
A TOOL TO DETERMINE CROWN AND PLOT CANOPY TRANSPARENCY FOR FOREST INVENTORY AND ANALYSIS PHASE 3 PLOTS USING DIGITAL PHOTOGRAPHS

Matthew F. Winn and Philip A. Araman

ABSTRACT

The USDA Forest Service Forest Inventory and Analysis (FIA) program collects crown foliage transparency estimates for individual trees on Phase 3 (P3) inventory plots. The FIA crown foliage estimate is obtained from a pair of perpendicular side views of the tree. Researchers with the USDA Forest Service Southern Research Station have developed a computer program that uses a different approach to estimate transparency utilizing digital photographs. The program can compute individual crown transparency as well as canopy transparency (multiple crowns) from vertical photographs taken below the canopy. The pictures and results can be stored for multiple year evaluations of each plot.

INTRODUCTION

The Forest Inventory and Analysis (FIA) program of the USDA Forest Service is charged with the task of conducting large-scale vegetation surveys on forestland throughout the U.S. For every 6,000 acres of land, a permanent sample plot has been established where FIA field crews periodically collect data on forest type, site attributes, tree species, tree size, and overall tree condition. These sample plots are referred to as Phase 2 (P2) plots. On a subset of the P2 plots, forest health attributes are also collected. These plots are referred to as Phase 3 (P3) plots and there is approximately one P3 plot for every 16 P2 plots. Forest health attributes measured on P3 plots include tree crown conditions, lichen communities, understory vegetation, down woody debris, and soil attributes. As part of the crown condition assessment, the following crown measurements are collected: uncompact live crown ratio, crown diameter, light exposure, foliage absent, density, foliage transparency and dieback. This paper will introduce a software tool developed by the USDA Forest Service Southern Research Station that can assist FIA with the transparency estimation portion of P3 inventories. The software, called ForestCrowns, measures individual crown transparency and canopy transparency from digital photographs taken vertically from the ground.

FIA FOLIAGE TRANSPARENCY ESTIMATION

FIA defines foliage transparency as the amount of skylight visible through a side view of the live, normally foliated portion of the crown (USDA Forest Service 2007). The “normally foliated” portion of the crown is where there is visible foliage, normal or damaged, or remnants of its recent presence. FIA crew members determine foliage transparency by first projecting a two-dimensional outline around the tree crown that extends from the live crown base to the top and outward to the branch tips. This imaginary outline will be the transparency rating region and can be thought of as shrink wrapping a side view of the live crown. Excluded from the rating region are dead branches in the lower live crown, snag branches, crown dieback (recent branch mortality), and areas where foliage is expected to be missing. Once the rating region has been established, a transparency reference card (figure 1) is used to estimate the amount of skylight that is or would be penetrating the foliated crown (expressed as a percentage of the total foliated crown area). Typically, an estimate is obtained by two crew members standing at perpendicular viewpoints from the tree and averaged.

FORESTCROWNS SOFTWARE

The ForestCrowns software tool provides an alternative method of measuring transparency using standard or fisheye digital photographs. Instead of estimating transparency from a side view, ForestCrowns uses an upward view of the crown and can estimate individual crown transparency as well as canopy transparency. Transparency, as defined by ForestCrowns, is the amount of skylight visible through all physically-present crown structures, including leaves, branches and fruit. The program can assess an entire image or select areas of an image and can also analyze multiple images together. Batch processing is also available, which

provides quick full-image analysis of multiple images. Assessment input and results can be written to a database for storage and imported back into the program later.

ForestCrowns consists of two windows: the Image window and the Data window (figure 2). The Image window contains the crown/canopy image to be analyzed, as well as, options for adding/removing images from an assessment, deleting previous assessments, and selecting the analysis region. The Data window consists of two tabs: *Properties* and *Assessment*. The *Properties* tab is where the user enters the input data associated with the analysis, including: tree ID and species (for individual crown analysis), location, photo date, analysis date, and comments. The *Assessment* tab is where the transparency estimates are displayed following analysis. Other features found in the Data window include the database menu and the batch processing option.

PHOTOGRAPHING THE CROWN/CANOPY

The foundation for the ForestCrowns analysis is the digital image of the crown/canopy. Prior to obtaining the photograph, the best photo location should be determined based on understory vegetation and lighting conditions. Dense understory vegetation can block the view of the canopy and produce inaccurate transparency results when the image is processed with ForestCrowns. Poor lighting conditions and shooting directly at the sun can also produce erroneous transparency estimates. The optimum photo location is away from dense understory vegetation and when the sun is not directly overhead.

