FIELD AND LAB PROTOCOL:
MEASUREMENT OF LEAF AREA INDEX

PREPARED BY:	ORGANIZATION:	DATE:
Courtney Meier	FSU	04/01/2013
Jennifer Everhart	FSU	04/01/2013
Katherine Jones	FSU	04/01/2013

APPROVALS (Name):	ORGANIZATION:	APPROVAL DATE:
Dave Tazik	CCB PROJ SCI	10/09/2013
Mike Stewart	SE	12/30/2013

RELEASED BY (Name):	ORGANIZATION:	RELEASE DATE:
Stephen Craft	SE	01/13/2014

See Configuration Management System for Approval History

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REVISION	DATE	ECO #	DESCRIPTION OF CHANGE
A_DRAFT	10/03/2011	ECO-00280	Initial Draft Release
B_DRAFT	01/13/2014	ECO-01140	Updates from 2013. Will be finalized in next rev.

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1 DESCRIPTION

1.1 Purpose

The primary purpose of this document is to provide a change-controlled version of Observatory protocols and procedures. This document provides the content for training and field-based materials for NEON staff and contractors. Documentation of content changes (i.e. changes in particular tasks or safety practices) will occur via this change-controlled document, not through field manuals or training materials.

This document is a detailed description of the field data collection, relevant pre- and post-field tasks, and safety issues as they relate to this procedure and protocol.

1.2 Scope

This document relates the tasks for a specific field sampling or laboratory processing activity and directly associated activities and safety practices.   This document does not describe:

- general safety practices
- site-specific safety practices
- general equipment maintenance

It does identify procedure-specific safety hazards and associated safety requirements such as safe handling of small mammals or safe use of required chemicals and reagents.

2   RELATED DOCUMENTS AND ACRONYMS

2.1 Applicable Documents

Applicable documents contain information that shall be applied in the current document. Examples are higher level requirements documents, standards, rules and regulations.

AD [01]	NEON.DOC.004300	EHS Safety Policy and Program Manual
AD [02]	NEON.DOC.004316	Operations Field Safety and Security Plan
AD [03]	NEON.DOC.000724	Domain Chemical Hygiene Plan and Biosafety Manual
AD [04]	NEON.DOC.001155	NEON Training Plan
AD [05]	NEON.DOC.050005	Field Operations Job Instruction Training Plan

2.2 Reference Documents

Reference documents contain information complementing, explaining, detailing, or otherwise supporting the information included in the current document.

RD [01]	NEON.DOC.000008	NEON Acronym List
RD [02]	NEON.DOC.000243	NEON Glossary of Terms
RD [03]	NEON.DOC.000914	NEON Science Design: Plant Biomass and Productivity
RD [04]	NEON.DOC.005003	NEON Scientific Data Products Catalog
RD [05]	NEON.DOC.014051	Field Audit Plan
RD [06]	NEON.DOC.000824	Data and Data Product Quality Assurance and Control Plan
RD [07]	NEON.DOC.005005	Level 0 Data Product Catalog
RD [08]	NEON.DOC.XXXXXX	AOP flight schedule (TBD)

2.3 Acronyms

CV	Coefficient of Variation
DHP	Digital Hemispherical Photo
DSLR	Digital Single Lens Reflex
LAI	Leaf area index
NDVI	Normalized Differential Vegetation Index (a proxy for vegetation "greenness")
PAI	Plant area index

2.4 Definitions

A **protocol** is a formal summary description of a procedure and its related rationale, and includes information on knowledge and resources needed to implement the procedure.   A procedure is a set of prescribed actions that must take place to achieve a certain result, and can also be called a method. It differs from a science design in that science designs provide a more complete description of the rationale for selecting specific protocols. It differs from a training manual in that training manuals provide materials in support of skills acquisition in the topic areas including information on how to best train staff rather than detailing only the steps of the procedure.

3   BACKGROUND AND OBJECTIVES

3.1 Background

Leaf area index (LAI) is a useful proxy variable for numerous other variables of ecological interest, including plant biomass, plant productivity, forage quality, carbon balance, ecosystem energy flux, plant density, and the heterogeneity of plant cover. LAI is also used widely as a key input variable to models that seek to predict ecological processes such as carbon cycling. Regional to continental scale estimates of LAI are typically derived from satellite data, but validation of satellite data with aircraft and ground-collected data is relatively uncommon. By leveraging NEON's aircraft and ground-collected estimates of LAI, it will be possible to develop ground-validated estimates of LAI at the continental scale.

There are numerous methods available for estimating LAI, and these fall into two general categories: direct and indirect. Direct methods are conceptually the most straightforward, and involve the destructive harvest and measurement of individual leaves from selected plants. Direct methods are also laborious relative to indirect methods, and as such, are not suitable for further consideration given the budgetary and logistical concerns that these methods pose at the continental scale of the Observatory. With indirect methods, on the other hand, it is possible to rapidly and non-destructively estimate LAI using a variety of optical instruments that measure the canopy gap-fraction, and then mathematically relate the gap-fraction to LAI.

Following the evaluation of four different optical instruments capable of generating LAI estimates, a DHP system consisting of a DSLR camera equipped with a 180˚ hemispherical fish-eye lens was selected. The benefits of using a DHP system compared to the other optical instruments tested include: 1) measurements of LAI in systems with tall woody stems are economical and efficient for field technicians to carry out; 2) measurement of low-stature vegetation – e.g. short-grass steppe – is possible without interfering with the vegetation itself during data collection; 3) because the Level 0 data produced by the DHP method is in the form of an image file, it is straightforward to perform QA/QC both in the field and at NEON HQ; and 4) as data analysis algorithms evolve in the future, digital images are readily archived and can easily be re-analyzed for LAI by the user community as desired.

3.2 NEON Science Requirements

This protocol fulfills Observatory science requirements that reside in NEON's Dynamic Object-Oriented Requirements System (DOORS). Copies of approved science requirements have been exported from DOORS and are available in NEON's document repository, or upon request.

3.3 NEON Data Products

Execution of this protocol procures samples and/or generates raw data satisfying NEON Observatory scientific requirements. These data and samples are used to create NEON data products, and are documented in the NEON Scientific Data Products Catalog (RD[04]).

4 PROTOCOL

There are two high-level components to the LAI data collection protocol: 1) data are collected on the ground every 5 years from Distributed and Gradient Plots, and these data are used in conjunction with AOP LAI data products to estimate LAI at the site scale; and 2) data are collected every two weeks from a subset of Tower plots (n=3) that will be used to construct a time-series dataset that will complement the spatially-extensive snapshot of LAI generated from AOP data. Distributed and Gradient Plots that will be used for LAI sampling are selected non-randomly for each site; selected plot IDs will be provided by Science Operations. For more details of the LAI spatial and temporal sampling strategy, see the Plant Biomass and Productivity Science Design Document (RD [03]).

