FORESTCROWNS: A SOFTWARE TOOL FOR ANALYZING GROUND-BASED DIGITAL PHOTOGRAPHS OF FOREST CANOPIES

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Abstract.—Canopy coverage is a key variable used to characterize forest structure. In addition, the light transmitted through the canopy is an important ecological indicator of plant and animal habitat and understory climate conditions. A common ground-based method used to document canopy coverage is to take digital photographs from below the canopy. To assist with analyzing below-canopy photographs, the U.S. Forest Service Southern Research Station has developed a computer software tool called ForestCrowns. ForestCrowns calculates canopy transparency (or light transmittance) for digital images taken with standard or fisheye (hemispherical) camera lenses. Specific areas of the photograph can also be targeted to obtain transparency estimates of individual tree crowns. Since images and assessment results can be saved within the program, ForestCrowns can also be used with forest health monitoring programs to detect changes over time in canopy structure due to storm, insect, or disease damage.

INTRODUCTION

There are several ground-based methods currently used for measuring the density of forest canopies. The most basic method involves assessing the canopy visually. Simple visual assessments are quick and require no specialized equipment. A downside of using this method, however, is that the assessments are very subjective and often unreliable (Ghosh et al. 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 density 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.

A third widely used ground-based option for measuring canopy density 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 et al. 2007). Though the use of a standard lens is not suitable for all canopy measurements, it can be used for more localized analyses.

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There are several software programs available for analyzing canopy photographs. Some examples are: Hemiview (Delta-T Device Ltd., Cambridge, UK), Hemiphot (Tropenbos International, the Netherlands), Gap Light Analyzer (Cary Institute of Ecosystems Studies, Millbrook, NY), DHP-TRACWin (Natural Resources Canada, Saint-Hubert, Quebec), CAN-EYE (INRA, Paris, France), and WinSCANOPY (Regent Instruments Inc., Quebec, Canada). The programs vary in price, ease of use, output, and their ability to analyze standard camera images. The purpose of this study was to develop a free, easy to use image analysis software program, capable of measuring canopy transparency from fisheye or standard digital camera imagery.

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.

PHOTOGRAPHING THE CANOPY

The foundation for the ForestCrowns analysis is the digital image of the canopy. Prior to obtaining the photograph, the best location to position the camera should be determined based on understory vegetation, lighting conditions, and adjacent trees. Photographing below dense understory vegetation should be avoided, as the leaves and branches can block the view of the 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 while overcast skies make it difficult for the software to distinguish between vegetation and sky. Ideally, photographs should be taken when skies are clear and sun is not directly overhead. Finally, the camera placement should not be directly adjacent to tree stems. All images will contain tree stems that partially block the view of the canopy, but the affect is minimized as the distance between the camera and adjacent stems is increased.

Once the photo location has been established, the camera should be mounted on a tripod and leveled so that the camera angle is truly vertical. The use of a tripod minimizes camera movement and prevents blurry images. If periodic photographs will be taken at the same location, the precise location of the camera should be documented 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. The radial orientation of the camera should also be documented, as subsequent photos should not only be taken from the same location, but at the same orientation as well. This consistency is necessary in order for ForestCrowns analyses to be comparable. If a hemispherical lens is used, care should be taken to ensure that the photographer is below the camera and not 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.

CANOPY ANALYSIS

ForestCrowns can produce transparency estimates for canopy images taken with either standard or fisheye camera lenses. Entire images can be analyzed or portions of the images can be isolated and analyzed separately. In addition, the program can assess multiple photos collectively and provide an average transparency value over all photos. Pictures and analysis results can be stored in a database for comparing seasonal or multiple year evaluations.

Standard Camera Lens

Figure 1 shows an example of a ForestCrowns analysis using a photo taken with a standard camera lens. In this example, the entire image is selected for analysis, but individual regions could also be selected if desired. The transparency value for this example is 21.2 percent, meaning that 21.2 percent of the pixels in the photograph are classified as sky, whereas 78.8 percent of the pixels are classified as leaves, branches, or stems. The program computes transparency by analyzing the relative color of each pixel within the photograph and then classifying each as either sky or biomass. If multiple regions of the image were selected, transparency values for each region would be given as well as an average transparency value over all regions. This type of analysis could be used for plot-level information including: monitoring yearly growth/decline of the forest canopy, leaf area index (LAI) estimation, and estimating light transmission to the forest floor.

