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ForestCrowns: A Transparency Estimation Tool for Digital Photographs of Forest Canopies

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Cover photo: A typical camera setup for capturing ground-based digital imagery of a forest canopy for input into the ForestCrowns program.

[All photographs (cover and those in figures) were taken by the lead author, Matthew F. Winn, USDA Forest Service.]

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Abstract

ForestCrowns is a Windows®-based computer program that calculates forest canopy transparency (light transmittance) using ground-based digital photographs taken with standard or hemispherical camera lenses. The software can be used by forest managers and researchers to monitor growth/decline of forest canopies; provide input for leaf area index estimation; measure light transmission to the forest floor; analyze canopy gaps; detect disease, insect, or storm damage; and monitor health treatments. ForestCrowns can analyze entire images or target specific areas to obtain transparency estimates of individual tree crowns.

Keywords: Crowns, forest canopy, light transmittance, monitoring, transparency.

INTRODUCTION

Canopy cover, defined as the proportion of an area covered by the vertical projection of tree crowns (Jennings and others 1999), is a key variable used to characterize forest structure. It can be used to identify areas susceptible to forest threats such as fire (Keane and others 2015) and disease/insect outbreaks (Hessburg and others 1999). Changes in canopy cover can also be used to detect and quantify forest disturbances such as disease, insect, and storm damage (Hargrove and others 2009). In addition to the canopy itself, the light transmitted through the canopy can be an important ecological indicator of plant and animal habitat (Denslow 1980, Hyde and others 2006) as well as understory climate conditions (Aussenac 2000).

Several ground-based methods are currently used for measuring canopy cover. The most basic method involves assessing the canopy visually without specialized equipment. While simple visual assessments are quick, a downside of using this method is that the assessments are very subjective and often unreliable (Ghosh and others 1995, Innes 1988). Some of the factors that can influence visual estimates are: observer experience, observer bias, weather conditions, and lighting conditions.

Another simple, yet more objective, approach for measuring canopy cover is to use a spherical densiometer (Lemmon 1956, 1957). A spherical densiometer consists of a concave or convex mirror shaped as a portion of a sphere. The mirror is held horizontally so that it reflects the sky and canopy. A graticule is engraved on the mirror and four equally spaced dots are assumed in each square of the graticule. Readings are taken by counting the number of dots that intersect with the reflection of the canopy. Due to the reflective differences of the canopy from different viewpoints, however, the variation between observer estimates can be significant (Ganey and Block 1994, Vales and Bunnell 1988). Also, the small size and low resolution of the reflected image can result in reduced accuracy of the measurements, which are typically overestimated (Cook and others 1995).

A third, widely used ground-based option for measuring canopy cover is to photograph the canopy from below and analyze the photographs using computer software. Typically, photographs are taken with a fisheye (hemispherical) camera lens in order to capture the full 180° view of the canopy. A less costly alternative to using hemispherical photography is to take canopy photographs using a standard camera lens (Bunnell and Vales 1990, Macfarlane and others 2007). Though the use of a standard lens is not suitable for all canopy measurements, it can be used for more localized analyses.

Though there are several software programs available for analyzing canopy photographs, the programs vary in price, ease of use, output, and their ability to analyze standard camera images. The purpose of the ForestCrowns software development was to create a free, easy-to-use image analysis software program, capable of measuring canopy transparency from fisheye or standard digital camera imagery. Transparency, as it relates to this software, is defined as the amount of skylight visible through the forest canopy from a particular point on the ground and is expressed as a percentage of the total 2-dimensional forest canopy area. This definition of transparency varies slightly from that used by the Forest Service, U.S. Department of Agriculture Forest Inventory and Analysis program, which uses the term foliage transparency to describe the light visible through the live, normally foliated portion of an individual tree crown.

The ForestCrowns software was designed to be a simple yet effective tool for estimating light transmission through the forest canopy. No specialized photography or computer

skills are necessary to collect and analyze a photograph. In addition, the software will be made available to the public at no cost. The basic procedures for obtaining transparency estimates include: photographing the canopy, importing the photo into the ForestCrowns computer program, and delineating the areas of the photograph to be analyzed. Rectangular and elliptical selection tools are available to delineate the analysis region, or the entire image can be selected. Results of the analysis include transparency estimates for each individual selection region as well as the average transparency over all regions. All pictures and analysis results can be stored in a database for comparing seasonal or multiple year evaluations of each site.

This report serves as a user's guide for the ForestCrowns software. Potential users/uses of the program as well as detailed instructions for carrying out different types of analyses are presented.

ACQUIRING CANOPY PHOTOGRAPHS FOR USE WITH FORESTCROWNS

The foundation for the ForestCrowns analysis is the skyward digital image of the forest canopy. Prior to obtaining the photograph, determine the best photo location based on understory vegetation, lighting conditions, and adjacent trees (fig. 1). Avoid photographing below dense understory vegetation, as the low-hanging leaves and branches can block the view of the overstory canopy and produce inaccurate transparency results when the image is processed. Poor lighting conditions and shooting directly at the sun can also adversely affect the ForestCrowns analysis. Sunspots on the image can mask existing canopy structures and lead to an overestimation of transparency. Ideally, obtain photographs when skies are clear and the sun is not directly overhead. Finally, avoid placing the camera directly adjacent to tree stems. All

