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Comparing Photographic and GIS-based Applications for Estimating Canopy Cover in Southern Appalachian Bogs

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Abstract

Mountain bogs are among the rarest natural communities in the Southern Appalachians. For the past several years, UNC Asheville faculty and students have been collecting data on a wide variety of parameters such as water levels, water quality, soils, vegetation surveys, and GPS locations of key features in these bogs. A better understanding of these parameters will ultimately lead to better management decisions in the future. Bog management involves linking and being able to analyze biotic and abiotic processes and components of the bog ecosystem. One of these key processes is evapotranspiration, the process by which plants draw water from the ground and transpire it into the atmosphere. Trees and underbrush are often manually removed from bogs to reduce evapotranspiration, open the canopy, and restore more natural conditions. Quantifying canopy cover in mountain bogs will help determine the amount of vegetation to remove. However, methods for determining canopy cover are often either cheap but labor intensive or faster but expensive. As a result, there are few methods that are both readily-accessible and reliable. The purpose of this study is twofold. The first goal is to investigate free and inexpensive cell phone applications or 'apps' that can be used to process canopy cover images and determine which, if any, produce reliable data. The second goal is to evaluate ESRI ArcGIS classified imagery to determine canopy cover and then test both the 'apps' and GIS-based process against traditional densiometer readings which have been used for decades.

Keywords: Bog management, GIS, Classified Imagery

1. Introduction

Bog management involves linking and being able to analyze biotic and abiotic processes and components of the bog ecosystem. One of these key processes is evapotranspiration, the process by which plants draw water from the ground and transpire it into the atmosphere. Trees and underbrush are often manually removed from bogs to reduce evapotranspiration, open the canopy, and restore more natural conditions. Quantifying canopy cover in mountain bogs can help determine the amount of vegetation to remove. However, methods for determining canopy cover are often either cheap but labor intensive or faster but expensive. A densiometer is relatively inexpensive (approximately $100) and has been used for decades; however, a reading can be tedious and time intensive. Hemiview is one of several newer systems which includes an integrated camera and computer system and cost from $7000[5]-$10,000[3]. A device or technique that could bridge the gap of speeding up processing time without driving up the cost for studying canopy cover would be very helpful to conservationists and bog managers.

With advancements in cellular technology and the availability of smartphones among the general population, a plethora of applications exist to provide information and services ranging from romantic advice, games, and sometimes, useful tools. These tools include several free Google Play applications ('apps') that offer canopy cover analysis to the public. With the ease and availability of Android products on the market, these apps could be very useful if they can provide meaningful, reliable information regarding canopy cover. This study evaluated four of these free applications: Habit App, Canopy App, GLAMA App, and Canopeo. These apps are inexpensive, relatively simple to use, and – if information provided by the apps is capable of producing meaningful information—are a means to include more volunteers in data collection and analysis.

Another tool widely used in research and conservation efforts is ESRI ArcGIS (GIS). It is a common practice in GIS to use classified imagery, remote sensing, and normalized digital vegetation indexes to identify key surface features such as impermeable surfaces, buildings, forests, streams, and other miscellaneous surfaces. Normalized digital vegetation indexing (NDVI) is an established method to study large macrostructures in GIS for vegetation cover[1]. However, NDVI's prove to be a challenge for smaller sites, as typical satellite resolution is 15m x15m or 30m x 30m. The NDVI will give an average reading per block of its resolution, but cannot define smaller, finer details like those found in bogs and fens. NDVI results are then skewed towards dominant features of the squared 'pixel' and provide generalized information at best. This is not always helpful to bog managers, conservationists, and scientists attempting to study and preserve the bogs and fens.

Supervised classified imagery can focus in and identify specific features using a pixel by pixel analysis of an image. Additionally, GIS does not necessarily need to have a defined 'surface' to track changes in an image. Any photograph can be subjected to a supervised image classification for analysis and processing. A sufficiently high resolution photograph aimed upwards at the canopy therefore should be able to provide depth and detail regarding the physical condition and cover of the canopy in question. A hemispherical photograph, however, takes the entire horizon when photographed (Figure 1). The fisheye lens has an opening of about 180º and takes it one continuous photograph of the horizon at the point the photo is taken. This allows for a more complete analysis of the canopy cover, rather than a portion of the horizon, that would be included in a regular photograph. This is to be tested in comparison the densiometer, which due to its long history and use in canopy cover measurements, is to be the baseline reading that all apps and GIS readings will be compared to. Although the densiometer is a well-established method, it is time consuming and does not offer long-term storage or reading afterward. It is also difficult to read the points off a densiometer in windy, brightly lit conditions outdoors, and can rely too much on the operator's discretion in estimating canopy cover.

