



## Environmental Analysis Program

Pomona College  
Biogeochemistry Laboratory

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SOP-F606

# Canopy Cover (Densiometer and Hemispherical Photography)

Standard Operating Procedure

|                     |                            |
|---------------------|----------------------------|
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## 1. Purpose

This SOP describes two methods for estimating canopy cover: the convex spherical densiometer and hemispherical (fisheye) photography. Canopy cover is a key variable in stream habitat assessments (SWAMP protocol), forest ecology, microclimate studies, and solar radiation modeling. Separating this SOP from [SOP-F304](#) allows the methods to be applied in any habitat, not just stream reaches (Jennings et al., 1999; Lemmon, 1956).

The distinction between canopy cover and canopy closure is important for data interpretation. Canopy cover is the proportion of the forest floor covered by the vertical projection of tree crowns; canopy closure is the proportion of the sky hemisphere obscured by vegetation as seen from a single point below the canopy. The two metrics are related but not equivalent, and values can differ by 10–20% at the same location depending on canopy heterogeneity and the method used (Jennings et al., 1999; Paletto & Tosi, 2009).

## 2. Scope

- **Applies to:** Measurement of overhead canopy cover in forests, riparian corridors, oak woodlands, restoration sites, and any habitat where tree or tall shrub canopy is present; includes both the spherical densiometer method and hemispherical photography
- **Does not apply to:** Canopy closure measured by line-intercept or vertical projection methods (see [SOP-F603](#)); leaf area index (see [SOP-F605](#)); remote sensing canopy cover from aerial or satellite imagery
- **Location:** All EA Program field sites with tree or tall shrub cover

## 3. Definitions

- **Canopy cover:** The proportion of the forest floor covered by the vertical projection of tree crowns, expressed as a percentage. Canopy cover is an areal measurement that integrates across an entire stand or plot (Jennings et al., 1999).
- **Canopy closure:** The proportion of the sky hemisphere obscured by vegetation when viewed from a single point below the canopy. Canopy closure is a point measurement and is what both the densiometer and hemispherical photography directly estimate (Jennings et al., 1999).
- **Canopy openness:** The complement of canopy closure: openness = 100% - closure. Some software and instruments report openness rather than closure.
- **Convex spherical densiometer:** A hand-held instrument with a convex mirror etched with a grid. The observer counts sky-visible grid intersections to estimate canopy openness (Lemmon, 1956).
- **Gap fraction:** The fraction of the sky visible through the canopy at a given zenith angle, measured from hemispherical photographs. Gap fraction is the basis for estimating both canopy closure and effective LAI.
- **Binary threshold:** The image-processing step in hemispherical photography analysis where each pixel is classified as either sky (white) or canopy (black). The threshold value strongly influences the estimated canopy closure.
- **SWAMP:** Surface Water Ambient Monitoring Program (California). The SWAMP protocol uses densiometer readings to characterize stream canopy cover as part of physical habitat assessment.

## 4. Responsibilities

| Role              | Responsibility                                   |
|-------------------|--------------------------------------------------|
| PI / Field Lead   | Specify method and number of measurement points  |
| Trained Personnel | Perform measurements per this SOP                |
| New Students      | Complete training before independent measurement |

## 5. Safety and Hazards

### Hazards

- **Physical:** Looking upward while walking increases trip and fall risk. Stop walking before looking up.
- **Biological:** Ticks, poison oak, and snakes in forested and riparian habitats.
- **Environmental:** Bright sunlight reflecting off the densiometer can cause glare. Wear sunglasses when not actively reading the instrument.

### 5.1. Required PPE

- ☐ Closed-toed shoes or field boots
- ☐ Long pants
- ☐ Sun protection (hat, sunscreen)
- ☐ Tick repellent (riparian and woodland sites)

### 5.2. Emergency Procedures

Refer to [SOP-F001 Field Safety](#).

## 6. Equipment and Materials

### 6.1. Method A: Spherical Densiometer

| Item                                                                    | Notes                                                  |
|-------------------------------------------------------------------------|--------------------------------------------------------|
| Convex spherical densiometer (Forestry Suppliers Model A or equivalent) | Concave models also exist; specify which model is used |
| Bubble level (built into the densiometer)                               | Essential for consistent readings                      |
| Field notebook or data sheet                                            | For recording dot counts                               |
| Compass                                                                 | For orienting the four cardinal readings               |

### 6.2. Method B: Hemispherical Photography

| Item                                                 | Notes                                                                                        |
|------------------------------------------------------|----------------------------------------------------------------------------------------------|
| Camera with fisheye lens                             | Full-frame fisheye (180 degrees circular) preferred; or smartphone with clip-on fisheye lens |
| Self-leveling tripod or monopod                      | Camera must be level and facing directly upward                                              |
| Bubble level (hot-shoe mounted or tripod-integrated) | For leveling the camera                                                                      |
| Gray card or exposure reference                      | For consistent exposure settings                                                             |
| Laptop with canopy analysis software                 | Gap Light Analyzer (GLA), hemIMAGE, or ImageJ with the Hemispherical plugin                  |
| GPS unit                                             | Per <a href="#">SOP-F006</a>                                                                 |

## 7. Procedure

### 7.1. Measurement Point Selection

Canopy cover measurements are typically taken at systematic intervals along a transect or at the center and edges of fixed-area plots.

- **Stream habitat surveys (SWAMP):** Measure at 11 equally spaced points along each cross-section transect (left bank, center, right bank at each of the main transect positions). See [SOP-F304](#).
- **Forest inventory plots:** Measure at the plot center and at 4 points on the plot boundary (N, E, S, W).
- **Transect-based surveys:** Measure at regular intervals (e.g., every 10 m or 25 m along a 50 m transect).

