Indirect Methods of Estimating Canopy Structure

A Comparison of the LAI-2200C, Ceptometry, and Hemispherical Photography

Introduction

There are a variety of methods used to measure canopy gap fraction, leaf area index (LAI) and other canopy attributes. These include the LAI-2200C Plant Canopy Analyzer, ceptometry, and cameras equipped with 'fisheye' lenses that take hemispherical photographs. These indirect methods infer leaf area from measurements of how radiation is intercepted by the canopy, making use of a simple light interception model.

The LAI-2200C and hemispherical photography measure what fraction of diffuse sky radiation passes through the canopy (gap fraction) as a function of zenith angle. They both capture a range of angles simultaneously. The LAI-2200C requires an above canopy reading for reference, while the hemispherical photograph analysis requires a threshold brightness to distinguish sky from foliage. Both methods have traditionally relied on a uniform, overcast sky, since the effects of sunlit leaves are problematic. The LAI-2200C, however, provides post-measurement corrections for direct sunlight, using a sophisticated scattering model.

Ceptometry, by contrast, is generally done in clear sky conditions, and uses an array of sensors to estimate average light beneath the canopy. One can either assume a canopy-specific extinction coefficient and compute LAI, or one can use above canopy reference readings and below canopy readings over the course of half a day to get a range of sun angles, and compute LAI and leaf angle using the gap fraction method.

LAI-2200C Plant Canopy Analyzer – Calculates the interception of blue light (320-490 nm) at five zenith angles from readings taken above and below the canopy.

Ceptometry – Uses a sensor probe with multiple Photosynthetically Active Radiation (PAR) sensors inserted into the canopy; LAI is estimated from intercepted PAR.

Hemispherical Photography – Wide-angle photographs looking up through the canopy are analyzed to compute gap fraction at a range of zenith angles.

Indirect methods of measuring LAI in canopies infer leaf area from measurements of radiation through the canopy.

Considerations

LAI-2200C Plant Canopy Analyzer

- Performs light scattering correction to improve accuracy under direct sunlight. **The only instrument able to measure any type of canopy under nearly any daytime sky conditions.**
- Integrated Global Positioning System (GPS) allows for mapping of results in Google Earth.
- Filters light above 490 nm to minimize errors due to leaf reflectance and transmittance.
- Measures gap fraction, which can be applied to continuous canopies, as well as row structure and individual trees.
- Automatic logging and processing of data in control unit.
- Calibration not required.
- Requires above canopy and below canopy readings. A single optical sensor can be used to make both measurements. In tall canopies, this may require restricting the field of view of the sensor, or finding a clearing to make the above canopy reading. Alternatively, a second, wireless, optical sensor can be deployed in a clearing to log automatically while the user operates the first optical sensor throughout the canopy.
- Uses a 360° azimuthal view at each zenith angle, with the ability to restrict azimuth or zenith view angle(s). This allows for measurement of small plots.

Ceptometry

- Requires that samples be taken at multiple sun angles, or relies on extinction coefficients. The extinction coefficient (K) value is the measure of extinction of any transmitted light in the crop canopy, and as such, requires extensive sampling to derive its value, as well. And because a range of sun angles is needed, it can take hours to complete the necessary readings.

Hemispherical Photography

- Requires extensive post-processing. And because each image is processed independently of the others, it is subject to many potential errors, including camera positioning, exposure, evenness of sky lighting, image editing, consideration of clumping, etc.
- Arbitrary selection of brightness threshold to distinguish leaf area from sky area is required to produce binary image.