This protocol highlights critical details that are required to collect LAI data with a high degree of accuracy and repeatability. Hemispherical photos are taken at 12 points within each of the specified Distributed plots, and these photo points radiate outward from the plot center in the cardinal directions (Figure 1). For Distributed Plots, not all plots are used for LAI measurement, and it is the responsibility of Science Operations to determine which Distributed Plots are measured for LAI at each site. For Tower Plots, a small subset (n=3) are measured for LAI per site. In order to speed data collection from Tower Plots, those selected for LAI measurement should be the three plots that are closest to, or most readily accessed from, the TIS Tower. In order to minimize travel time and logistical impact, the exact Tower Plots sampled at a given site are chosen by Field Operations.

Collection of quality LAI data with a DHP system at each point-location is highly dependent on taking the hemispherical photos in appropriate light conditions, and on properly exposing the images. The technician(s) will also determine whether only downward-facing images will suffice for a given plot (vegetation is on average shorter than breast height), or whether upward-facing images are also required to properly capture LAI for the plot. In the laboratory, image files are processed with Photoshop to adjust image size and ensure that leaf elements are properly exposed. Sets of 12 images are then analyzed using CanEye software to generate a plot-level LAI estimate.
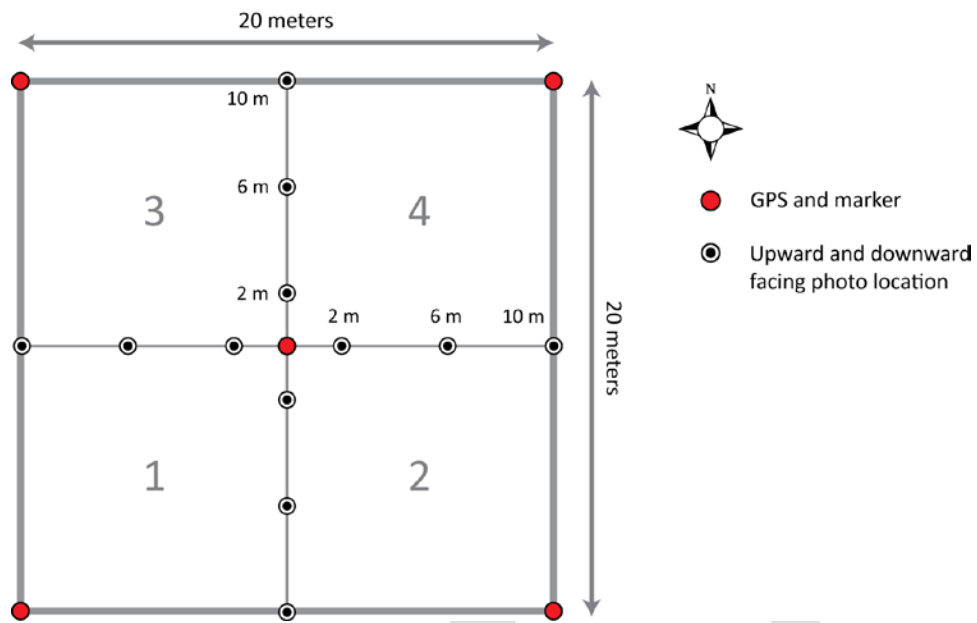
Figure 1. The central core of a Distributed plot showing the location of LAI photo points; the spacing between points along the cardinal axes should initially be 4 m.

5   QUALITY ASSURANCE AND CONTROL

The field procedures associated with this protocol will be audited according to the Field Audit Plan (RD[05]). Additional quality assurance will be performed on data collected via these procedures according to the NEON Data and Data Product Quality Assurance and Control Plan (RD[06]).

A critical component of image analysis in CanEye is the classification of pixels into plant and non-plant categories. In order to 'calibrate' pixel classification across different technicians, technicians performing the CanEye analysis will analyze a standard set of images provided by Science Operations before proceeding to analyze additional images. The standard image set will be analyzed at least three times in order to calculate a CV for the individual technician. The CV must be < 10%, and the mean LAI value produced by the technician with this standard image set must be within ± 10% of the provided LAI value before the technician may proceed to analyze additional images. The CV is calculated as follows:

(1) $CV = \dfrac{\sigma}{\mu} \times 100$, where $\sigma = $ the standard deviation, and $\mu = $ the mean.

A combination of hot, cold, and blind checks will be used to ensure that quality hemispherical images are collected in the field, that images are repeatably taken from the same locations in each plot, and that images are analyzed properly with the CanEye software.

5.1 Decision tree

When unexpected field conditions require deviations from this protocol, the guidance below must be followed to ensure that basic data quality standards are met:

Table 1. Decision tree associated with the plant leaf area index measurements, indicating how to respond to unanticipated delays in field work, and consequences of these delays.

Delay	Action	Adverse outcome	Outcome for Data Product
Hours	If 1) Delay interrupts data collection mid-plot: a) stop data collection for the plot, and delete any images taken; b) upon resuming, ensure light conditions are favorable; and c) repeat data collection for entire plot on the same day if possible.	A delay of hours can lead to poor light conditions for collection of LAI data.	Overestimation or imprecise estimation of LAI.
	If 2) Delay occurs between plots: a) Ensure light conditions are favorable for data collection; and b) resume data collection for next plot.	A delay of hours can lead to poor light conditions for collection of LAI data.	Overestimation or imprecise estimation of LAI.
1-7 Days	If 1) Delay interrupts data collection mid-plot: a) stop data collection for the plot, and delete any images taken; b) next day, ensure light conditions are favorable; and c) repeat data collection for the plot.	None	None
	If 2) Delay occurs between plots: a)	None	None

Delay	Action	Adverse outcome	Outcome for Data Product
	Return to the field ASAP; b) ensure light conditions are favorable for data collection from an entire plot; and c) resume data collection for the next plot.		
8-14+ days	If 1) Delay interrupts data collection mid-plot: a) stop data collection for the plot, and delete any images taken; b) return to the field ASAP and ensure light conditions are favorable for data collection from an entire plot; and c) repeat data collection for the plot.	LAI may change over a delay of this length.	Imprecise estimation of LAI.
	If 2) Delay occurs between plots: a) Return to the field ASAP; b) ensure light conditions are favorable for data collection from an entire plot; and c) resume data collection for next plot.	LAI may change over a delay of this length.	Imprecise estimation of LAI.

6 SAFETY

Personnel working at a NEON site must be compliant with safe field work practices as outlined in the Operations Field Safety and Security Plan (AD[02]) and EHS Safety Policy and Program Manual (AD[01]). Additional safety issues associated with this field procedure are outlined below. The Field Operations Manager and the Lead Field Technician have primary authority to stop work activities based on unsafe field conditions; however, all employees have the responsibility and right to stop their work in unsafe conditions.