Record the GPS coordinates of each measurement point or its position along the transect.

### 7.2. Method A: Convex Spherical Densimeter

The densimeter has a convex mirror with an etched grid. The observer counts the number of grid intersections that are open to the sky (not obstructed by vegetation) in each of four cardinal directions (Lemmon, 1956; Strickler, 1959).

1. Hold the densimeter at elbow height (approximately 30–40 cm in front of your body), level it using the bubble level.
2. Position your head so that its reflection is just outside the grid area. This ensures a consistent viewing angle.
3. Face **north**. Imagine the grid divided into 24 squares (4 rows x 6 columns). At each of the 24 grid intersections, determine whether the sky or vegetation is reflected. Count the number of open (sky) intersections. Record this count.
4. Rotate 90 degrees and face **east**. Repeat the count.
5. Repeat for **south** and **west**.
6. Calculate canopy cover:

$$\text{Canopy openness (\%)} = \frac{\text{sum of 4 counts}}{96} \times 100$$

$$\text{Canopy cover (\%)} = 100 - \text{canopy openness (\%)}$$

where 96 is the total number of possible open points across 4 directions (24 per direction x 4 directions).

#### ! Known Densiometer Bias

The convex densiometer systematically overestimates canopy openness (and therefore underestimates canopy cover) compared to hemispherical photography because of the wide-angle optics and the observer's head position (Cook et al., 1995; Fiala et al., 2006). The magnitude of the bias varies with stand density, observer experience, and lighting conditions but is typically 5–15 percentage points (Korhonen et al., 2006; Paletto & Tosi, 2009). Report the method used alongside all canopy cover values, and do not mix methods within a dataset or monitoring program.

### 7.3. Method B: Hemispherical Photography

Hemispherical photographs capture a 180-degree view of the canopy and are analyzed digitally to classify sky vs. canopy pixels (Frazer et al., 2001).

#### In the field:

1. Mount the camera on the tripod at breast height (1.37 m) or at a height specified by the project protocol.
2. Level the camera using the bubble level. The lens must point directly upward (zenith).
3. Orient the top of the camera toward magnetic north. Record the declination if relevant.
4. Set the camera to manual exposure. Bracket the exposure (take 3 photos: one at the metered exposure, one stop under, one stop over) to ensure at least one well-exposed image.
5. Shoot in overcast or uniformly cloudy conditions whenever possible. Direct sunlight produces bright spots that confound automatic thresholding.
6. Include a gray card in one reference photo per site for exposure calibration.
7. Record the photo number, GPS coordinates, date, time, and sky conditions in the field notebook.

#### In the lab:

1. Import images into canopy analysis software (Gap Light Analyzer, hemIMAGE, or ImageJ with the Hemispherical plugin).
2. Register the image (set lens projection, define the circular boundary, orient to north).
3. Apply a binary threshold to classify each pixel as sky (white) or canopy (black). Adjust the threshold manually if automated thresholding produces obvious errors.
4. The software calculates canopy openness, canopy cover, leaf area index (effective), and gap fraction by zenith angle.
5. Export results as a .csv file. Save to the project repository under `data/canopy/`.

## 7.4. Reporting

Report canopy cover values with the following metadata:

- Method (densiometer or hemispherical photography)
- Instrument model (densiometer type; camera and lens model)
- Measurement height above ground
- Date, time, and sky conditions
- Software and thresholding method (for photography)
- Number of measurement points and their spatial arrangement
- Whether the reported metric is canopy cover (vertical projection) or canopy closure (hemispherical view); see Section 3 definitions

## 8. Quality Control

- **Densiometer:** Have two observers independently read the same point. Readings should agree within 5 percentage points. If they disagree by more than 10 points, re-read together to identify the source of discrepancy. Observer bias is the largest error source for densiometer measurements (Korhonen et al., 2006).
- **Hemispherical photography:** Process the same image twice using different threshold values (+/- 10 units). If the resulting canopy cover differs by more than 5 percentage points, the image may be poorly exposed; re-shoot if possible.
- At a subset of sites, measure canopy cover with both methods and report the comparison. This allows future users to relate datasets collected with different methods and to quantify the systematic offset between them (Fiala et al., 2006; Paletto & Tosi, 2009).
- Record the observer's name with every densiometer measurement.

## 9. References

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- Strickler, G. S. (1959). Use of the densiometer to estimate density of forest canopy on permanent sample plots. *USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, Research Note PNW-180*, 1–5.

## 10. Related SOPs

| SOP                  | Title                         | Relationship                   |
|----------------------|-------------------------------|--------------------------------|
| <a href="#">F001</a> | Field Safety                  | Required prerequisite          |
| <a href="#">F304</a> | Stream Physical Habitat       | Canopy cover in stream reaches |
| <a href="#">F603</a> | Vegetation Transects          | Understory cover companion     |
| <a href="#">F604</a> | Tree DBH and Forest Inventory | Stand structure companion      |
| <a href="#">F605</a> | Leaf Area Index               | Related canopy metric          |

## 11. Training Record

Before measuring canopy cover independently, personnel must:

1. Read this SOP in full
2. Demonstrate correct densiometer technique (leveling, head position, cardinal-direction counts) with results within 5 percentage points of the trainer’s reading on at least 5 test points
3. If using hemispherical photography, demonstrate camera setup, exposure bracketing, and image analysis in the lab
4. Be signed off by the PI or field lead