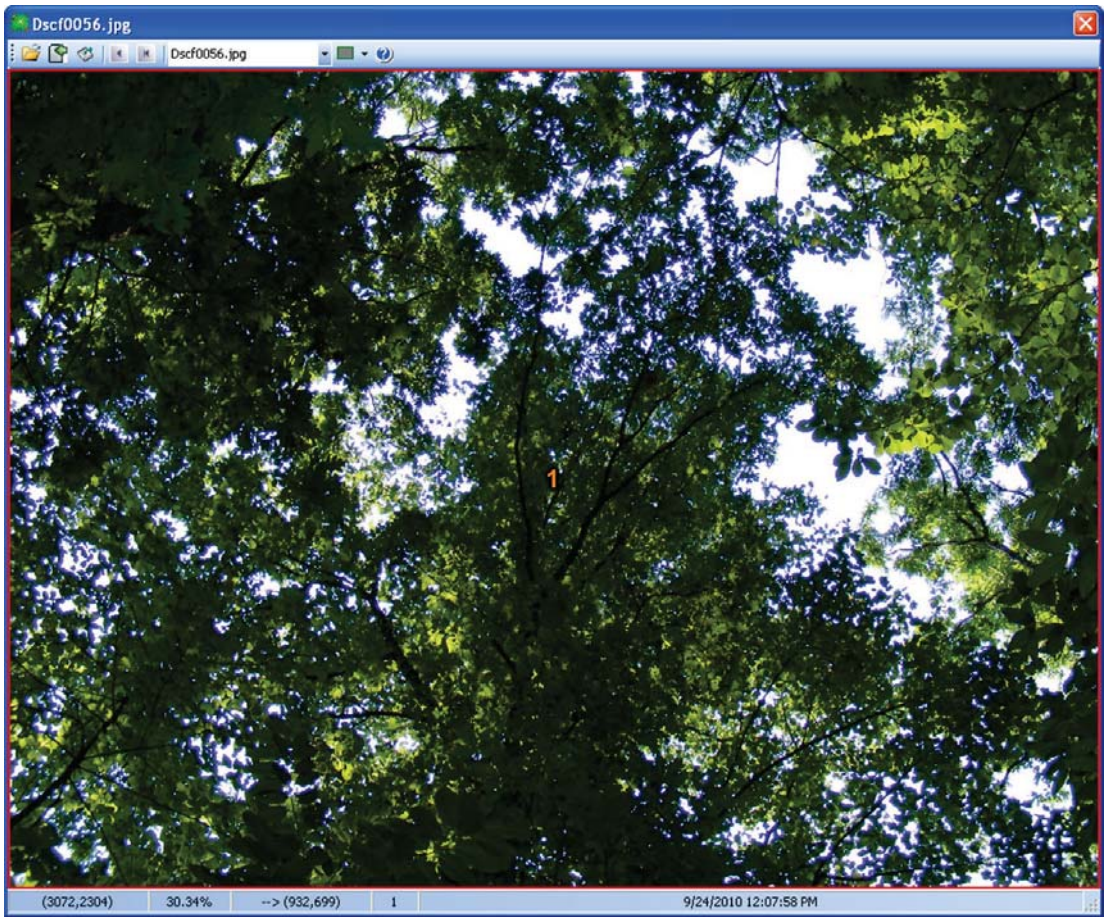

Figure 1.—Example of a ForestCrowns canopy transparency analysis using a photo taken with a standard camera lens. Calculated transparency is 21.2 percent.