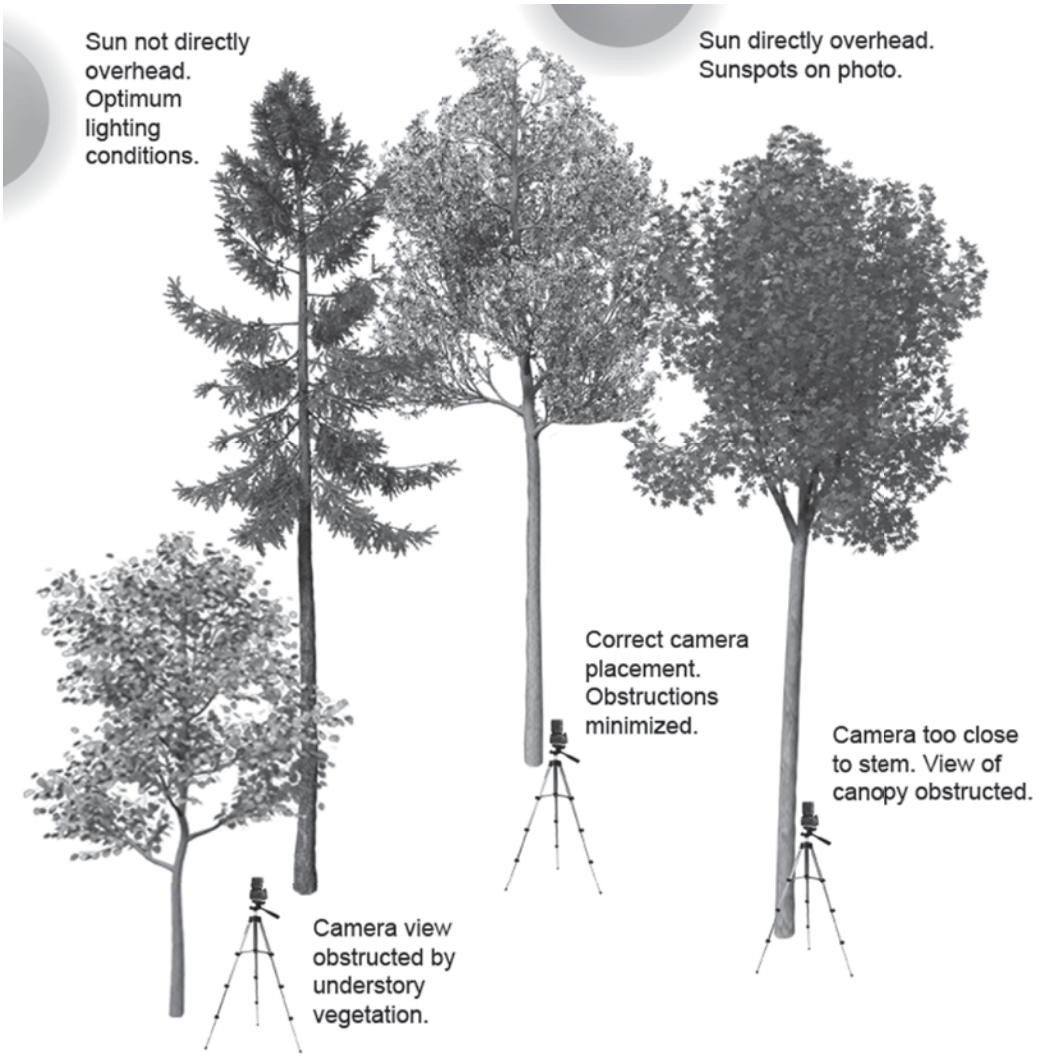


Figure 1—Lighting and other factors to consider when choosing the best camera location for photographing the forest canopy.

images will contain tree stems that partially block the view of the canopy, but the effect is minimized as the distance between the camera and adjacent stems is increased.

Once the optimal photo location has been established, mount the camera on a tripod, and then level the tripod so that the camera angle is truly vertical. The use of a tripod minimizes camera movement which can produce blurry images. If periodic photographs will be taken at the same location, document the precise location of the camera using a combination of GPS coordinates and distances to adjacent trees. A metal pin may also be placed in the ground, which can be easily found later using a metal detector if necessary. If standard photos are being taken, document the radial orientation of the camera, as subsequent photos should not only be taken from the same location, but at the same orientation as well. Though digital photos generally store the camera settings used, it is also a good idea to document the settings, including the lens type and size. Consistency with the camera location, orientation, and settings is necessary in order for ForestCrowns analyses to be comparable. If using a hemispherical lens, consistent camera orientation is not necessary, though the camera should still be leveled. When using a hemispherical lens, care should be taken to ensure that the photographer is below the horizontal plane of the camera lens so as not to be included in the picture. Once the camera has been positioned correctly, the location has been documented, and the lighting conditions are favorable, the photograph can then be taken. Be sure to turn the flash off as the light reflections on the underside of the leaves can sometimes be confused with sky during the analysis.

SOFTWARE INSTALLATION

Before installing the ForestCrowns software, be sure that the computer is running Microsoft® Windows® 7 or later. The program may run on older versions of Windows® but has only been tested on version 7. Both 32-bit and 64-bit platforms will work. The ForestCrowns installation file can be downloaded at the following Web address: http://www.srs.fs.usda.gov/pubs/software/forestcrowns.zip. Unzip and save the contents of the "forestcrowns.zip" file to the computer. Navigate to the unzip location and double click the "setup.exe" file. A screen will appear that reads "Welcome to the InstallShield Wizard for ForestCrowns" (fig. 2). Click the "Next" button to continue. The following screen prompts for the folder where the program is to be installed (fig. 3). Install to the default folder or select a new location by clicking on the "Change" button and selecting a different folder. Make sure there are at least 15 megabytes of free disk space available at the chosen location. Click the "Next" button to continue. The next screen is the installation confirmation screen (fig. 4). Click the "Install" button to proceed with the installation or the