The purpose of this study was twofold. The first goal was to investigate free and inexpensive cell phone applications or 'apps' that can be used to process canopy cover images and determine which, if any, data comparing well to the densiometer data as the baseline reading. The second goal was to evaluate GIS-classified imagery to determine canopy cover and then test both the 'apps' and GIS-based process against traditional densiometer readings which have been used for decades.

Figure 1. A- regular photo, and B-hemispherical photograph, of different photo's depicting the horizon and demonstrating the differences between how the horizon is depicted between the two lenses

2. Materials and Methods

2.1. Site selection

Thirty-four sample plots were selected in forested bogs and areas around Western North Carolina. At each plot, each corner of a 1m square was marked with a flag. Moving sequentially from flag to flag, canopy cover was estimated using each app, photo, and densiometer method described below. The photographs used in this study were captured from a Sony Alpha a390 14.2 MP compact DSLR camera with a 3.5-5.6/18-55 SAM lens and Opteka Super Wide Fisheye Lens 0.20 lens attachment. A Samsung Galaxy s6 was used to collect and analyze data using smartphone applications (apps), which were downloaded for free from the Google Play service.

2.2. Densiometer

In this study, the densiometer served as the baseline method against which all other readings were compared to. At each flag, readings were taken facing each of the four cardinal directions. Each reading then consisted of 16 overall readings combined into one reading for canopy closure. The readings were then averaged together to define canopy cover at that point.

2.3. Habit App

Habit App uses photos taken prior to opening the app or while running the app. Once the photograph is selected, canopy cover is estimated by moving a selection bar to scroll various degrees of sensitivity. The sensitivity can be checked side by side with the original photo until the user is satisfied. Canopy cover must be recorded manually, as there is no long term storage or digital trace left of the estimation process.

2.4. Canopeo

Developed by the University of Oklahoma, Canopeo records GPS coordinates of each photograph taken, offers long term storage, and can take and accept photographs from outside the app. While simple in its design and powerful in its function and features it offers, it was not originally designed for use in canopy cover from below; rather, the original scope for Canopeo was for photographs directed towards the ground and for use with crops.

2.5. Canopy App

Canopy App offers GIS-like features and functionality for mobile computing on a smartphone device. It offers long term storage of the photos, GPS coordinates of where the images were taken, and can export images and resulting canopy coverage estimates to an Excel spreadsheet automatically. However, this also means an increase in operating difficulty. Even when starting with high-resolution photos, the app reduces the images to a lower resolution, and all input must be manually entered during the masking process that arrives at the canopy cover percent coverage.

2.6. GLAMA App

This app is the most current version of Gap Analyzer Software (GLA) that was a free program available for many years. GLAMA allows photographs to be taken, analyzed, and processed on the device it is installed on. A normal photograph of the canopy will need to be taken, as there is no function in the software to allow for a hemispherical photo to be taken from the camera or imported into the app. The appropriate levels of darkness, light, and pixel counts are manually selected by the individual operating the app. Once selected, the app will process the photo in accordance to what is set as light and dark areas that will define a canopy closure or canopy openness at the end of the process.

2.7. GIS & hemispherical classified photos processing

For GIS classified photo processing, whether it be a hemispherical photo or a regular photo, the process is the same. Each photo was loaded into GIS as a map layer. Processing was performed using a signature (sig) file with previously identified elements. Figure 2 shows samples being selected to represent sky and open canopy values in a sig file. A basic sig file requires simple elements such as sky, vegetation, and for hemispherical photos, background/delete values to evaluate the photo against in the image classification process.

Once a basic general purpose sig file has been developed the stored settings will automatically evaluate and classify the photo every time an image is processed. This considerably speeds up the process, but did not allow for batch processing of photos; each photo was classified and evaluated individually.

After an image was classified, the pixel count information of the newly classified photo is stored in the 'attributes table' of the new classified photograph as a map layer in GIS. For each photo, a simple percentage of open and closed canopy were calculated with the values stored under the 'attributes table'. The new layer was saved and could be referenced at a later date, and added to new or existing maps in GIS. The information generated in the attributes table was used to calculate percentages of open and closed canopy.