LAI-2200C Specifications

LAI-2270C Control Unit

- **Sensor Inputs:** Two 6-pin connectors for LAI-2250 Optical Sensors. Two BNC connectors for LI-COR Light Sensors.
- **Data Storage Capacity:** 128 MB of FAT16 memory.
- **Keypad:** 22 button tactile response keypad.
- **Display:** 128x64 graphics display.
- Communications:
  USB (as mass storage device).
- **Global Positioning System** (GPS RADIONOVA® RF Antenna Module):
  - Horizontal position accuracy: 2.5 m CEP (50% Circular Error Probability, Open-Sky, 24hr Static, good view of the sky).
  - Maximum position update rate: 1 Hz.
  - GPS receiver sensitivity, autonomous acquisition: -148dBm.
  - WAAS enabled receiver
  - Time to first fix (TTFF), hot start: 1 second.
  - TTFF, warm start: 6s (typical).
  - TTFF, cold start (with good view of the sky): 37 seconds at 90% probability.
- **Clock:** Year, Month, Day, Hour, Minute. Accuracy of ±3 minutes per month.
- **Power Requirements:** 4 "AA" alkaline, NiMH, lithium batteries.
- **Battery Life:**
  - 90 hours based on 4 "AA" alkaline batteries without optical sensor attached and without GPS enabled.
  - 60 hours based on 4 "AA" alkaline batteries with optical sensor attached and without GPS enabled.
  - 40 hours based on 4 "AA" alkaline batteries without optical sensor attached and with GPS enabled.
- **Low Battery Warning:** Display indicates when battery power is <15%.
- **Size:** 20.9 x 9.8 x 3.5 cm (8.2" x 3.9" x 1.4").
- **Weight:** 0.454 kg (1.0 lb) with batteries.

LAI-2250 Optical Sensor

- **Sensor Inputs:** One 6-pin Bulkhead connector for control unit interface.
- **Memory:**
  - 1 MB flash memory for record storage.
  - 1 KB EEPROM for calibration and configuration storage.
- **Keypad:** 2 button, tactile response keypad.
- **Clock:** Year, Month, Day, Hour, Minute. ± 3 minutes per month. Can be synced with control unit clock when joined with a data cable.
- **Power Requirements:** 2 "AA" (alkaline, NiMH, lithium) Batteries.
- **Battery Life:** 180 hours of typical operation (based on 2 "AA" alkaline batteries).
- **Optics:** 1.00° maximum decentering error as measured from center of mass of ring 4. 0.50° maximum magnification error as measured from the center of mass of ring 4.
- **Radiation Rejection:**
  - > 99% from 490-650 nm.
  - > 99.9% above 650 nm.
- **Wavelength Range:** 320-490 nm.
- **Nominal Angular Coverage:**
  - Ring 1: 0.0-12.3°
  - Ring 2: 16.7-28.6°
  - Ring 3: 32.4-43.4°
  - Ring 4: 47.3-58.1°
  - Ring 5: 62.3-74.1°
- **Lens Coating:** MgF_2 for improved transmission at oblique angles (external and internal lenses).
- **View Caps:** Provide azimuthal masking of view into quadrants of 10°, 45°, 90°, 180°, and 270°.
- **Diffuser Cap:** Used to cover the lens when measuring sky radiation properties for scattering corrections.
- **Size:** 63.8 L x 2.9 W x 2.9 D cm (25.1" x 1.125" x 1.125") (Endcap: 4.4 W x 5.1 D cm; 1.75" x 2.0").
- **Weight:** 0.845 kg (1.86 lbs) with batteries.
- **Environmental Conditions:**
  - Operating Temperature Range: -20 to 50 °C.
  - Humidity Range: 0 to 95% RH (non-condensing conditions).
- **Storage:** -40 to 65 °C.

LAI-2200C Ordering Information

LAI-2200C Plant Canopy Analyzer

Includes one LAI-2250 Optical Sensor with data cable, LAI-2270C Control Unit, carrying case, USB cable, view-restrictors, diffuser cap, 6 "AA" batteries, belt clip, and Windows FV2200 software.

LAI-2200TC Plant Canopy Analyzer - Tall Canopy Package

Two LAI-2250 Optical Sensors with data cables, one LAI-2270C Control Unit, carrying case, USB cable, view-restrictors, diffuser cap, 8 "AA" batteries, belt clip, and Windows FV2200 software.

2200CLEAR Clear Sky Kit with GPS Upgrade

For upgrading the LAI-2200 for GPS integration and clear sky measurements. Includes GPS board, flex cable, Anti-static wrist strap, 2 light diffuser caps and instructions.

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