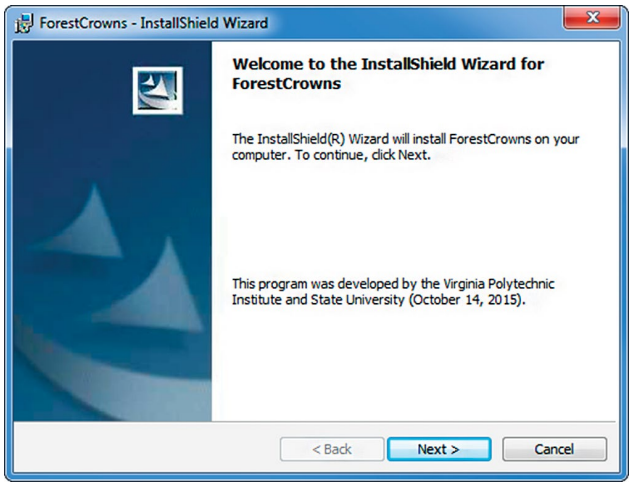


Figure 2—Welcome screen for ForestCrowns installation program.

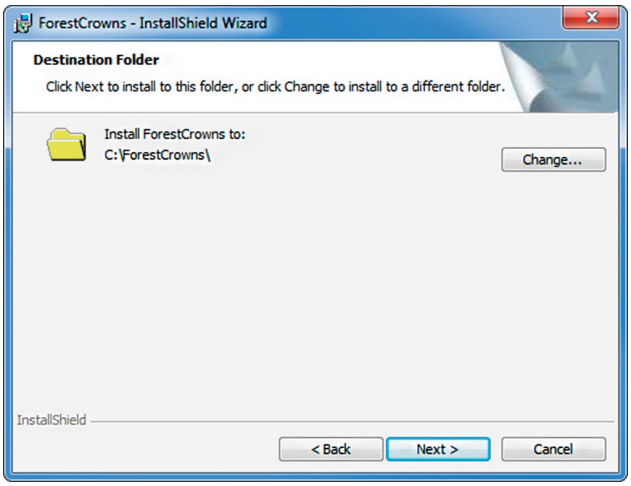


Figure 3—ForestCrowns installation program prompting for installation location.

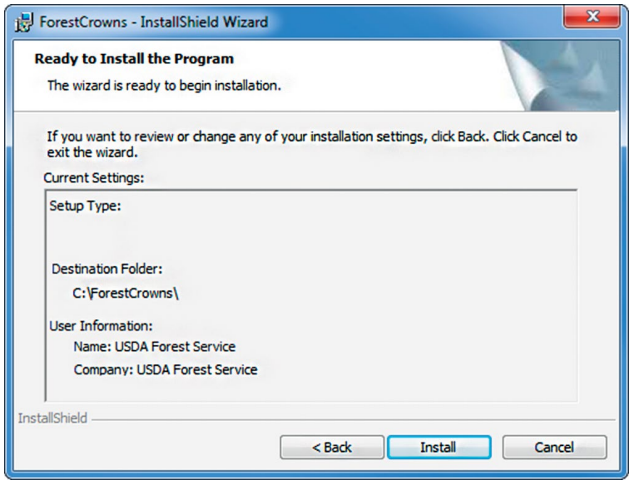


Figure 4—ForestCrowns installation initiation screen.

"Back" button to change the installation configuration. To abort the installation, click the "Cancel" button. After a short period of time, a confirmation screen will appear indicating that the installation was successful. A shortcut to the program labeled "ForestCrowns" will be placed on the computer's desktop.

PROGRAM OVERVIEW

To begin using the program, double click on the ForestCrowns icon located on the computer's desktop or the "forest_crowns.exe" file located in the installation folder. The ForestCrowns software comprises two main windows: (1) the View window, and (2) the Assessment window. The View window displays the uploaded canopy photograph currently being analyzed (fig. 5). Within the View window, you can add photographs to or remove photographs from the analysis. The View window is also where you define the analysis regions of each photograph. The entire photo can be analyzed or a portion of the photo can be analyzed using the rectangular or elliptical selection tool. If you want to remove an assessment, this can also be done from the View window. Finally, the button to initiate batch processing of images is located in the View window as well.

The Assessment window is for displaying and managing the output of the analysis. Within the Assessment window, there are three tabs: (1) **Properties**, (2) **Transparency**, and (3) **Output**. The **Properties** tab is where the user enters background information for the analysis (fig. 6). This includes a unique ID to distinguish one analysis from another, photo location, analysis date (generated automatically), and any comments you want pinned to the analysis. The **Transparency** tab is where the individual transparency estimates are displayed when a region is selected (fig. 7). If multiple regions are selected, the average transparency is given as well. Any assessment can be removed from the analysis by right clicking on the estimate and selecting "remove". The third tab in the Assessment window is the **Output** tab (fig. 8). Displayed under this tab is all the information associated with an assessment, including background information and transparency estimates. To retrieve the information, click on "Results" in the main menu and then select "View results". To save the information as a text file, select "Write results to a log file" under the "Results" menu item.