Figure 2: Selecting sample pixels of sky or open canopy for making a signature file in GIS Training sample manager window for a hemispherical photograph

3. Results and Discussion

At the end of sampling and processing, 34 sky plots were taken and analyzed across Western North Carolina representing varying states of canopy closure. Canopy cover estimates using the App- and GIS-based test methods were compared to densiometer measurements (Figure 3). plotted below in Figure 3. If the methods were in perfect agreement, the data points would fall directly on the 1:1 line for all applications tested. The variance from that line for each data point (R) was defined as the difference between the test method canopy cover (App or GIS) and the densiometer-estimated canopy cover. To quantify deviance from the 1:1 line, the absolute values of the variances (R) for each data point were summed (Σ |R|); if all points fell directly on the line, then Σ |R| = 0. To determine whether the test methods overestimated or underestimated canopy cover, the variances (R) for each data point were summed (Σ R); if data points were evenly distributed above and below the 1:1 line, then the positive and negative R values would cancel and Σ R = 0.

3.1 App-based methods

Out of the four applications tested, GLAMA had the lowest Σ|R| value and the lowest Σ R values, meaning that canopy cover estimates were most closely aligned with the densiometer estimates. However, the negative ΣR value indicates a consistent underestimate of canopy cover (as demonstrated by values skewed below the 1:1 line in Figure 3D). Habit App, Canopy App, and Canopeo had increasingly higher Σ|R| and Σ R values, respectively, and all apps consistently under estimated canopy cover. Canopeo in particular, produced unreliable data (Table 1).

While GLAMA performed reasonably well as compared to densiometer readings. It had some challenges to its daily operation. Specifically, the app frequently crashed or froze. Almost predictably every third reading, the app either crashed or gave a reading that was obviously erroneous. As an example, GLAMA would sometimes give a reading of 100% canopy cover on a clearly open horizon. This required restarting the program and taking the picture again. With this drawback in mind, GLAMA is a reasonable app for calculating canopy cover.

Table 1. Σ|R| and Σ R Values for App and GIS Methods Tested in Order from Best Fit with Densiometer Values

Name of Method	Σ R	Σ|R|
GIS-Hemi	-12.40	212.76
GLAMA App	-205.00	371.88
GIS Non-Hemi	-277.90	305.89
Habit App	-358.25	513.61
Canopy App	-700.24	703.22
Canopeo	-1665.84	1665.84

3.2 GIS-based methods

GIS with hemispherical photos performed the best of all methods considered (lowest Σ|R|) and most importantly this method had the lowest Σ R, meaning that it neither overestimates nor underestimates canopy cover as compared to the densiometer readings. GIS with regular photos performed similarly to the GLAMA App, the best of the app-based methods. While there is no in field processing for the GIS method as there would be for a smartphone app, the time it takes to load and process a photo is still significantly less than to do a densiometer reading in the field once a sig file best suited to the conditions of the study site has been developed. Once established, the training file can be used multiple times, typically takes a little more time than a app running in the field to process and collect data on canopy cover. Unlike the densiometer, the data and time invested with a GIS based method persists and creates a permanent record of both the conditions being studied, and the parameters and data used to analyze the study site or plot. The photos, resulting map later, and sig file can all be digitally stored and reviewed at any time. This means statistically, and in application, the GIS method is the most reliable and adaptive option available.

The flexibility of GIS allows for studies to be conducted at different times of year under different physical conditions of the vegetation. A file for defining the conditions and the visible characteristics of the vegetation and canopy (e.g. leaf color) at different conditions would need to be developed for the study and its parameters so that GIS could operate within those expectations. It is possible to conduct studies when vegetation is sparse or displaying different pigments than the traditional greens of spring and summer. This is important when considering that bog management decisions are made year round. Being limited to only spring and summer is a huge draw back and severely limits times of year when decision making is at its most effective for bog managers if they are only collecting information half of the year.