Because DHP images are collected in the field at dawn or dusk, it is advisable to bring a headlamp to aid navigation between plots. *The lamp should remain off during data collection to avoid influencing the measurements.*

7 PERSONNEL REQUIREMENTS

For image acquisition in the field, it is required that one technician have a proficient, working knowledge of manual image exposure, and evaluation of image exposure with the specified camera hardware. Field technicians must also know how to use a mirror-site compass.

For analysis of DHP images to calculate LAI, at least one technician is required; prior to image analysis with the specified software, it must be verified that the technician is capable of analyzing images within specified QA/QC parameters .

8   TRAINING REQUIREMENTS

All technicians must complete required safety training as defined in the NEON Training Plan (RD[04]). Additionally technicians complete protocol specific training for safety and implementation of protocol as required in Field Operations Job Instruction Training Plan (RD[05]).

Technicians must also be trained to configure, use, and care for the DSLR system when acquiring high-quality hemispherical photos.

Technicians should be trained to properly use a mirror-site compass, including looking up and setting the appropriate declination. Declination changes with time at each site, and should be looked up annually here: http://www.ngdc.noaa.gov/geomag-web/

Finally, technicians will require training to process image files in Adobe Photoshop, and to analyze processed images for LAI using the freely available CanEye software.

9   FIELD STANDARD OPERATING PROCEDURE

Prior to the first AOP flight at a given site, the spacing between photo-points is 4 m, as depicted in Figure 1. Once an initial AOP dataset has been generated for each site, the spacing between photo-points will be optimized based on LiDAR derived canopy height data from AOP on a per plot basis. **Care must be taken to use the correct spacing between photo-points for each plot.**

9.1 Sampling Frequency and Timing

9.1.1   Criteria for Determining Sampling Dates

Distributed and Gradient Plots

DHP images shall be acquired from all of the designated Distributed and Gradient Plots (typically n=20) **within a one month window centered on the actual date of the AOP overflight.** It is acceptable to begin measuring LAI on the ground before the AOP flight, provided that the flight date (or range of possible dates) is confirmed and not subject to change. If no AOP flight is scheduled in a given year, postpone ground LAI sampling at Distributed and Gradient Plots to the next year in which an AOP flight is scheduled. The annual schedule for AOP flights is provided by Science Operations RD [08].

Tower Plots

Sampling of Tower Plots for LAI shall begin following budburst at the start of the growing season, as new leaf or needle growth becomes visible and begins to expand. The date of sampling onset in a given growing season is determined by the Field Operations Manager or permanent field technicians. Sampling is stopped for a given growing season when satellite-derived, site-level NDVI values return to pre-growing-season baseline levels. The date of sampling cessation for a given growing season will be determined by Science Operations.

9.1.2   Sampling Frequency

Distributed and Gradient Plots

DHP images are collected from n=20 Distributed Plots once during the growing season every 5 years.

Tower Plots

DHP images are collected from Tower Plots (n=3) every other week during the sampling period. Collection of images every other week shall take place every growing season.

9.1.3   Sampling Timing Parameters

Two timing considerations arise with respect to collecting high-quality LAI data on a given day. First, it is not possible to measure LAI with the DHP system when weather conditions are such that water droplets form on the lens (i.e. it is raining, misting, there is heavy condensation, etc.) – check the local weather forecast prior to initiating field work to ensure that data collection will be possible. Second, **LAI data must only be collected when direct sunlight is NOT visible on the foliage** – i.e. an approximately 1.5 h period at dawn or dusk, or any time during the day when it is sufficiently overcast such that a person does not cast a visible shadow.

Understory vegetation in forested systems will typically not have direct sunlight on the foliage well before sunlight has left the canopy vegetation, so photograph understory plants with downward-facing images before taking upward-facing photos of the canopy to speed image acquisition. Alternately, downward-facing images of understory vegetation can be acquired any time during the day if canopy cover is dense enough that **direct sunlight is not visible on the understory foliage.**

 It is the responsibility of Field Operations to determine the exact timing of sampling within a given day.

9.2 Equipment and Materials

The following equipment is sufficient for a team of two field technicians to collect LAI data (i.e. DHP images) in any ecosystem. The quantities of equipment below can be doubled if a second team of two will be collecting LAI data.

Table 2. Field equipment required for a team of two people to measure LAI at a plot.

Maximo Item No.	Item Description	Quantity	Habitat-Specific	Special Handling
MX104649	DSLR camera body	1	No	No
MX104654	DSLR extra memory card, 16 Gb	1	No	No
MX104653	DSLR extra battery	1	No	No
MX104657	DSLR memory card reader	1	No	No
MX104651	Hemispherical 180˚ fisheye lens	1	No	No
MX104659	Camera and lens carry case	1	No	No
MX102760	Nikon micro-fiber lens cleaning cloth	1	No	No
MX104736	Camera monopod	1	No	No
MX100703	GPS unit, pre-loaded with plot locations	1	No	No
MX100320	Compass w/ mirror site, declination adjusted	1	No	No
MX101632	Headlamp	2	No	No
	Pencils	2	No	No
	LAI QC datasheet	1	No	No

The LAI QC datasheet is provided as Appendix A to this document, and is intended as an interim data collection medium until the NEON CI team develops a BioPDA application.

9.3 Preparation

1) Check DHP equipment to make sure it is in full working condition.

    a) Check the hemispherical lens for scratches, and clean with lens tissue if necessary. DO NOT clean the lens with regular tissue or KimWipes.

    b) Make sure the main and backup batteries for the DSLR are charged.

    c) Make sure the date and time on the camera are set properly. Time should be set to local time using 24-hour notation.

2) Check the DSLR to ensure that the settings are appropriately configured for low-light hemispherical photography (see Table 3, and Appendix A for more detailed instructions).

Table 3. Overview of configurable options and desired settings for collecting DHPs using the Nikon D800.