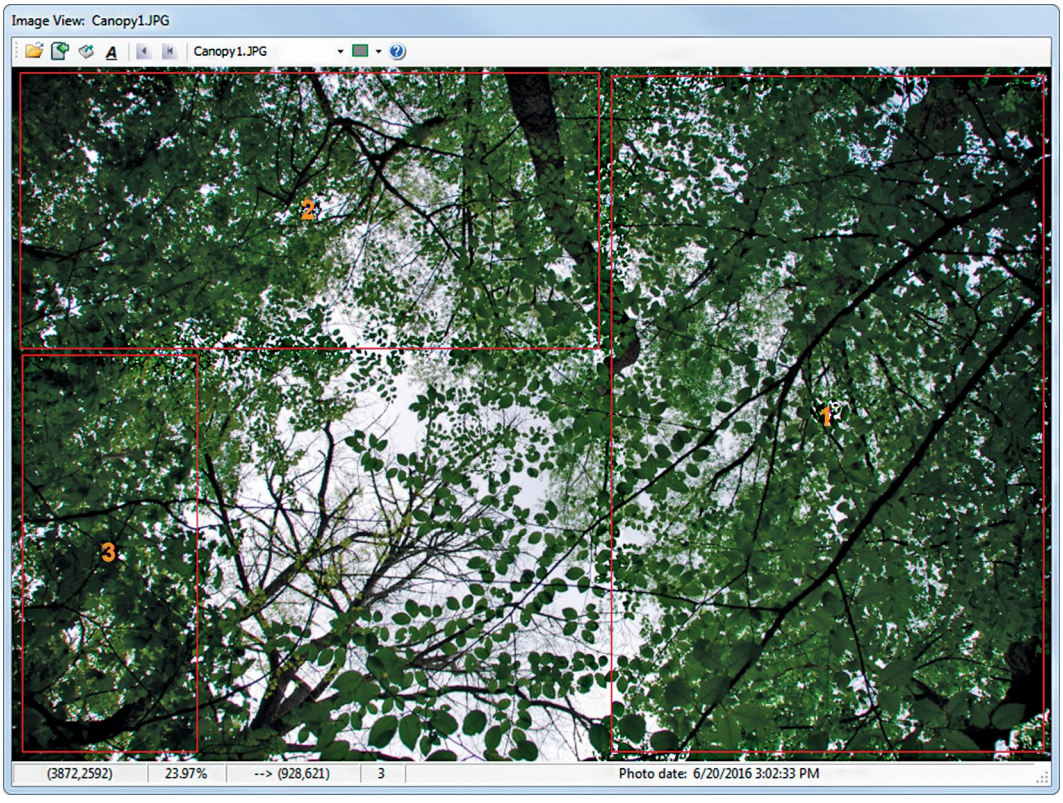


Figure 5—ForestCrowns "View" window showing canopy photo and transparency selection regions.

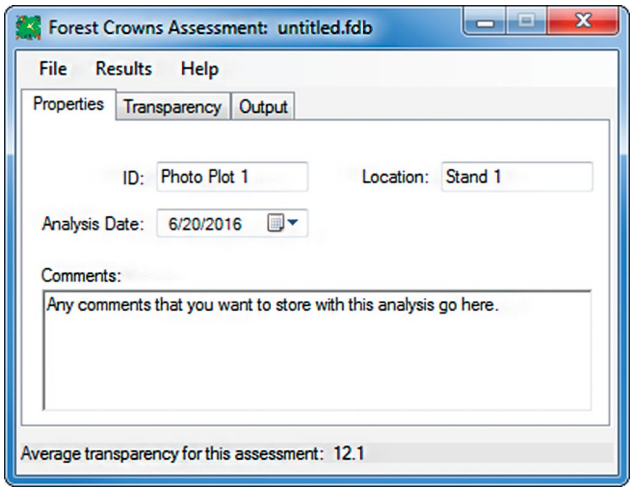


Figure 6—Properties tab of the ForestCrowns "Assessment" window showing analysis identification information.

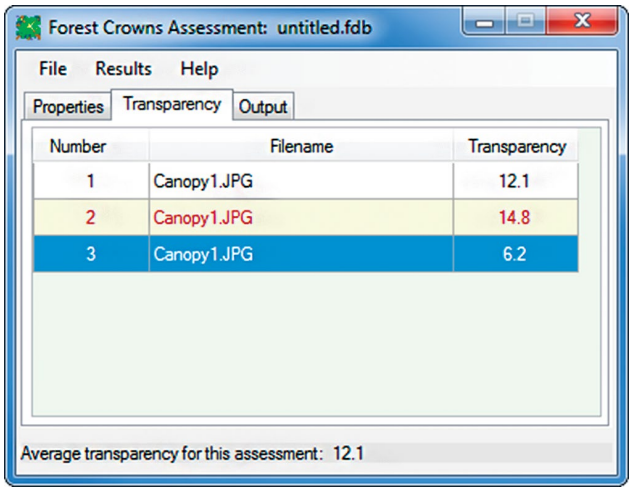


Figure 7—Transparency tab of the ForestCrowns "Assessment" window showing individual transparency values for selection regions and average transparency.

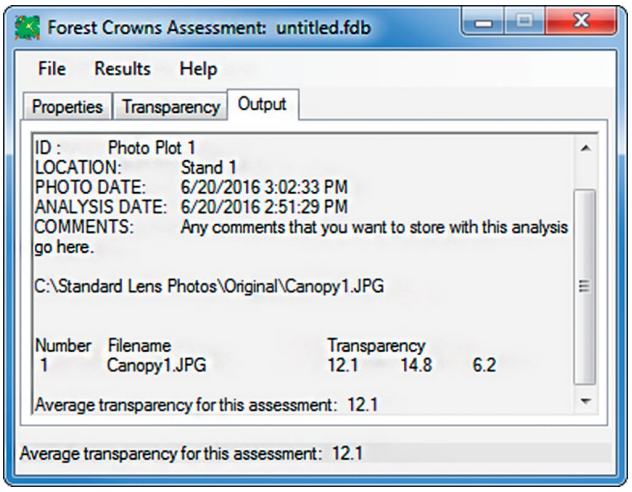


Figure 8—Output tab of the ForestCrowns "Assessment" window showing analysis input and output.

