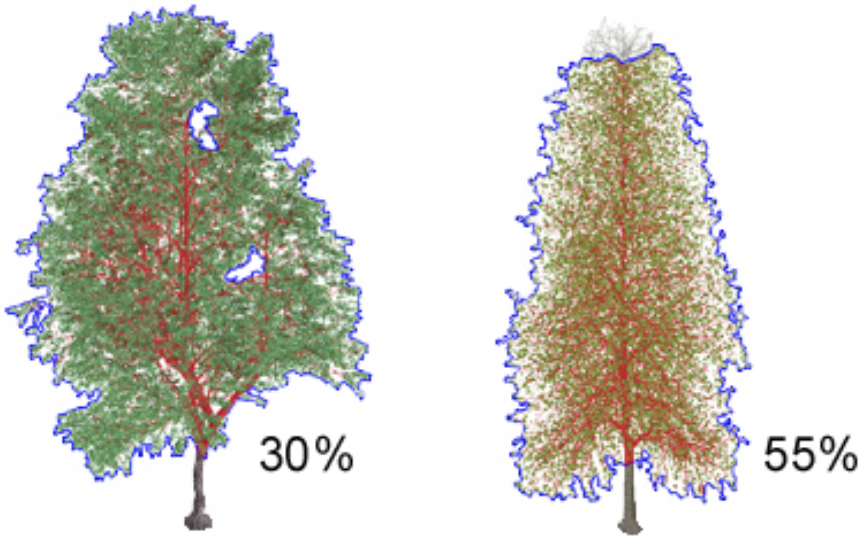


Figure 4. Sample Foliage Transparency Ratings For Urban Tree Crowns



Along with the output data, the summary page will include several post-processed images of the tree. These will include an image showing the user placement of the reference lines and a transparency distribution map of the tree crown.

Summary

Trees are a vital part of urban communities, but unfortunately, they must also deal with the many stresses associated with the urban environment. An important step in preserving the health of urban trees is detecting when a tree begins to decline. Monitoring of urban trees is essential to early diagnosis of tree health issues. With the increased involvement of community volunteers, a monitoring regime not only needs to be effective, but also needs to rely on tools available to the average citizen. The proposed urban tree crown assessment tool will allow citizen and urban foresters to monitor the health of urban trees with minimal forestry knowledge or equipment. The web-based tool will provide the crown metrics necessary for early diagnosis of tree decline and uses only a digital photograph and a few simple field measurements.

References

Clark, N.A., S.M. Lee, W.A. Bechtold, and G.A. Reams. 2006. Digital photography for urban street tree crown conditions. *In:* Proceedings of the Society of American Foresters 2005 National Convention. Ft. Worth, TX [published on CD-ROM]: Society of American Foresters, Bethesda, MD. 4 pp.

Lee, S.M., N.A. Clark, and P.A. Araman. 2003. Automated methods of tree boundary extraction and foliage transparency estimation from digital imagery. *In:* Proceedings of the 19th Biennial Workshop on Color Photography, Videography and Airborne Imaging for Resource Assessment. Logan, UT: American Society for Photogrammetry and Remote Sensing. 10 pp.

USDA Forest Service. 2006. FIA Field Methods for Phase 3 Measurements, 2006. USDA Forest Service. URL: <http://fia.fs.fed.us/library/field-guides-methods-proc/>, (date last accessed: 30 May 2007).

Zarnoch, S.J., Bechtold, W.A., and K.W. Stolte. 2004. Using crown condition variables as indicators of forest health. *Can. J. For. Res.* 34:1057-1070.

Proceedings

EMERGING ISSUES ALONG URBAN-RURAL INTERFACES II: LINKING LAND-USE SCIENCE AND SOCIETY

April 9-12, 2007
Sheraton Atlanta
Atlanta, Georgia

Edited by:
David N. Laband

Conference Co-sponsors:

Auburn University Center for Forest Sustainability:
A Peak of Excellence at Auburn University

USDA Forest Service
Southern Center for Wildland-Urban Interface Research & Information

National Science Foundation

Plum Creek Timber Company

Georgia Forestry Commission

Auburn University Forest Policy Center

Auburn University School of Forestry and Wildlife Sciences

Land Policy Institute, Michigan State University

September 2007