Option	Desired Setting	How to Change
Image quality	RAW	"QUAL" button, primary wheel
White balance	Auto (A)	"WB" button, primary wheel
Shutter Mode	Single shot (S)	Left knob, outer ring
Metering Mode	Matrix	Back knob, upper-right
Focus Mode	Auto-area Auto Focus (AF-S auto)	Focus switch/button, primary and secondary wheels
Playback display options	RGB histogram, Overview	Playback Menu
File naming	DXX (where XX is NEON Domain number)	Shooting Menu
Color space	sRGB	Shooting Menu
Active D-lighting	Off	Shooting Menu
High ISO NR	Normal	Shooting Menu
ISO sensitivity settings	Auto-ISO sensitivity control = ON; Maximum sensitivity = Hi2; Minimum shutter speed = 1/30	Shooting Menu
Time Zone and Date	Time Zone = Domain specific Date and Time = Current local Date Format = Y/M/D Daylight Savings = current local	Setup Menu
Image comment	Attach comment	Setup Menu
Custom menu	Add "Image comment" to custom MY MENU for easy access	My Menu, Add Items…

3) Check the adjustable declination setting on the mirror-site compass, and make sure that declination is correct. Declination changes with time and should be looked up annually here: http://www.ngdc.noaa.gov/geomag-web/

4) Pre-load the GPS unit with the plot locations that will be used for LAI sampling.Prior to performing field work, use a meter tape to calibrate individual technician pacing and determine how many paces are equivalent to 4 m, as this is the distance between photo-points. Being able to repeatedly pace off accurate distances in the field will speed collection of LAI data considerably, compared to having to lay out a meter tape in two directions for guidance at each plot.

9.4 Data Collection in the Field

On a given measurement day, technicians should plan on arriving at the location of the first plot to be measured at least 20 minutes before light conditions are appropriate.

9.4.1   Guidelines for taking Digital Hemispherical Photos

The following guidelines must be followed in order to obtain suitable upward and downward-facing hemispherical photos:

1. Use a declination-corrected mirror-site compass and calibrated pacing to locate photo-points within the plots. **Make sure that no ferrous metal objects are within at least 50 cm of the compass at all times.**

2. If the plot is on a slope, tilt the camera so that the photo is taken as close to perpendicular to the slope as possible.

3. Downward-facing images should be taken before the upward-facing photos.

4. To decide whether upward-facing photos, downward-facing photos, or both are required for a given plot, visually survey the vegetation structure in the entire area where photos will be taken, and refer to Table 4.

Table 4. Guidelines for determining proper camera positioning when taking hemispherical photos for LAI measurements.

Required photos	Understory Vegetation	Overstory Vegetation	Camera Placement
Single downward-facing photo per point	Majority < 0.5 m height	None	Breast height
Single upward-facing photo per point	Majority > 0.5 m height	Majority < 3 m height	On ground
Upward and downward-facing photos per point	Majority < 0.5 m height	Majority > 3 m height	Breast height
Two upward-facing photos per point	Majority > 0.5 m height	Majority > 3 m height	Breast height, On ground

5. Foliage should be ≥ 1 m from the lens; if foliage is < 1 m from the lens at the designated photo point, select an alternate spot as close to the designated point as possible. Important exceptions to this guideline include:

    a. Issue: For an upward-facing photo at breast height, vegetation is very dense at breast height, and there is no close-by point at which vegetation will be ≥ 1 m from the lens (e.g. a recently disturbed area with dense woody regrowth that is > 3 m height).

    Solution 1: Lower the height at which the image is taken until foliage is ≥ 1 m from the lens, and record the photo height in the "Notes" column of the QA/QC datasheet.

    Solution 2: If it is not possible to select a height at which foliage is ≥ 1 m from the lens, maximize the distance between the foliage and the lens, and record the photo height and the distance to the foliage in the "Notes" column of the QA/QC datasheet.

    b. Issue: For an upward-facing photo at ground level, vegetation is < 1 m from the lens.

    Solution: None. This situation is expected when upward-facing images are taken at ground level.

6. For upward-facing images taken at ground level, minimize disturbance to the vegetation as the camera is placed into position.

7. To obtain optimal image exposure, configure the camera for taking either upward or downward-facing images (Table 5). Consult Appendix A for detailed instructions on how to configure the Nikon D800.

Table 5. Camera settings for obtaining optimal exposure for upward- and downward-facing hemispherical images.

Camera Setting	Upward-facing (camera breast height)	Upward-facing (camera on ground)	Downward-facing
Exposure Mode	Manual (M)	Manual (M)	Aperture priority (A)
Focus Settings	Manual, set to "∞"	Auto-area Auto Focus	Auto-area Auto Focus
ISO	Initial = 6400, adjust manually if necessary; ISO-auto = OFF	Initial = 6400, adjust manually if necessary; ISO-auto = OFF	Initial = 400 ISO-auto = ON
Shutter	Open no longer than 1/30 s	Open no longer than 1/30 s	Open no longer than 1/30 s
Aperture	> f/5.6 best, f/4 okay	> f/5.6 best, f/4 okay	> f/5.6 best, f/4 okay

9.4.2 Prior to collecting data

The following tasks should be completed prior to image acquisition. If you are measuring the first plot of the day, these tasks may be completed before the sun goes down, and light is still visible on the foliage.

1) Navigate to the target plot using a GPS or compass and map.

2) Place backpacks and any other gear outside the plot and out of the potential field of view of the camera.

3) Determine whether light conditions are appropriate for data collection (see Section 9.1.3 Sampling Timing Parameters).

4) Determine whether downward-facing, downward- and upward-facing, or two upward-facing photos are required for the photo-points within the plot (Table 4).

5) In the D800 "Setup Menu", add the current **plot ID** to the "Image comments" (see Appendix A).

9.4.3 Downward-facing hemispherical photos

1) If downward-facing photos are required, take all 12 downward-facing images in sequence **before** shooting the upward-facing images in the same sequence. Take pictures first at the 2 m, 6 m, and 10 m photo-points along the North plot axis; then proceed to the East plot axis, South plot axis, and West plot axis – always taking pictures first at the 2 m photo-point, than at the 6 m and 10 m photo-points (Figure 1).

   a) Configure the camera according to the settings specified in Table 4. For each image, it is necessary to check that the shutter is open no longer than 1/30th of a second. Ideally, f-stop values should be f/5.6 or greater, and should not drop below f/4.

i) Before beginning, orient the camera downward, set the aperture to f/4, and take a test image. If the shutter is open longer than $1/30^{th}$s, conditions are too dark for downward-facing images.

ii) Downward-facing photos may be taken at a separate time during daylight hours if the canopy is too dense to obtain a decently exposed image of the understory when upward-facing photos are acquired.

b) Navigate to the plot marker at the plot center, and using a mirror-site compass, use calibrated pacing to find the 2 m photo-point along the North plot axis (0° azimuth).

c) Visually assess the distance between the lens and the vegetation, and if necessary, adjust photo-point location or camera height as specified in "Guidelines" above.

d) Note the direction of the sun, and face toward it – at dusk, this should be West.

e) Adjust the f-stop value so it is as high as possible with shutter speed no slower than $1/30^{th}$ s.

f) Place the monopod at breast height with the lens facing down.

g) On flat ground, use the bubble levels to make sure the lens is as close to perpendicular with the ground as possible. If the plot is sloped, follow the general guidelines above.

h) Press the shutter release button half way, until a "beep" is heard indicating the camera has achieved focus and exposure lock.

i) Carefully press the shutter release button the rest of the way to take the photo. Check the image for blurriness and proper exposure. If required, delete and re-shoot until a satisfactory image is taken.

j) **Fill out the LAI QC datasheet as images are acquired** so that camera orientation metadata and image file names may be linked to specific point and plot IDs.

k) Continue acquiring images at the designated photo-points in the sequence indicated above.

l) Once all downward-facing images have been taken, proceed to taking upward-facing images, if required. See section 9.4.4 below.