DATABASE

ForestCrowns can store all of the input and output from an assessment in a database. The first step when performing any type of assessment is to create a new database file. Under "File" in the main menu, select "New". You can then open one or more canopy images and perform the transparency assessment. When finished, select "Save as" under "File" in the main menu, name the database, and click the "Save" button. **Important: Always save the database file in the same folder as the images that were analyzed**. To retrieve a previous assessment, select "Open" under "File" in the main menu. Navigate to where the assessment was stored, select the database file (with extension ".fdb"), and click the "Open" button.

CANOPY ANALYSIS

Standard Photograph

One of the features that makes ForestCrowns unique is its ability to analyze photos taken with a standard camera lens. To analyze a standard canopy photo, first create a new database file. Next, open the image file by clicking on the folder icon in the View window and selecting the desired photo. Once the image has been imported into the program, choose one of the selection methods from the pull down menu (rectangle, ellipse, or entire image) (fig. 9). Typically, the "entire image" option will be used for canopy analysis when using standard imagery, though

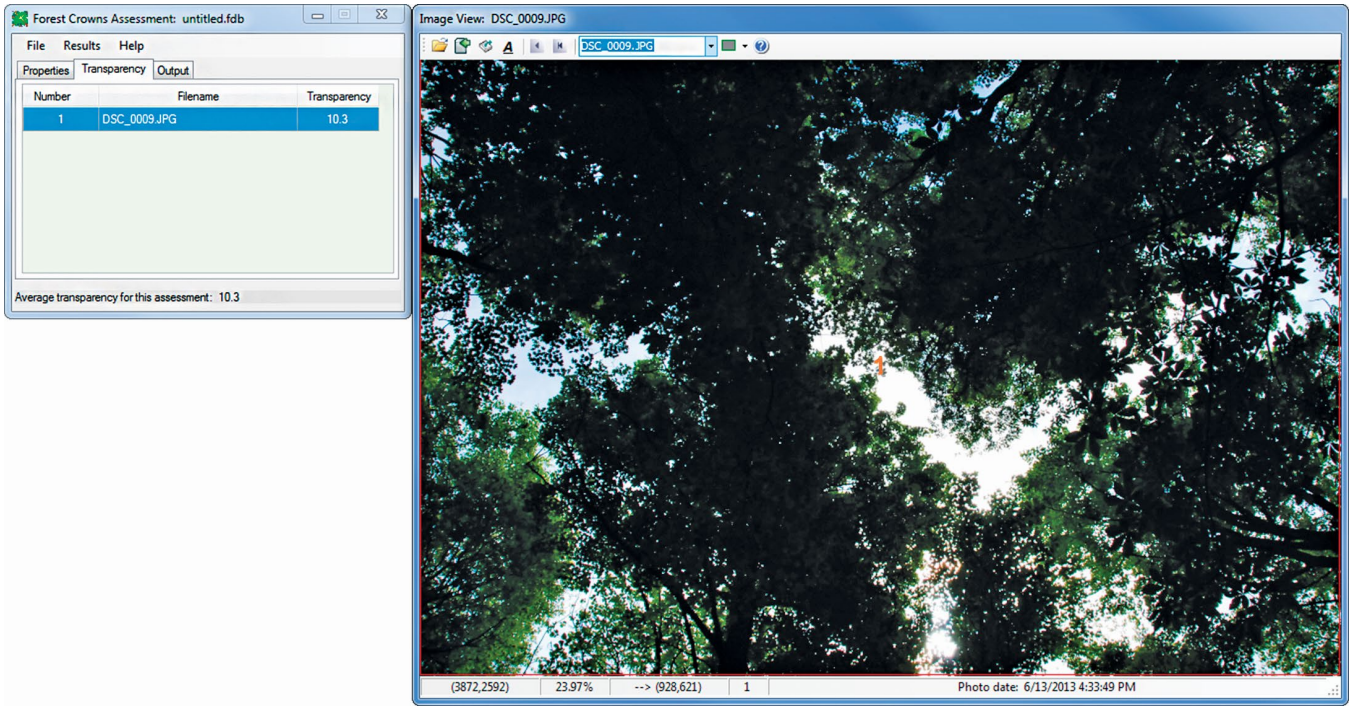


Figure 9—Example of ForestCrowns assessment for analyzing entire rectangular photo.

there may be times that you want to isolate a portion of the canopy. If this is the case, you can use the rectangle or ellipse tool to select the area of interest. Once the assessment region has been defined, the transparency value for that region will show up under the **Transparency** tab in the Assessment window. For this example, the calculated canopy transparency is 10.3 percent.

Hemispherical Photograph

Though not as cost effective as using a standard camera lens, the use of a hemispherical lens (also known as a fisheye lens) to document the forest canopy has become more common. A hemispherical lens is an extreme wide-angle lens that has a viewing angle of 180 degrees in all directions, thus capturing more of the canopy within a single photograph. To analyze a hemispherical photo, first create a new database file, then open the desired image file (fig. 10). Click on the selection tool drop-down menu and select the elliptical tool. **Note: Never use the entire image selection tool on hemispherical photos as it will include the outer black area in the analysis as well**. Highlight the circular photo area in the image using the elliptical selection tool. The transparency value for the region will show up under the **Transparency** tab in the Assessment window. The transparency value for this example is 11.0 percent.

Multiple Photographs

In some situations, it may be desirable to perform an analysis on a canopy area that can't be captured in one photograph. If this is the case, ForestCrowns can analyze multiple photos together and provide an average transparency value over all photos. Image types can be standard, hemispherical, or a combination of the two. If the entirety of each photo is selected for analysis, equal weight is given to each photo when calculating the average transparency (regardless of image size or resolution). However, if a portion of one or more photo is used, then the transparency value for the larger selection area is given more weight when determining average transparency. The weight is based on the selection area size relative to the size of the entire photograph.