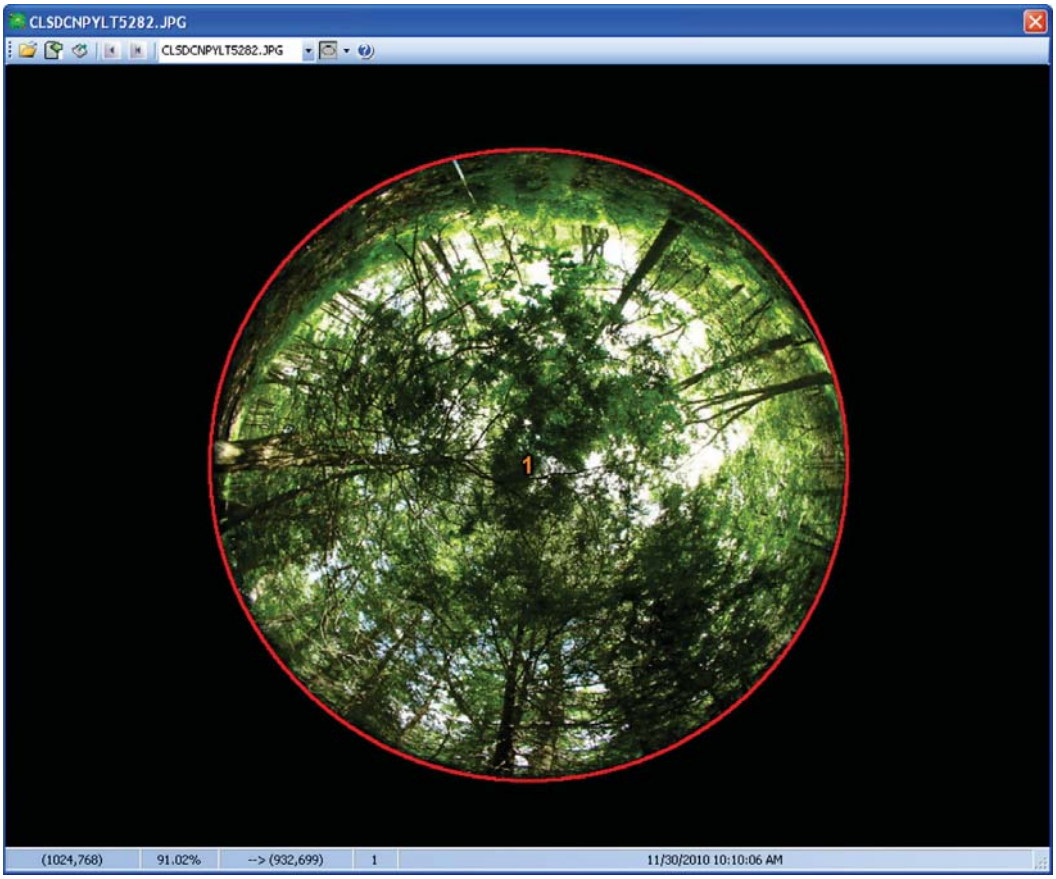

Figure 2.—Example of a ForestCrowns canopy transparency analysis using a photo taken with a fisheye (hemispherical) camera lens. Calculated transparency is 13.8 percent.

For photographs taken with a standard camera lens, ForestCrowns offers a batch processing option for quickly analyzing multiple photos. If this option is used, each individual image will be assessed in its entirety (specific regions within the photo cannot be targeted) and the results will be written to a text file. The batch processing option is not available for fisheye images since the circular image is nested inside a rectangular frame and cannot be analyzed without first selecting the circular region.

Fisheye Camera Lens

Photographs taken with a fisheye (hemispherical) camera lens are commonly used for ground based canopy analysis because they allow for a larger coverage area than photographs taken with a standard lens. A fisheye lens captures everything above the horizontal plane of the camera. One difference between a photograph taken with a fisheye lens and a photograph taken with a standard lens is that the resulting image is circular. Therefore, before a fisheye image can be analyzed in ForestCrowns, the circular area must be delineated using the elliptical selection tool. Figure 2 shows an example of a ForestCrowns analysis of a fisheye image. The red outline in the image represents the outer edge of the analysis region. For this example, the transparency value is 13.8 percent.

Fisheye image analyses in ForestCrowns can be used for monitoring gaps in the canopy and for estimating light transmission to the forest floor. Gap analysis can show evidence of forest disturbances (blow-downs, insect infestations, disease) while light transmission estimates are important for predicting such things as plant regeneration potential, soil moisture retention, and subcanopy climatic conditions.