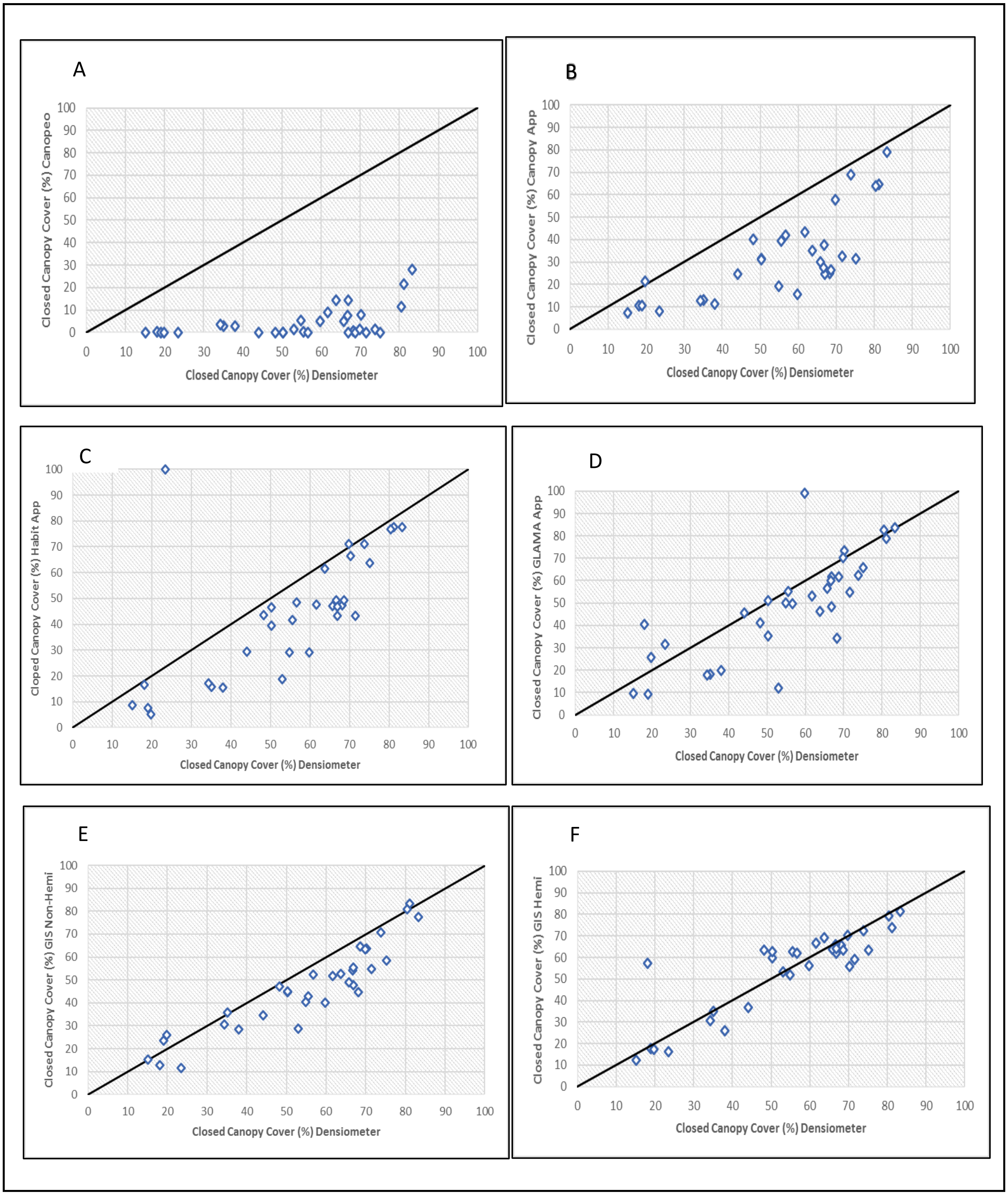

Figure 3. Scatterplots comparing (A) Canopeo App, (B) Canopy App, (C) Habit App, (D) GLAMA App, (E) GIS Non Hemispherical Photos, and (F) GIS Hemispherical Photos to Densiometer readings.

4. Conclusion

The main goal was to study methods that would provide reliable information for estimating canopy cover in Southern Appalachian bogs, fens, and wetlands. GLAMA App is a free Android app that despite some software issues and produces results that neither under or overestimate canopy cover. GLAMA data was comparable to GIS based methods for standard photographs and classified image processing. The method that most closely aligned with the densiometer values was the GIS based hemispherical photo analysis. Bog managers and conservation groups can use these relatively quick, low cost, methods for estimating canopy cover and make informed management decisions regarding the wetlands.

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