The process for analyzing multiple photos is similar to the method used to measure single photos. First, create a new database then click on the "Open Images" icon in

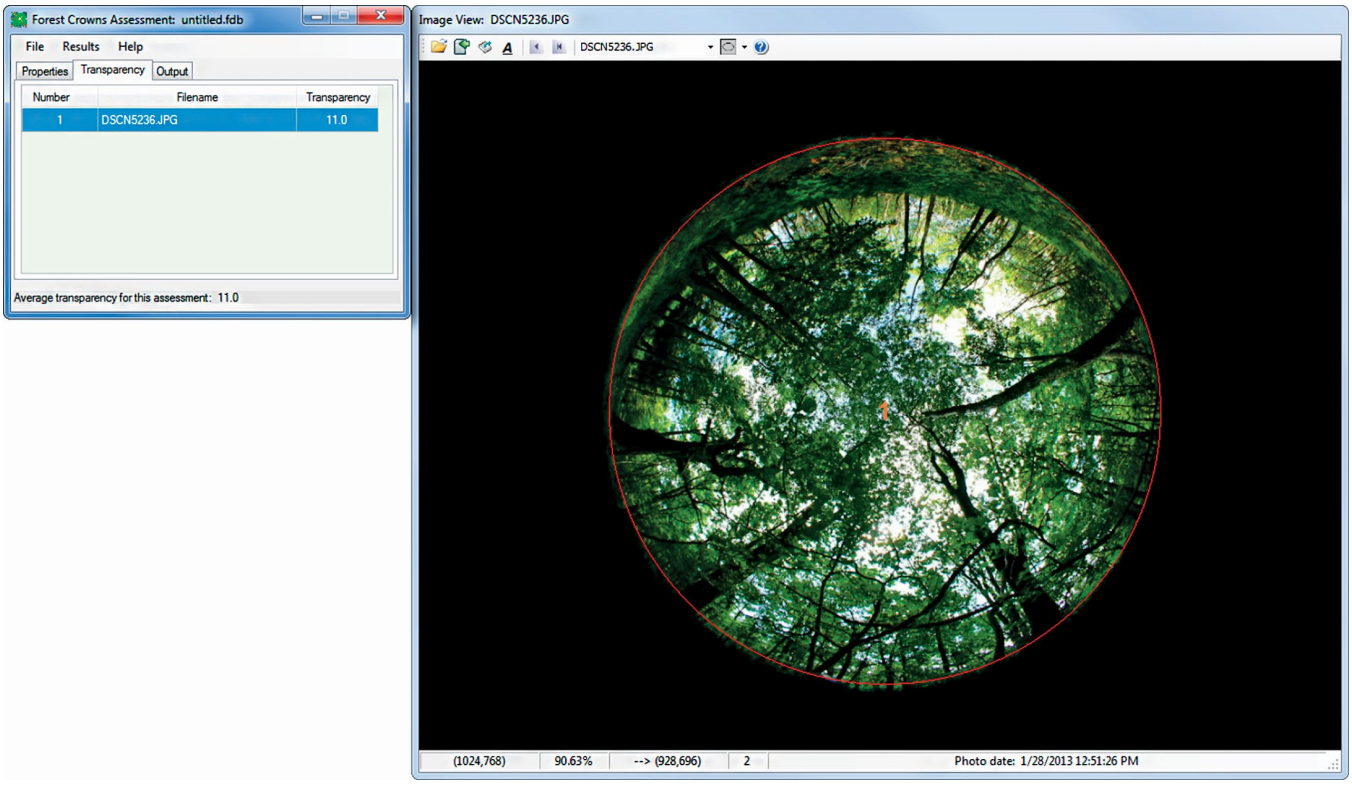


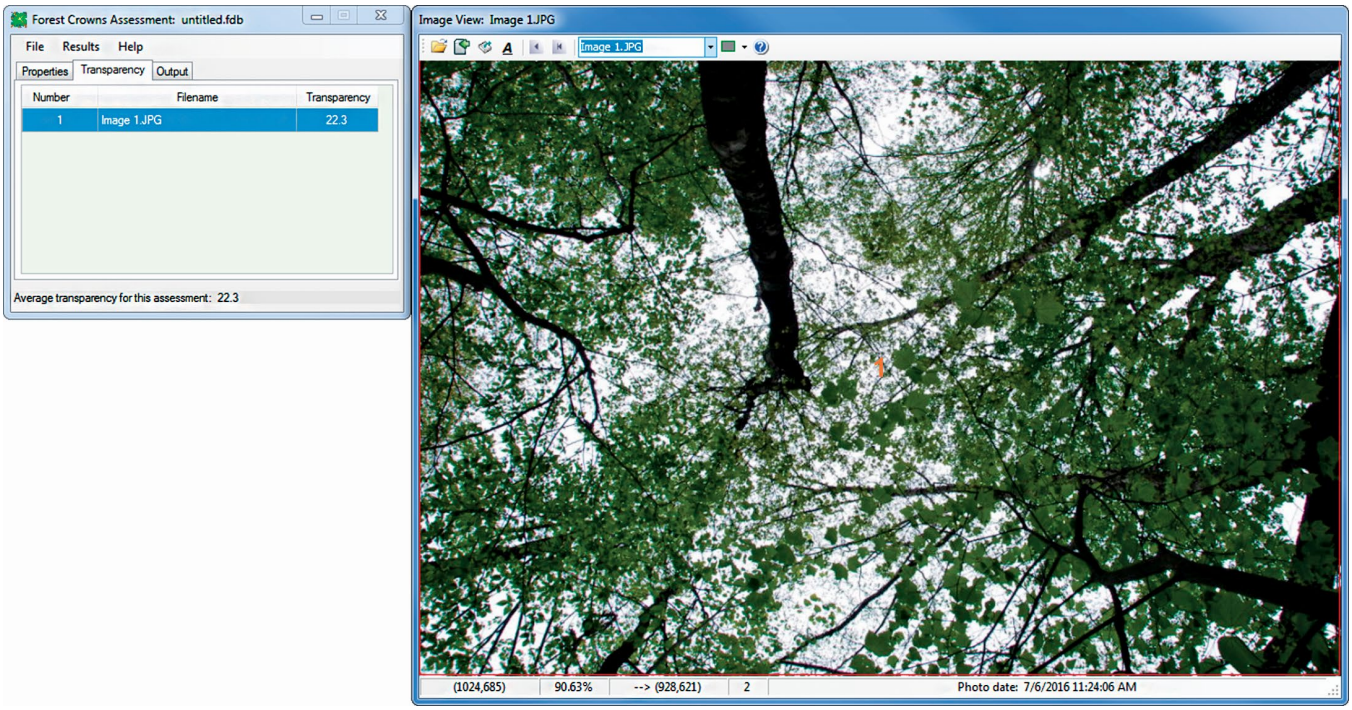
Figure 10—Example of ForestCrowns assessment for analyzing hemispherical photo.