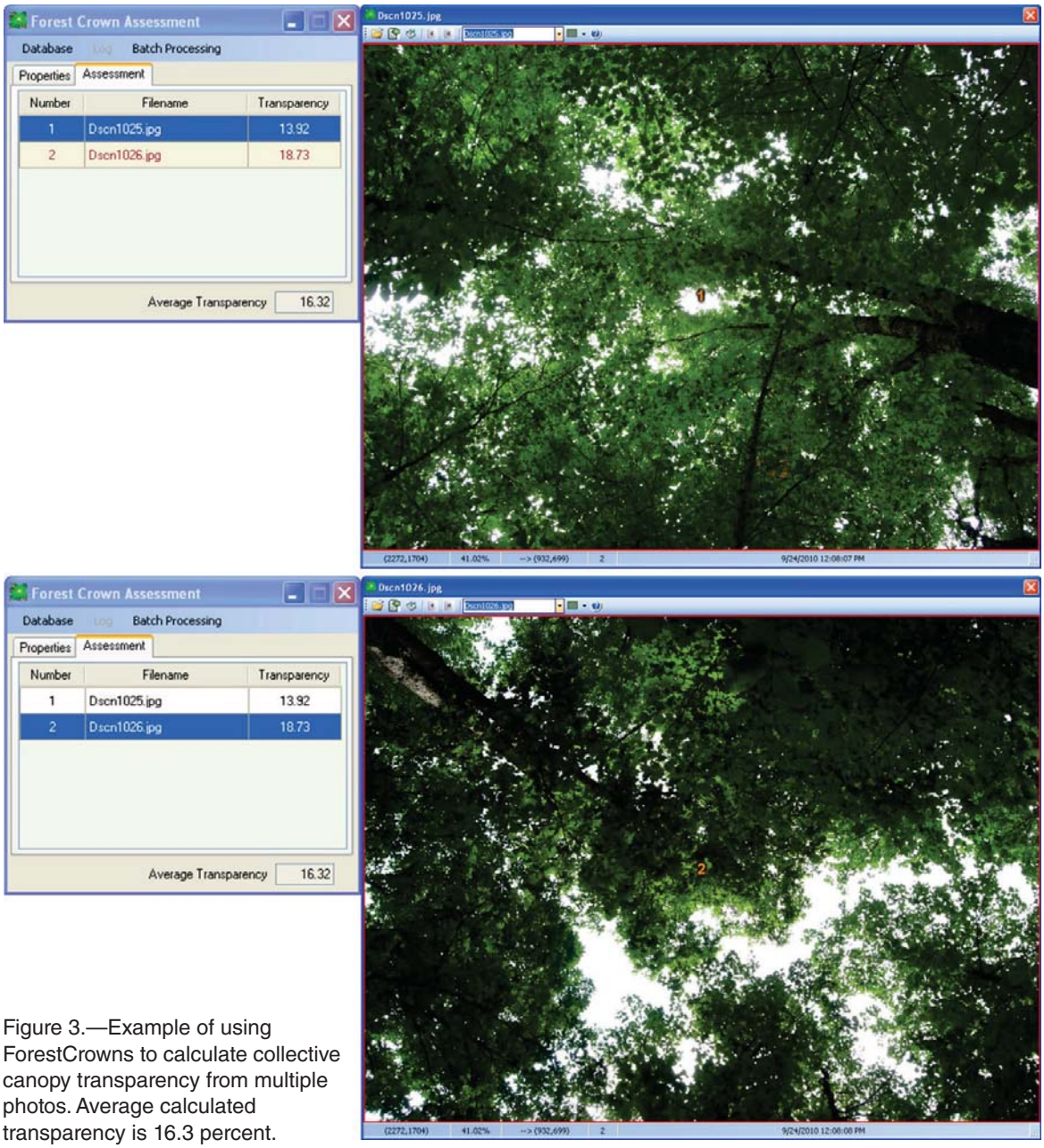

Figure 3.—Example of using ForestCrowns to calculate collective canopy transparency from multiple photos. Average calculated transparency is 16.3 percent.

Multiple Photos

In addition to being able to analyze individual photos, ForestCrowns can also analyze multiple photos collectively. The images are assessed as a group, which differs from the batch processing option where each photo is assessed individually. When multiple photos are imported into the program and the analysis regions are selected, ForestCrowns generates transparency values for each photo as well as the average transparency for all photos. This feature works with both standard and fisheye imagery. Figure 3 shows an example of analyzing two photos collectively. The first photo has a transparency value of 13.9 percent while the second has a transparency value of 18.7 percent. In the lower right corner of the results window, the average transparency value for the two photos is shown as 16.3 percent. Multi-photo assessments can be used for forest-level canopy analyses such as monitoring yearly canopy growth/decline, LAI estimates, and estimates of light transmission to the forest floor.