Figure 2. Example of a properly exposed downward-facing hemispherical photo (D01 Harvard Forest site).

9.4.4   Upward-facing hemispherical photos

1) If upward facing photos are required, take all 12 upward-facing images in the same sequence that downward-facing images were taken, beginning with the photo-points along the North cardinal plot axis.

   a) For upward-facing images, optimal exposure for the camera in a forested setting is with the sky minimally saturated white, and foliar elements as dark as possible. Using the histogram view, saturation levels should be checked for each image (see Appendix A).

   b) Note the direction of the sun, and this time face away from it – at dusk this should be East.

   c) Set the camera to Manual exposure mode, and Manual focus mode (Appendix A).

   d) On the lens, set the focus distance manually to infinity (∞).

   e) To determine the appropriate exposure settings, acquire a test image. The goal is for the sky to be minimally saturated white, and for foliar elements to be as dark as possible – i.e. the image should show high contrast between leaves and sky, but without overly bright sky "bleeding through" and obscuring small leaves and needles.

      i) Find a position with distinct sky and foliage elements directly overhead.

      ii) With the camera in Manual mode, adjust the aperture so that it is f/5.6 or greater (f/4 is acceptable, but not desirable, and aperture should not drop below f/4).

      iii) Looking through the camera viewfinder, point the lens straight up toward the canopy and adjust the shutter speed so that the image is properly exposed according to the built-in light meter. **Shutter should not be open longer than 1/30th s,** as images will be too blurry for analysis.

iv) Using the LCD screen on the camera, use the histogram view to check white saturation levels. White saturation levels appear as a very thin peak at the right of the histogram. The height of this right-most peak should be between ¼ and ¾ of the potential height (Figure 3).

    (1) If the exposure is too bright, the white peak will reach the top of the histogram graph.

    (2) If the exposure is too dark, there will be little or no white peak on the right side of the histogram.

v) While still in Manual mode, adjust the shutter speed and/or aperture – **taking into account the f-stop and shutter-speed constraints listed above** – and take additional test images as necessary until a correctly exposed image is produced (Figure 4).
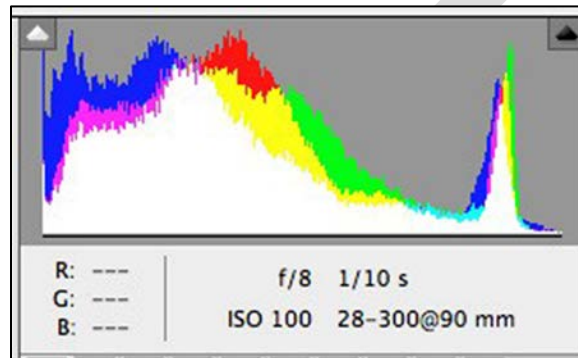
Figure 3. An example histogram from a properly exposed image. The red, green, and blue histograms are depicted in their respective colors, and a combined luminance histogram is shown in white.
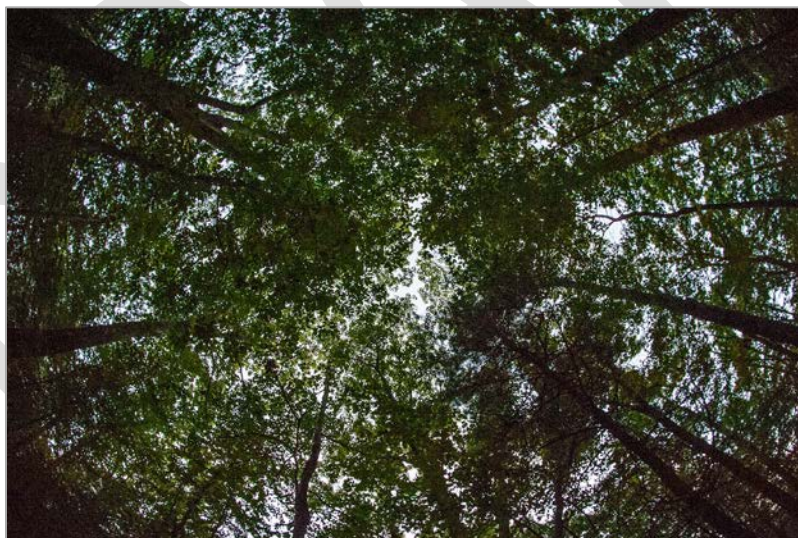
Figure 4. An example of a properly exposed upward-facing hemispherical photo taken at the NEON D1 Harvard Forest site.

f) Navigate to the first photo-point – i.e. 2 m along the North cardinal plot axis.

g) Visually assess the distance between the lens and the vegetation, and if necessary, adjust photo-point location or camera height as specified in "Guidelines" above.

h) Depending on the vegetation structure in the plot (see Table 5), place the monopod either at breast height or on the ground (Figure 5).

Figure 5. Image of a field researcher acquiring an upward-facing hemispherical photo with the monopod/camera ensemble held at breast height.

i) Make sure the focus is in manual mode, and the lens is focused to "∞" (Figure 2).

j) Press the shutter release button carefully, to avoid moving the camera too much.

k) Check the image for blurriness, and for proper white saturation using the histogram.

   i) If the image is in focus and properly exposed, proceed to the next photo-point.

   ii) If the image is blurry and either over or under-exposed, delete and take another image.

l) **Fill out the LAI QC datasheet as images are acquired** so that camera orientation metadata and image file names may be linked to specific point and plot IDs.

m) Continue taking images along the same sequence of photo-points specified above, checking each image for blurriness and white-point saturation.

n) After acquiring all images for the plot, proceed to the next plot if measurement conditions are still favorable and there is time.

9.5 Data Handling

Transcribe data from the "LAI Image metadata" sheet into the appropriate Excel spreadsheet, and copy the .NEF image files from the camera to NEON servers.

1) There should be one Excel file containing Leaf Area Index ingest datasheets for all of the plots measured in a given year.

   a) Enter data into tabs with "csv" in the tab name. Choose the appropriate tab for the field datasheets at hand.

2) Once data have been entered from all plots, save the "csv" tab as a .csv file for CI ingest.