One advantage of using photographic records is that differences in canopy and crown transparency can be detected in subsequent inventories. In order for the results to be comparable, however, the location and orientation of the photograph should be consistent from one inventory to another. Once the photo location has been established, it is documented using a combination of GPS coordinates and distances to adjacent trees. In addition, a permanent metal pin can be placed in the ground at the photo location. The camera is then mounted to a tripod, centered over the pin, and leveled to insure that the camera angle is truly vertical. The radial orientation of the camera is documented and subsequent photographs are taken at the same orientation. If a fisheye lens is used, care should be taken to insure that the photographer is below the camera and not included in the picture. During subsequent inventories, if new lower vegetation exists that impedes the photographic view of the canopy, either have another crew member hold the vegetation out of the frame of view or, as a last resort, relocate the photo location close to the original.

INDIVIDUAL CROWN ANALYSIS

The first step in analyzing an individual tree crown using the ForestCrowns software is to upload the photo and enter the

input data (figure 2). Next, areas within the crown that have sky in the background are delineated on the image using the rectangular selection tool, the elliptical selection tool, or a combination of both (figure 3). The greater the proportion of tree crown that is delineated, the more accurate the overall transparency estimate will be. After each area is drawn, the transparency for that region will be displayed in the *Assessment* tab of the Data window. In addition to the individual transparency values, the weighted average transparency value for all regions is displayed in the lower right corner of the window. For this example, the individual transparency values range from 6.87 percent to 32.07 percent and the overall transparency value is 16.06 percent.

CANOPY ANALYSIS

ForestCrowns can determine canopy transparency from a single image or multiple images. To estimate transparency from a single image, the photo is first uploaded and input data entered as was done with the individual crown analysis. Next, the option to analyze the entire image is chosen under the selection menu. The transparency value of the entire image is then displayed under the *Assessment* tab (figure 4). For this example, the overall transparency value is 17.62 percent. Additional images can be added to the assessment by clicking on the “Add Images” button. Once the additional images have been uploaded, each image is assessed as in the above example. The Assessment tab will show the transparency values for each individual assessment as well as the combined average transparency value for all photos. To quickly analyze a large quantity of photos for full canopy transparency, the user can run the batch processing function. Finally, to assess photographs taken with a fisheye lens, the elliptical selection tool is used to select the entire circular photo region prior to processing (figure 5). The transparency for the fisheye image example is 13.41 percent.

DISCUSSION

Foliage transparency, one of the key crown variables collected by FIA on P3 inventory plots, serves as an indicator of overall tree health. High transparency values, relative to what is normal for a species, indicate that a tree has less leaf area to capture sunlight for photosynthesis. Some of the factors that can cause an increase in transparency are disease, insect damage, or drought. Foliage transparency is important for classifying tree health, but it is one of the most difficult variables to measure.

Current FIA estimates of transparency can be very subjective (Ghosh and others 1995; Innes 1988). Some of the factors that can influence a field crew’s assessment are: background vegetation, foreground vegetation, tree height (distance to crown), weather and lighting conditions, observer training/experience, and observer perception. Background vegetation, which occurs in just about every

forest setting, blocks light and makes it difficult to see light coming through the crown of the tree being assessed. In addition, dense forest environments create a situation where it is difficult to determine which foliage belongs to which crown. Foliage that does not belong in the assessment may be included and foliage that should be in the assessment may be omitted. Another problem associated with dense forests is foreground vegetation, which can prevent the observer from viewing the full crown. Tall trees can also pose a problem for transparency estimation due to increased distance and viewing angle. Weather conditions can affect ratings by altering the amount of light available while making an assessment. Crown ratings done on sunny days can differ from crown ratings done for the same tree on overcast or rainy days. Finally, observer bias can significantly add to discrepancies in transparency ratings. Training and experience are just two of the variables that can add to observer bias, but the bottom line is that not everyone sees the same things in the same way.

Because of the subjectivity involved in current FIA crown rating procedures, we propose a more objective method of estimating transparency for individual tree crowns using digital photographs and the ForestCrowns software. Though the protocols for viewing and rating the crown are significantly different, ForestCrowns provides an unbiased estimate of transparency. The main procedural difference is that FIA uses a side view of the tree and rates the foliated area only, whereas ForestCrowns uses an upward view of the crown and includes all crown structures in the rating. Though some of the same variables that adversely affect FIA ratings can still come into play, the one important variable that is removed from the equation is observer bias. Another advantage of using a photograph is that it serves a permanent visual record of the tree crown at that time. Results of crown assessments from multiple inventory years can also be compared to detect changes in individual crown transparency.