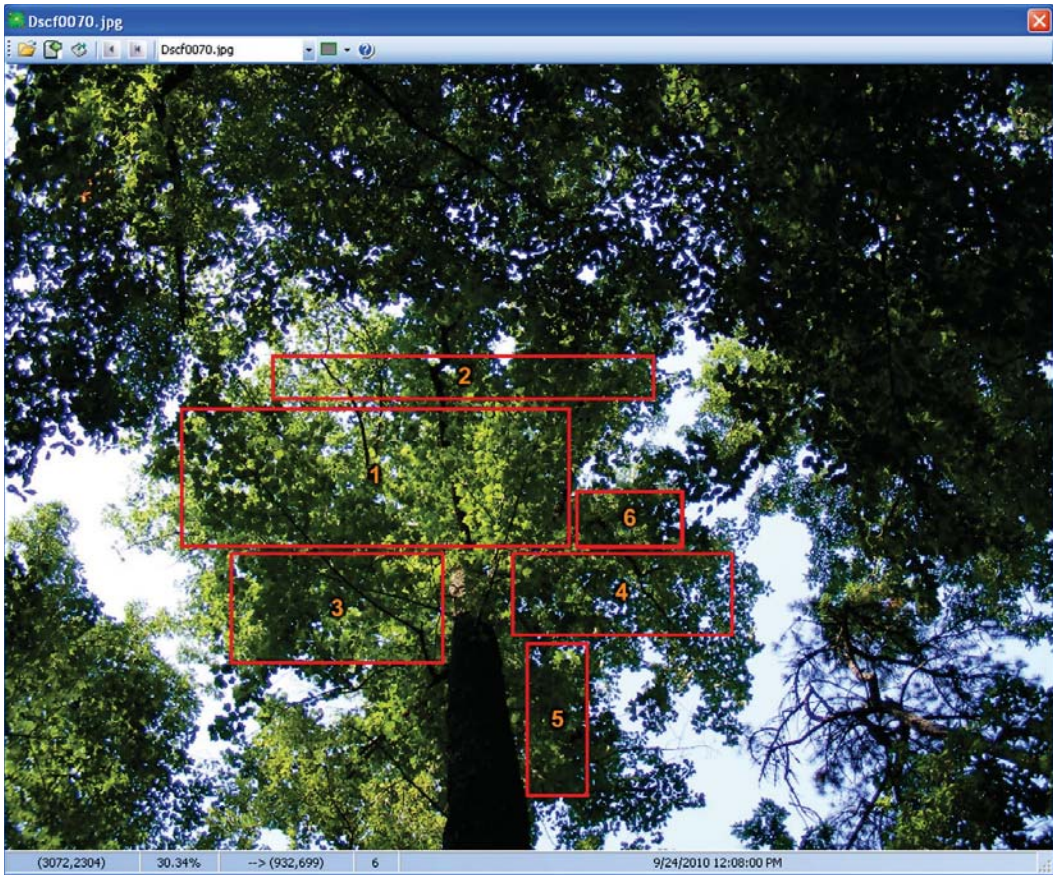

Figure 4.—Example of using ForestCrowns to calculate transparency of an isolated tree crown using multiple selection regions.

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 4 shows an example of an isolated tree crown. Multiple selection regions are drawn to cover as much of the crown as possible. Transparency is calculated for each individual region and the weighted average crown transparency is determined (Fig. 5). The individual transparency values range from 5.8 percent to 21.3 percent. The average transparency value for the crown is 13.7 percent. Some of the potential uses for individual crown analysis include: monitoring yearly growth/decline of individual tree crowns; early detection of disease, insect or storm damage; and monitoring health treatments.

SUMMARY

One alternative to using aerial photography or satellite imagery to analyze forest canopies is to assess the canopies from below using digital photographs. ForestCrowns is a simple and cost-effective software tool developed by the Forest Service Southern Research Station 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. ForestCrowns can be used to: monitor growth/decline of forest canopy; estimate LAI; measure light transmission to the forest floor; analyze canopy gaps; detect disease, insect, or storm damage; and monitor health treatments. The expected release date for the software and user's guide is 2012.

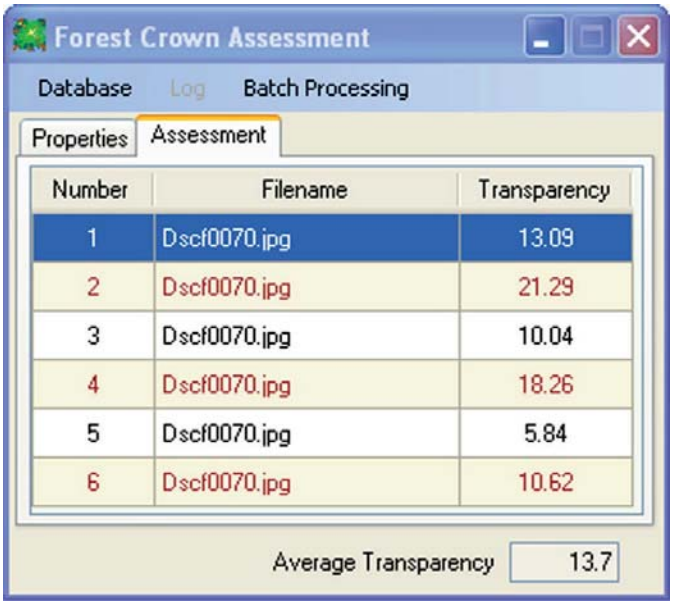

Figure 5.—Results of the ForestCrowns analysis shown in Figure 4. Average calculated crown transparency is 13.7 percent.

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