3) Copy RAW images from the camera flash card to the NEON servers for storage and analysis.

a) Create the following folders and sub-folders, if they do not exist already: "LAI_data →
LAI_RAW_images → YYYY → eventID → plotID → image_type", where

    i)   YYYY = the current year,

    ii) eventID = YYYYXX, where YYYY is the current year, and XX = bout # if plot type = Tower or XX
= 00 if plot type = Distributed or Gradient,

    iii) plotID = a separate sub-folder for images from each plot, and

    iv) image_type = a sub-folder named either "canopy" or "understory"

        (1) Images in the "canopy" folder should contain *ONLY* canopy vegetation, and camera
orientation may be either downward-facing or upward-facing.

           Example 1: Downward-facing DHPs of short-grass vegetation from the D10 CPER site are
placed in the "canopy" folder.

           Example 2: Upward-facing DHPs of tree canopies from the D01 HARV site are placed in
the "canopy" folder.

        (2) Images in the "understory" folder may contain understory only or understory + canopy,
and camera orientation may be either downward-facing or upward-facing.

           Example 1: Downward-facing DHPs of herbaceous vegetation from a forested plot at the
D01 HARV site are placed in the "understory" folder.

           Example 2: In a regenerating forested plot, upward-facing DHPs of herbaceous
vegetation > 1 m height (camera placed on the ground), also including canopy
vegetation are placed in the "understory" folder.

b) *Example:* Folder names for images from a hypothetical forested plot with plotID = SCBI_123:

    i)   LAI_data → LAI_RAW_images → 2013 → 201308 → SCBI_123 → Canopy

    ii) LAI_data → LAI_RAW_images → 2013 → 201308 → SCBI_123 → Understory

4) After successfully copying all of the images to the NEON servers, image files on the camera flash
memory may be erased if space on the memory card is limited.

9.6 Refreshing the Sampling Kit

1) Check battery levels on the DSLR LCD screen; recharge if necessary.

2) Recharge batteries on the GPS unit.

3) Check that the micro-fiber lens cleaning cloth is clean.

9.7 Equipment Maintenance, Cleaning and Storage

1) If necessary, clean the hemispherical lens with lens tissue.

10 LABORATORY STANDARD OPERATING PROCEDURE

Downward-facing and upward-facing images collected in the field are analyzed separately per plot to create plot-level LAI values. Images are first optimized for analysis using Adobe Photoshop software, and are then analyzed for LAI using the free CanEye software. CanEye is prone to crashing inexplicably, and requires patience. Better software options for image analysis are currently being explored. CanEye produces a data report in .html and .xls format for each batch of 12 images analyzed, and LAI data must be copied from the .xls file to a new Excel spreadsheet that summarizes the data across all the plots.

10.1 Sample Processing Timing

DHP images collected in the field may be processed for LAI with Photoshop and CanEye any time after collection. However, it requires approximately 30-60 min per plot to process and analyze the images (depending on whether 12 or 24 images were taken per plot), so it is good practice not to amass a large volume of un-analyzed images.

10.2 Equipment and Materials

Table 6. Laboratory equipment required to process DHP images and calculate LAI.

Maximo Item No.	Item Description	Quantity	Habitat-Specific	Special Handling
	Adobe Photoshop (version CS5 or CS6 are suitable)	At least 1, more as needed	No	No
	CanEye, with associated MatLab libraries	At least 1, more as needed	No	No

10.3 Preparation

1) Confirm required software is installed and available for use.

   a) CanEye software and the associated MatLab libraries must be installed, and administrator rights must be available. CanEye and MatLab libraries are available from the French National Agricultural Institute: https://www4.paca.inra.fr/can-eye/Download

2) Verify that all images to be analyzed are focused properly and are not blurry.

10.4 Image Processing in the Lab

10.4.1 Setting up a Batch Processing Droplet in Photoshop

1) Select a test image file – either upward or downward facing – in order to make a batch processing "Droplet". In Photoshop, a "Droplet" is an icon onto which files can be "dropped" and processed according to a standard set of actions encoded in the Droplet. Make a copy of one of the DHP image files to create a suitable test image.

2) Open Adobe Photoshop.

3) Make sure the "Actions" pane is visible: from the drop-down menus click "Window → Action" (Alt-F9).

4) Within the "Actions" pane, create a new set of actions by clicking the folder icon at the bottom of the pane, and name the new action set "CanEye processing".

5) Create a new action within the "CanEye processing" set by clicking the "Create New Action" button at the bottom of the pane (post-it icon). Name the new action "RAW to JPG Q60". Click "OK" to begin recording the new action – from this point onward, until you click the "Stop" button at the bottom of the Action pane, Photoshop will record everything you do as part of the new action.

   a) The "Q60" indicates the JPG files will be generated with quality set to 60 out of 100, which should be a moderately high-quality image.

   b) Additional droplets may be created with lower JPG quality as necessary – i.e. Q40, Q20, Q10, etc.

6) Open the test image file: "File → Open"

7) In the "Camera RAW" plug-in that opens with the image, adjust "Clarity" and "Shadows" so that there is good contrast in darker areas of the image. The following are starting points:

   a) Clarity = +50

   b) Shadows = +50

8) To adjust the size of the photo, click the link at the bottom of the Camera RAW window that states the image size, and in the "Workflow Options" window that opens, make the following selections:

   a) Space: sRGB IEC61966-2.1

   b) Depth: Leave at 8 bits/channel

   c) Size: 2048 by 1363 pixels (2.8 MP). When analyzing 12 photos at a time, CanEye appears to crash no matter the image quality if the 12 photos have an image size greater than what is specified here.

   d) Resolution: Set to 240 pixels/inch

   e) Sharpen for: leave as None, and amount as standard.

   f) Click "OK".

9) In the Camera RAW window, click "Open Image" at the bottom-right.

10) Verify that the image has changed size by clicking "Image → Image size" from the drop-down menus. Click "OK".

11) Select "File → Save for web", which will open a new "Save for Web & Devices" window. In the top-right of this window, select "Quality = 60", which should produce an image of approximately 1.5 Mb size

12) Click "Save", and as this image is a test image, the save location is unimportant.

13) When saving is complete, click "Stop Recording" at the bottom of the Action pane.

14) To create the Droplet, select "File → Automate → Create Droplet" and name the Droplet as indicated above. The Droplet can be saved to the Desktop for ease of use, or any other location. Click "Save".

15) A new menu will appear requesting you to assign an Action to the Droplet. Select the Action that you just created above.

   a) **Check the "Override action 'Open' commands" box.** This ensures that Photoshop will batch process photos without opening the Camera RAW plugin.

   b) Set the destination folder. One option is to create a "Batch Output" folder on the Desktop.

   c) Check the "Override action 'Save as' commands" box.

   d) Set the file naming scheme so that the original file names are preserved.