One subplot-level variable not currently collected by FIA is canopy cover, or inversely, transparency. Canopy transparency can be a good predictor for understory plant survival, growth, and succession, as well as many other sub-story ecosystem functions. Adding a measure of canopy transparency to FIA inventories would not significantly

increase data collection time and would provide additional useful data to land managers. What we propose is that four digital photographs are taken at each FIA plot [one at the center of each subplot (figure 6)], and then the images analyzed using the ForestCrowns software to determine transparency. Photographs can be taken with a standard or fisheye camera lens. In addition to providing an accurate estimate of transparency, the images can also be used to detect gaps in the canopy, which can indicate blow-downs, removals, or other tree mortality.

CONCLUSION

As part of FIA P3 inventories, crews measure a variety of health related tree variables, including foliage transparency. However, due to observer bias and other limiting factors, transparency estimates using current FIA guidelines can be very subjective. This paper proposes an alternative method of estimating crown transparency using digital photographs and crown analysis software developed by the USDA Forest Service Southern Research Station. The software, ForestCrowns, analyzes standard or fisheye photographs taken vertically from the ground and provides an accurate estimate of crown transparency. In addition to individual crown analysis, the software can also perform canopy transparency analysis. Our recommendation is to collect and analyze photos at each FIA subplot center. The photos would serve as permanent records of the canopy condition at the time, and the canopy transparency estimates derived from ForestCrowns would be a valuable addition to FIA inventory data. A future study is planned that will examine comparisons between crown cover estimates obtained from aerial photographs and ground-based estimates using the ForestCrowns software.

LITERATURE CITED

- Ghosh, S.;** Innes, J.L.; Hoffmann, C. 1995. Observer variation as a source of error in assessments of crown condition through time. *Forest Science*. 41(2): 235-254.
- Innes, J.L.** 1988. Forest health surveys: problems in assessing observer objectivity. *Canadian Journal of Forest Research*. 18(5): 560-565.
- USDA Forest Service.** (2007). Phase 3 Field Guide - Crowns: Measurements and Sampling, Version 4.0. <http://www.fia.fs.fed.us/library/field-guides-methods-proc/>. [Date accessed: November 24, 2010].

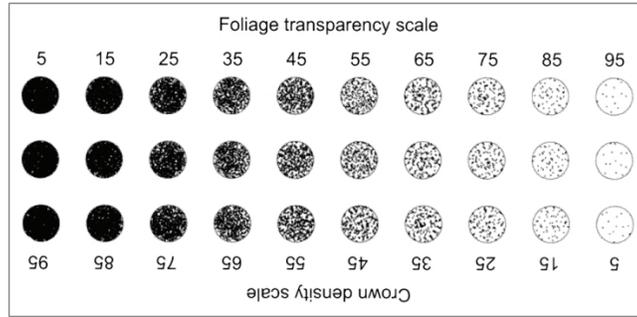


Figure 1—Reference card used by FIA field crews to determine foliage transparency of tree crowns.

