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# CHARACTERIZING CANOPY DYNAMICS USING HEMISPHERICAL PHOTOGRAPHY

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*Abstract.* Forest canopy which is the main interface through plants interact with the environment and the center for primary productivity is of fundamental importance in a number of critical ecosystem processes. Characterizing canopy structure is critical not only to understand a variety of canopy processes but also undercanopy processes such as light penetration and seedling establishment. Direct measurements are tedious and labor intensive and therefore typically limited to short periods at few spots. Indirect measurements using hemispherical photography has been applied to study forest canopy in a variety of environments (conifer forests, tropical and temperate hardwood forests) and ecological researches. Hemispherical photography has been applied in forest research for > 30 years, but the descriptions on published reports are to concise for new users to follow. Different researchers used different camera and image analysis systems and no generalizations have been made. Inexperienced researchers would find it difficult to apply without some discussion with experienced researchers. Here I summarize basic procedures, for taking hemispherical photographs and the subsequent image analysis. I also compared several existing image acquisition and analysis systems and provide some suggestions and tips.

## HARDWARE

### *Camera System*

Digital photography: Nikon Coolpix 900 or 950 with a FC-E* fish-eys lens converter, an at least 8 MB memory card (for 32 basic images, 16 normal images, 8 fine images or 1 high quality image), a tripod or monopod.

Film photography: Nikkor or Sigma 8 mm fish-eys lens with a FM2 or MF-16 body, databack, ASA400 (either black and white or color) films, a tripod or monopod.

### *Additional Supplies*

1. Shoulder satchel for carrying film, memory cards, data notebooks, pens or pencils, a compass, lens cleaning supplies, spare batteries, and plastic bags.
2. A compass for orienting the camera assembly relative to north.
3. Cleaning brushes, lens cleaning fluid, and lens tissue.
4. Spare batteries for the camera light meter and databack.
5. Plastic bags should for enclosing all equipment in case of rain.

### *Self-Leveling Camera Mount*

A self-leveling camera mount that causes the lens to point directly upward can facilitate positioning of the camera, particularly in situations where hemispherical canopy photographs are taken at great heights above the ground or in awkward positions.

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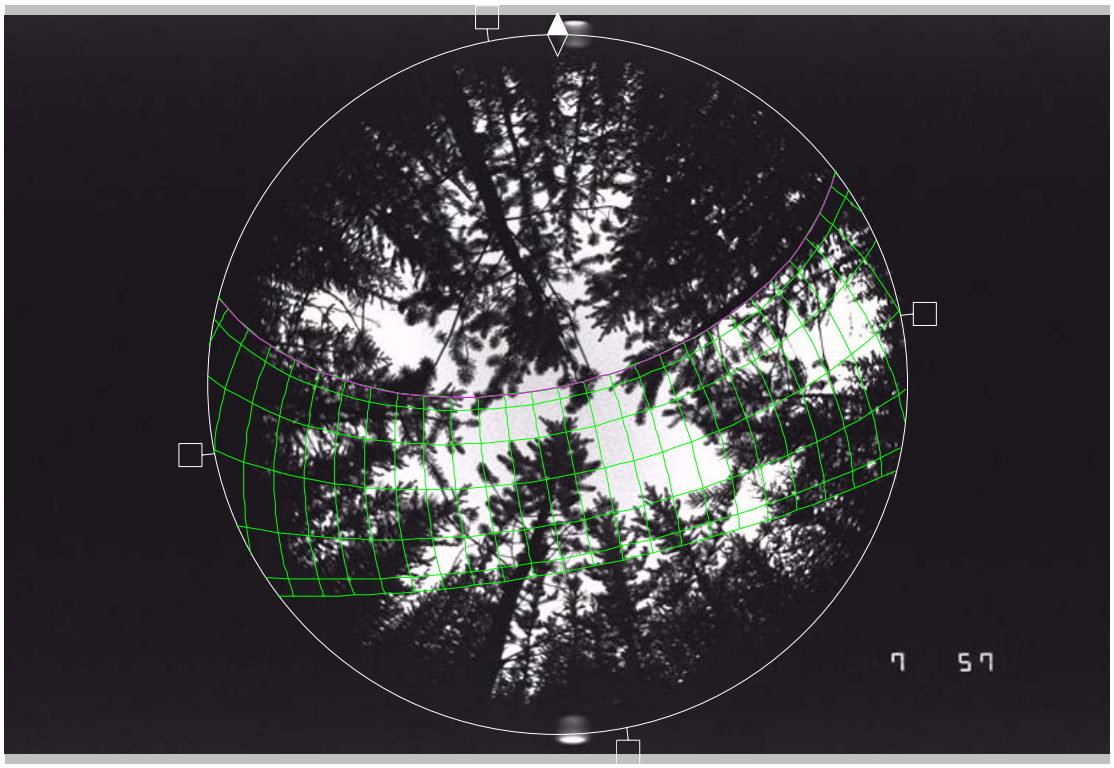
### *Optional Equipment for Camera Orientation and Location of Photograph Edges*

Various researchers have found it useful to use lights in the field of view to facilitate camera orientation or to assist in identifying the edges of photographs.



## IMAGE ACQUISITION

### *Preparations Prior to Going into the Field*

Before going into the field, all equipment and supplies should be assembled and tested. A checklist of equipment and supplies should be reviewed. For efficiency, data notebooks can be partially filled out ahead of time.

### *General Protocol for Photograph Acquisition*

A standardized field protocol should be adopted for acquisition of hemispherical canopy photographs, thus ensuring uniform quality of photographs for analysis.