16) The Droplet will now be saved to your Desktop and be available for use. Photos can be selected from within Windows Explorer and dragged onto the Droplet in order to batch process them all, and processed photos will appear in the "Batch Output" folder.

17) Move the processed .jpg images from the "Batch Output" folder to a folder with the following structure: LAI_data → LAI_processed_images → YYYY → eventID → plotID → image_type, where:

   a) YYYY = year images were taken,

   b) eventID = YYYYXX, where YYYY is the current year, and XX = bout # if plot type = Tower or XX = 00 if plot type = Distributed or Gradient,

   c) plotID = unique NEON plot ID, and

   d) image_type = a sub-folder named either "canopy" or "understory"

      i) Images in the "canopy" folder should contain *ONLY* canopy vegetation, and camera orientation may be either downward-facing or upward-facing.

         Example 1: Downward-facing DHPs of short-grass vegetation from the D10 CPER site are placed in the "canopy" folder.

         Example 2: Upward-facing DHPs of tree canopies from the D01 HARV site are placed in the "canopy" folder.

      ii) Images in the "understory" folder may contain understory only or understory + canopy, and camera orientation may be either downward-facing or upward-facing.

         Example 1: Downward-facing DHPs of herbaceous vegetation from a forested plot at the D01 HARV site are placed in the "understory" folder.

         Example 2: In a regenerating forested plot, upward-facing DHPs of herbaceous vegetation > 1 m height (camera placed on the ground), also including canopy vegetation are placed in the "understory" folder.

   e) Example: LAI_data → LAI_processed_images → 2013 → 201308 → SCBI_123 → Canopy

10.4.2 Image Processing in CanEye

Use CanEye software to analyze all of the upward-facing and all of the downward-facing photos from a given plot in separate batches.

It is necessary to analyze a minimum of 8 distinct images per batch in CanEye. This is because the software makes certain assumptions about the distribution of canopy gaps in the images, and these assumptions are violated when the image sample size drops below n=8. For most plots, images will be analyzed in batches of n=12.

1) Launch CanEye using the "Run as Administrator" command. To do this, right-click on the CanEye program icon and select "Run as Administrator".

2) From the menu bar, select "Hemispherical Images → RGB images", and then select either "Upward" or "Downward," depending on the type of images to be analyzed.

   a) The program may indicate "No directory selected" and return to the launch screen. This is a known bug, and if this happens, simply re-select the image type according to the step above, and a "Browse for Folder" window will appear.

3) Select the directory containing the images to be analyzed (the images previously processed through Photoshop). A "Can-Eye Parameterization" window will appear.

   a) In the comment field, enter the plot_ID, which is the same as the name of folder selected in step 2 above, and indicate whether the images are "upward" or "downward" facing.

   b) In the "Calibration Parameters" portion of the window, click "Create" under "Optical Center and Projection Function".

      i) Enter the line and column #s associated with the optical center of the image.

         (1) The value for "lines" = Total Line # / 2

         (2) The value for columns = Total Column # / 2

         (3) For the 2048 px × 1363 px images created in Photoshop, this corresponds to line = 681.5, and column = 1024.

      ii) Enter the Projection Function slope. This value describes the relationship between zenith angle and column #.

         (1) *Example:* For an image with 2048 pixels representing 180˚ of zenith view, the slope = 180/column # = 0.08789.

      iii) Click in the graph window, and see if the Projection Function displayed makes sense. It should be a straight line with a positive slope.

      iv) Click "OK".

   c) Returning to the "Calibration Parameters" window, enter the following values, overwriting existing values where necessary:

      i) COI (Circle of Interest) = 75˚

      ii) For "Angular Resolution":

(1) Azimuth = 5˚

(2) Enter the day of the year the images were collected, in Julian days. The correct Julian day can be found by checking the file creation date on one of the .RAW image files. Dates in YYYY-MM-DD format can be converted to Julian day by checking here: http://www-air.larc.nasa.gov/tools/jday.htm

(3) Enter latitude of image collection site – this can be determined from GPS data logged from camera (if images were acquired with a GPS enabled camera), or estimated from Google Earth using current NEON .kmz files for site locations.

d) Click the box to save data as an Excel file.

e) Click "Save". A window will open as the images are being processed.

4) Click "Save" parameter file.

5) A grid of images will appear – click "OK".

6) ***Image Masking:*** The masking process allows the analyzer to remove certain areas from individual images from the analysis process. Objects that should be masked include feet and legs, plot marker flags, and for downward-facing images, any upright (vertical) trunks and branches. DO NOT mask leaves that are attached to overhanging branches as these are NON-CANOPY leaves and should count toward the downward LAI value.

a) **If processing upward-facing photographs**, click "Done" on the screen with the grid of images. A color reduction process bar will appear.

i) *This step may crash the program if attempting to analyze images that are too large (file size), and there are significant number of masks.*

ii) If a crash occurs, reprocess the images and create lower quality JPG files using a different Photoshop droplet.

b) **If processing downward-facing photographs**, the following features should be masked: the photographer's feet, vertical boles/stems/branches, and plot markers/flags.To do this, click Select at the bottom, the click on the photo that you want to mask. Then click "Mask" and begin to draw an outline around the object by clicking around its perimeter.

c) Once you have traced around the entire object, right click on the mouse. For each object in the image that you want to mask, you will need to repeat this masking process. Once you have masked all the images in the set, click "Done" on the screen with the grid of images.

i) *The program may crash/freeze at this point.* When a crash occurs, It appears to depend either on how much total masked area is in the images, or the total number of masks. CanEye is typically able to analyze a given set of 12 images, but once the masks have been applied, it may no longer be able to process this same set of 12 images.

ii) The only solution discovered to date is to create a Photoshop Droplet that creates lower quality .jpg files (i.e. quality = 40, 20, etc.), re-process the set of images, and try again with CanEye.

7) The "Class Definition" window will appear. Select "This Option" from the right pane of the window. Click "Done".

8) A grid of images with a color grid on the right will appear.

9) Left-click on an image to view. Repeated left-clicking will zoom in, Shift-clicking will zoom out.