the upper left of the View window. Select the images you wish to analyze, then click on the "Open" button. You can select multiple images by holding down the "control" or "shift" key on the keyboard while selecting files. The "control" key is used to select non-sequential files while the "shift" key allows sequential file selection. You can also add or remove photos later using the "Add Images" and "Remove Image" buttons located in the upper left of the View window. Once the images are imported into the program, choose the desired selection tool and select the area to be analyzed within each photo. You can toggle between photos using the pull-down filename list in the View window. Figure 11 (A and B) shows an example of analyzing multiple images. The entire area of Image 1 was selected for analysis (fig. 11A) while only half of Image 2 was selected for analysis (fig. 11B). Image 1 had a transparency value of 22.3 percent while the selected area of Image 2 had a transparency value of 8.9 percent. The weighted average transparency for the photos combined is 17.8 percent, with more weight given to the larger selection area in Image 1.

Batch Processing

The batch processing function within ForestCrowns provides a quick method of determining transparency values for multiple photos. Batch processing can only be used to analyze rectangular photographs in their entirety. Hemispherical photographs cannot be batch processed, nor can isolated areas of rectangular photographs. To batch process canopy photos, first move all images to a separate folder and ensure that there are no other files in the folder. Open ForestCrowns, create a new database, and then open one of the images in the batch processing folder. This is required in order to activate the batch processing function. Next, click on the "Batch Processing" icon in the View window. The icon appears as an underlined capital letter "A". A window will appear prompting you to select the folder that contains the images to process. Select the folder and click on the "OK" button to initiate batch processing of the images. Once complete, a text file is generated that contains the transparency values for each image. The text file will be in the same folder as the canopy images and will have the file extension ".txt".

(A)



(B)

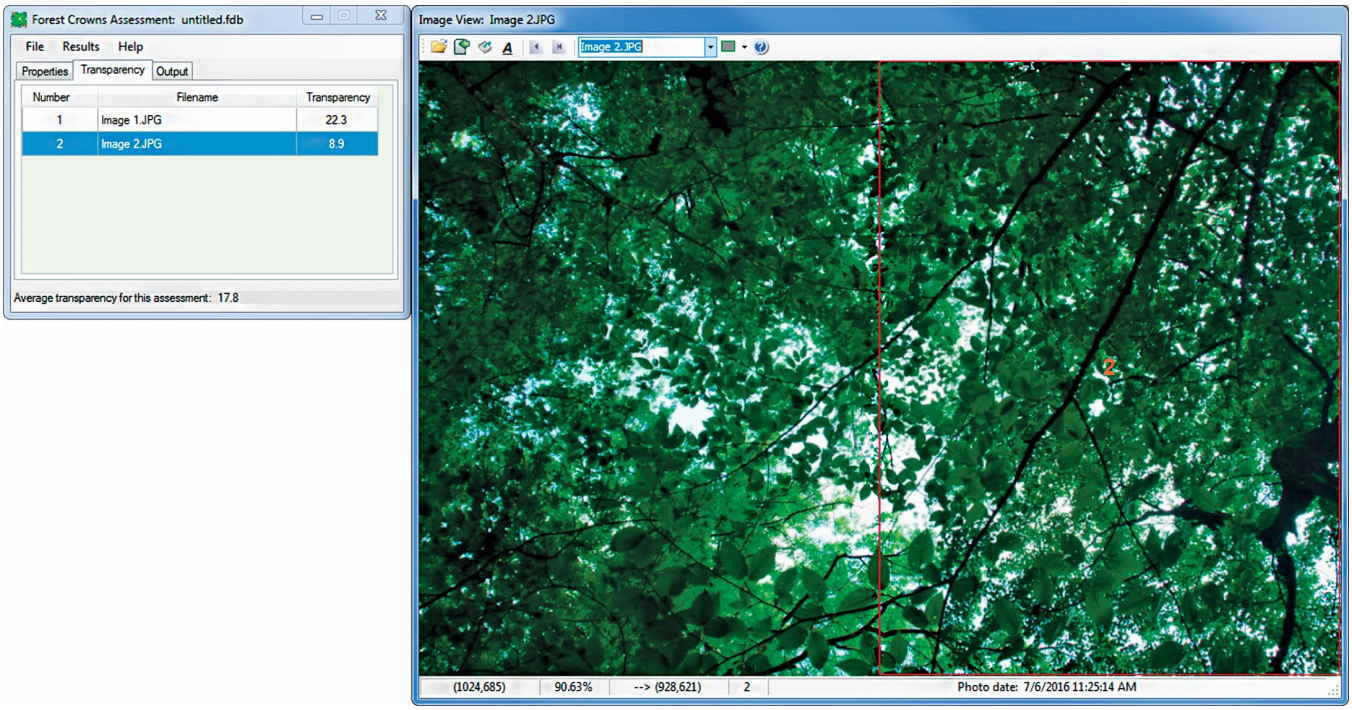


Figure 11—Example of ForestCrowns assessment for analyzing multiple photos collectively. The entire area of the first image (A) was selected for analysis while only half of the second image (B) was selected.