1. Set up--assemble camera and lens in mount; set ASA; load film (not necessary for digital camera); place assembly on tripod or monopod; remove lens cap.
2. Position and level camera assembly at proper height above ground.
3. Orient top of camera assembly to magnetic north.
4. Set exposure time and aperture.
5. Take photograph using the camera self-timer.
6. Repeat steps 2-5.

### *Field Records*

Field records should be kept to keep track of pertinent hemispherical canopy photograph data. At minimum, field records should include the film roll number (not required for digital photography), unique photograph number (as imprinted by the databack), and location. In addition, the date, time of day, exposure settings, height above the ground, weather/sky conditions, and additional notes can be recorded. Weather/sky conditions can include such categories as sunny, partly cloudy, overcast, sprinkling, and raining. [Note: Taking photography at 1-2 stops over-exposure would yield images with better contrast. This has been tested with film photography but not digital photography.]

## IMAGE ANALYSIS

### *Software Options*

Several soft wares are available for analyzing hemispherical photographs and two of them are

most accessible, GLA and Hemiview. GLA, Gap Light Analyzer, is a windows-based software designed to import, display, and analyze digital hemispherical canopy photographs. It was developed from an earlier true-color imaging program GLI/C, cread by Dr. Charles Canham. It can be downloaded free via internet at http://www.ecostudies.org/. GLA will compute canopy and iste openness, effective leaf area index, sunfleck frequency distribution and daily duration and the amount of above- and below-canopy direct, diffuse, and total solar radiation incident on a horizontal or arbitrary inclined receiving surface. HemiView, on the other hand, is a commercial software ($1000) which basically serve the same purpose as GLA. Canopy leaf area index, direct, diffuse, total solar radiation index, and duration (hours) of direct sunlight can be computed using HemiView.

***Basic Procedures for Analyzing Hemispherical Photographs Using HemiView***

1. Open an image. Choose File, Open. The image opens in its own image window.
2. Specify the lens used. This information will be used by HemiView to calculate the proportion of the radial distance from the center of the image as a function of zenith angle.
3. Align image with the co-ordiante system, so that the program know where North is and where the horizon is. [Note. Since the lens has been specified, the size of the alignment circle should be exactly the size it should be. Unless you have a good reason, you should only move it around to enclose the image and do not change the size of the circle. Sometimes, the center and edge of the image cannot be easily identified. If the photographs are well centered, then the circle should be in the right place. However, my experience indicates this is not always the case. That is why some suggest that two light emitting diodes mounted on the top and bottom of the lenses would help to solve this problem. [The LEDs should not be too bright to affect the quality of the images.]
4. Register site information. Latitude, longitude, elevation, magnetic declination, and topographic shading should be specified for the program to generate Sunmap and Daytrack (the maps that show the movement path of the sun at different seasons of the year and time of day at your site). While all the above information can be used to analyze all photographs taken from a study site, the last information, topographic shading could be very different for photographs taken few meters apart. [Magnetic declination is the angle formed between true north and the projection of the magnetic field vector on the horizontal plane. By convention, declination is measured positive east and negative west (i.e. D -6 means 6 degrees west of north). For surveying practices, magnetic declination is the angle through which a magnetic compass bearing must be rotated in order to point to the true bearing as opposed to the magnetic bearing. Magnetic declination varies from year to year and places to places. You can find out the magnetic declination of any location online at http://www.ngdc.noaa.gov/cgi-bin/seg/gmag/fldsnth1.pl]
5. Overlay Skymap, Sunmap and Daytrack. This is not a require procedure but could be very useful. These overlays can be used to examine patterns in the images such as how the sunmap coincides with canopy openings. [Overlays are useful when producing illustration]
6. Specify the solar model used for computing light indices. You can choose between a standard overcast sky model and a uniform overcast sky model (which assumes that equal amounts of diffuse radiation originate from all sky directions). These describe the pattern of diffuse illumination from a clear sky.
7. Choose the output information based upon your research interests. The three most basic and reliable parameters that can be computed are gap fraction, direct solar radiation index and diffuse solar radiation index (ISF and DSF). Total solar radiation index, or total site factor (TSF), which is a function of ISF and DSF can also be computed if the relative contribution of ISF and DSF on TSF is available based upon long-term measurement on nearby open site. However, for researchers who are interested in plant ecophysiology sunfleck is a useful parameter to compute. [Note that the parameters are merely index. To convert the

index to quantity of radiation, correlation between light indices and quantity of solar radiation must be derived from direct measurement in the opening or above the canopy. Many researchers have found that they are highly correlated as such for studies that are interested in relative levels of solar radiation, the indices could serve the purposes.]

8. Classify image. This is one of the most critical step for analyzing hemispherical photographs and considerable error could be introduced if not performed properly or consistently. One must choose a threshold to differentiate canopy from openings. Although sounds straightforward, it is very subjective and requires high consistency. Most of the accuracy depends on the quality of the image. An image with very good contrast between the canopy and the open sky can be easily classified. On the other hand, classifying images with poor contrast could be mission impossible. For this reason, it is highly recommended that the photographs be taken in times that show greatest contrast. [As a rule of the thumb, canopy foliage near the center of the image can be easily classified as opening whereas openings near the edge (i.e. near the horizon) are often classified as canopy. In other words there is a trade-off between making the two types of error]
9. Compute results. Click on calculate or Alt C, or the calculate button to initiate calculations and you can level your computation (e.g. the name of the image) and make comments on the dialog window.
10. Examine results. The results from HemiView are displayed in an Excel 5.0 compatible workbook. You can manipulate the data the way you would do on an Excel workbook.