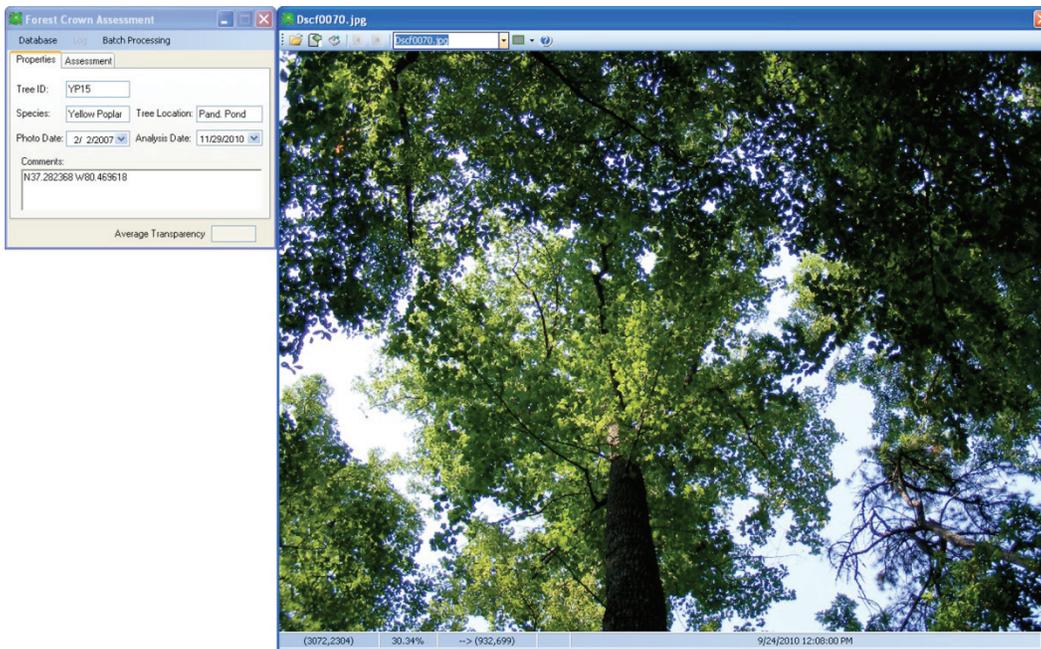


Figure 2—Screen shot of the ForestCrown computer program showing the Data window with input parameters on the left and the Image window on the right.

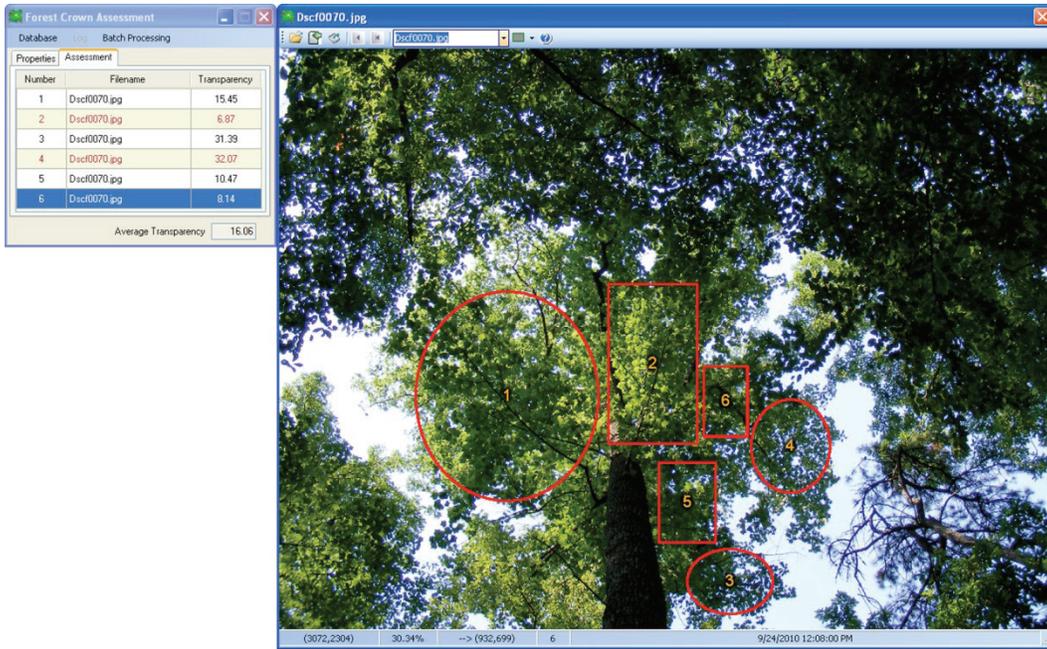


Figure 3—Sample crown delineation and transparency results for individual crown analysis in ForestCrowns.