INDIVIDUAL CROWN ANALYSIS

For instances where an individual tree crown can be isolated from the rest of the canopy, ForestCrowns can be used to assess the transparency of the crown. Figure 12 shows an example of an isolated tree crown in a canopy photograph. Multiple selection regions are drawn to cover as much of the crown as possible. In this example, only rectangular selections are made, but elliptical selections can be used as well. Transparency is calculated for each individual region, and the weighted average crown transparency is determined. The individual transparency values range from 8.1 to 36.7 percent with an average crown transparency value of 15.6 percent.

CONCLUSION

One alternative to using aerial photography or satellite imagery to analyze forest canopy cover is to assess the canopies from below using digital photographs. ForestCrowns is a simple and cost-effective software tool that can be used to determine canopy transparency values from ground-based digital photographs. The program can be used to assess photos taken with a standard or fisheye camera lens and is also capable of processing multiple images collectively. If an individual tree crown can be isolated from the rest of the canopy, crown transparency can be determined as well. Some potential uses for ForestCrowns are: monitoring growth/decline of a forest canopy; providing input for leaf area index estimation; measuring light transmission to the forest floor; analyzing canopy gaps; detecting disease, insect, or storm damage; and monitoring health treatments.

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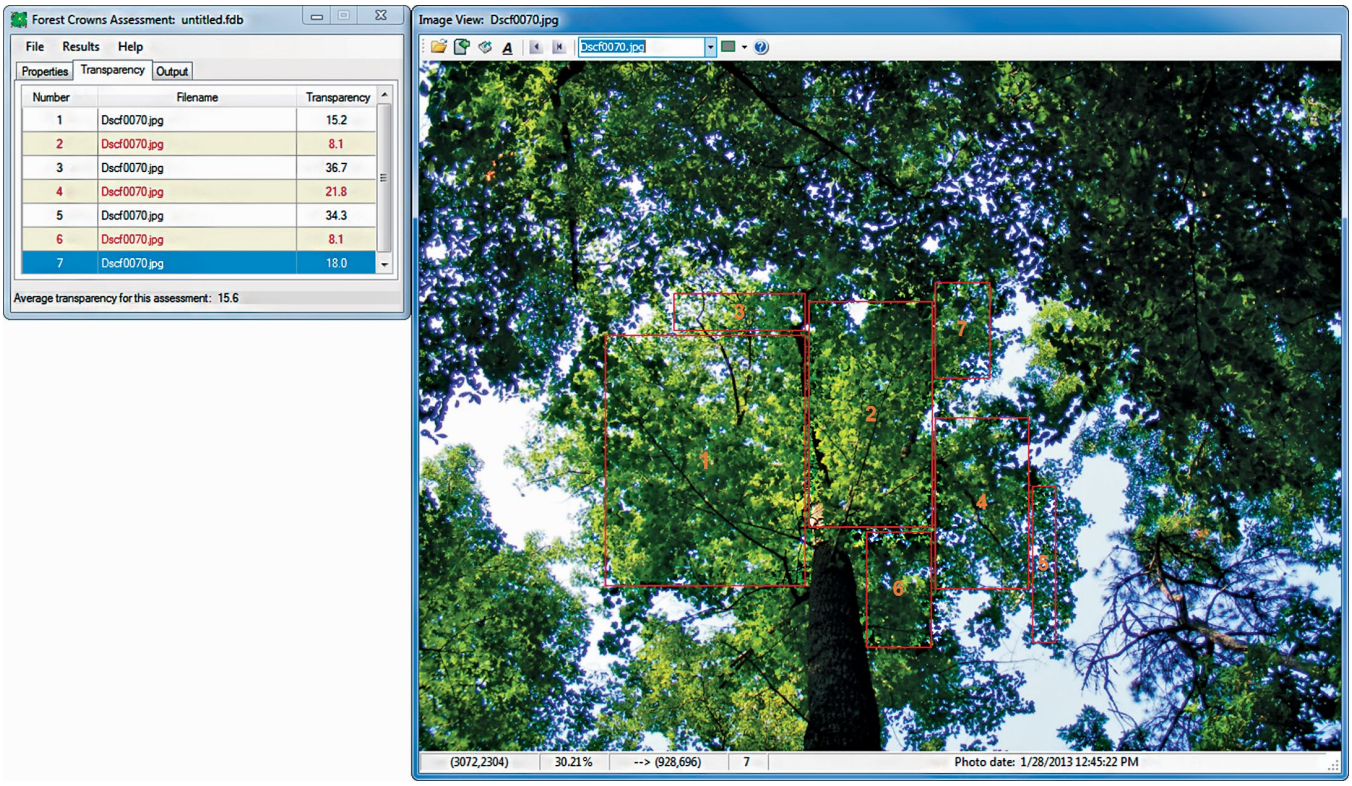

Figure 12—Example of ForestCrowns assessment for individual tree crown.

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Keywords: Crowns, forest canopy, light transmittance, monitoring, transparency.

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