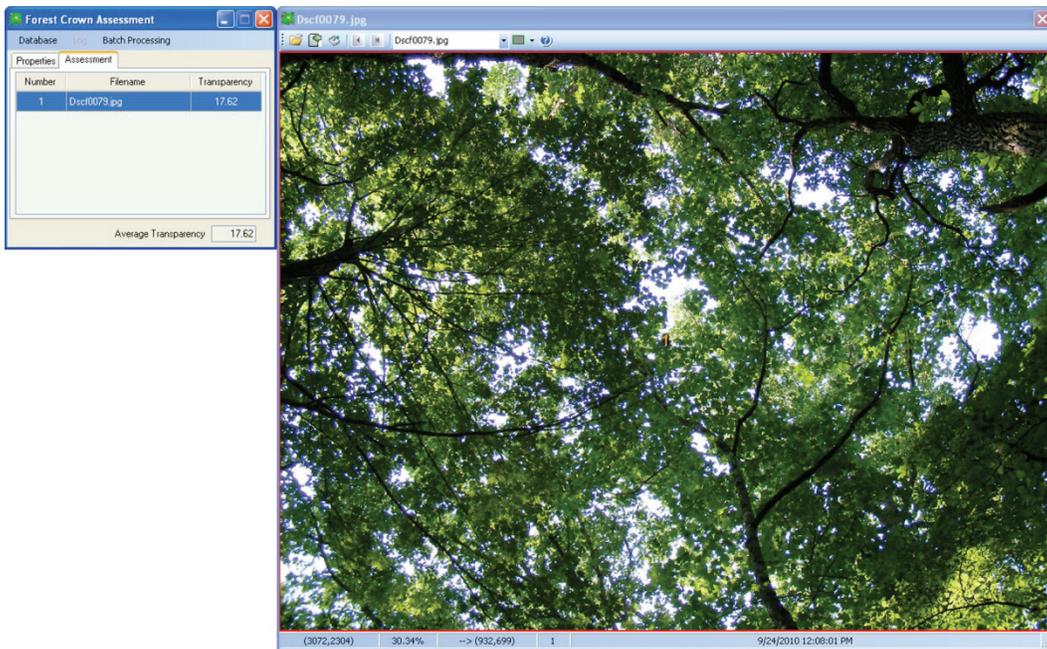


Figure 4—Delineation area and transparency results for canopy analysis using ForestCrowns.

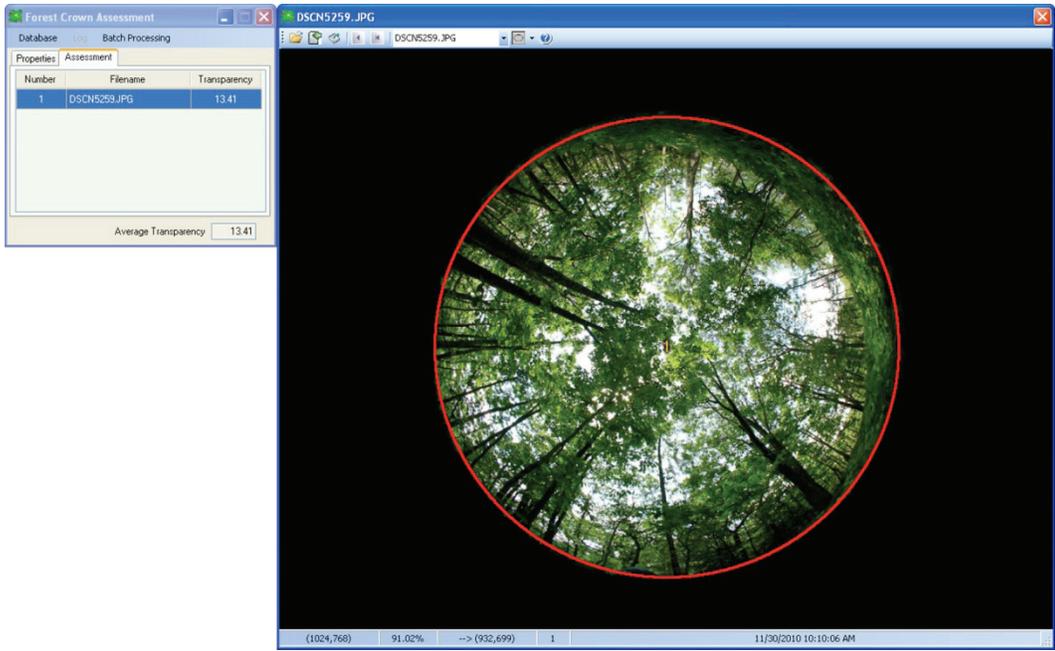


Figure 5—Delineation area and transparency results for canopy analysis of fisheye photograph using ForestCrowns.

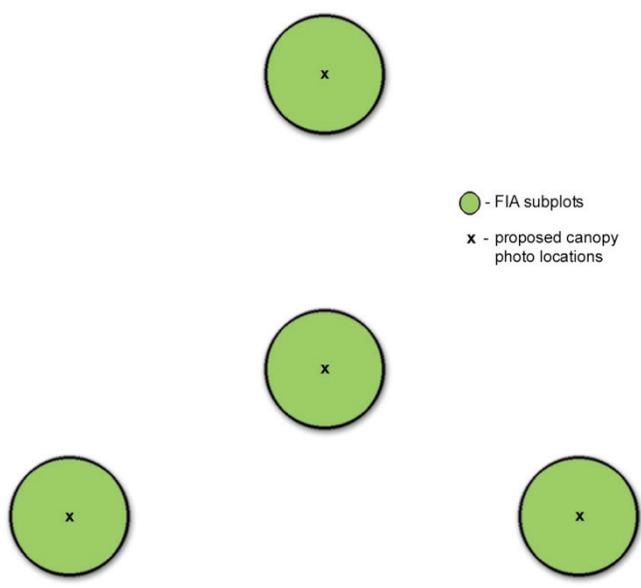


Figure 6—FIA subplot arrangement and proposed canopy photo locations.