10) Assign appropriate colors to "Green" and "Soil"/"Sky" so that the pixels assigned to these categories stand out well compared to background colors. The following work well:

   a) Soil/Sky = Orange or yellow

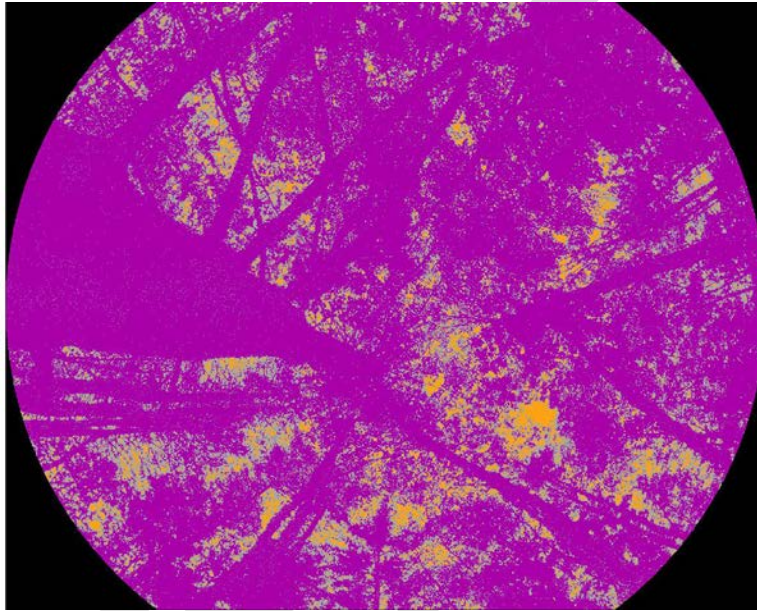   b) Plant material (Live Foliage, stems) = Purple

Figure 6. Example of a hemispherical image classified into sky (orange) and plant material (purple); ambiguous pixels the user has not categorized are classified as mixed (grey).

11) Pre-classify the images. Clicking on the radio box to the left of either of the "green" and "sky" boxes will open the Pre-classification window, **but only the first time** you click on a radio button.

   a) If classifying downward facing images, adjust the brightness slider all the way to the left for a value of 0. You do not want any pixels pre-classified.

   b) If classifying upward facing images, click on the radio box to the left of "sky" and move the brightness option all the way to the right for a value of 1.000. Then adjust the slider until areas highlighted and assigned to "Sky" become suspect, then back the slider off a little and click "OK."

12) Examine the color palette to the right of the images, and inspect the colors that have been assigned to the "green" and "sky/soil" categories. For each category, re-assign to "Mixed" any colors that seem like they may be ambiguous. Be very conservative in this step: it is better to err on the side of caution when assigning pixel colors to categories. To re-assign a color to "mixed":

   a) Select the radio button next to "Mixed".

   b) Click the colors in the palette that are ambiguous, then R-click.

c) Repeat as necessary.

13) ***For Downward facing images***, next assign colors to the "Soil" and "Green" categories:

   a) First assign colors to the "Soil" category:

      i) Select the radio button next to "Soil".

      ii) L-click in the images on pixels that are unambiguously soil.

      iii) R-click to apply the yellow color mask to see which pixels throughout the image set are selected.

      iv) Continue repeating "ii" and "iii" until all obvious and unambiguous soil pixels have been classified.

      v) **IMPORTANT**: Examine the pixels assigned to "Soil" in the color palette, and re-assign to "Mixed" any colors that seem like they may originate from plant leaves. Look for colors that seem greenish, even olive to drab olive and reassign to "Mixed."

   b) Next assign colors to the "Green" category:

      i) Select the radio button next to "Green".

      ii) L-click in the images on pixels that are unambiguously parts of living plant leaves. Do not click on leaf litter.

      iii) R-click to apply the purple color mask to see which pixels throughout the image set are selected.

      iv) Continue repeating "ii" and "iii" until all obvious and unambiguous plant leaf pixels have been classified.

      v) **IMPORTANT**:

         (1) When an image contains flowers (e.g. goldenrod), the flowers should be assigned to the green classification.

         (2) Examine the pixels assigned to "Green" in the color palette, and reassign to "Mixed" any colors that seem like they may originate from soil. Look specifically for colors that are grey and brown.

14) ***For Upward facing images***, assign colors to the "Sky" and "Green" categories. Follow the same general procedure outlined above for Downward facing images, making sure to reassign to "Mixed" any colors that are ambiguous.

15) Continue assigning pixels to "Sky/Soil", "Green", and "Mixed" until the "Mixed" pixels are 15% -20%.

16) Click "Done" at the bottom of the image grid.

   a) Finished classifying? → click "Yes".

   b) A series of computations are completed.

10.5 Data Handling

1) The CanEye image analysis procedure produces multiple plant area index (PAI) values, and these are reported in the output .xls file. PAI is roughly equivalent to LAI, but includes the contribution of non-leaf plant parts (i.e. stems and branches).

2) PAI values from the CanEye .xls output must be transcribed into the appropriate Excel spreadsheet for CI ingest.

3) When transcribing PAI values for the whole plot, **pai** is reported as follows:

   a) Forested canopy: **pai** = the "True PAI" value from the CEV5.1 row in the "PAI, ALA" tab (Figure 8).

   b) All other systems: **pai** = the "True PAI" value from the CEV6.1 row in the "PAI, ALA" tab (Figure 8).

Figure 7. Example "PAI, ALA" tab from CanEye output, showing different values of "True PAI".

4) When transcribing PAI values per point within plot, **pai** = the value from column C in the "P57 results" tab of the CanEye .xls output file that corresponds with the appropriate image file name (Figure 9).

   a) Use data from the "LAI QC datasheet" to match the image file name listed in the CanEye output to the appropriate **point_ID**.

Figure 8. Example "P57 results" tab from CanEye output. Column C shows PAI values associated with individual image files taken at specific points within the plot.

APPENDIX A   CONFIGURING THE NIKON D800 FOR LOW-LIGHT HEMISPHERICAL PHOTOGRAPHY

The Nikon D800 must be configured appropriately in order to take satisfactory images for LAI analysis with the CanEye software. There are several suites of settings that need to be adjusted prior to low-light shooting, and these can be grouped into a few general categories (see Table 3): settings adjusted with physical buttons and knobs, and settings adjusted with the playback, shooting, and setup menus. A customizable menu called "My menu" can also be modified so that frequently adjusted settings are readily available.

Settings Adjusted with Physical Knobs and Buttons

1) **Exposure Mode:** Desired setting = Manual (M) or Aperture Priority (A), depending on whether upward or downward-facing photos are taken, respectively. To adjust, press the **Mode** button, and rotate the primary wheel until the top LCD shows the desired mode.

2) **Shutter Mode**: Desired setting = S, single shot per press of the shutter-release button. To adjust, press the small button near the left control knob (below left), and rotate the outer-ring of the control knob until "S" is selected (below right).

3) **Focus Mode (Downward-facing photos):** Desired setting = AF-S Auto. To adjust, 1) set the focus switch to AF, 2) press the focus button in the middle of the switch (below left), and 3) spin both the primary and secondary wheels until the small LCD reads "AF-S" with "auto" above it (below right).

4) **Focus Mode (Upward-facing photos):** Desired setting = Manual. To adjust, 1) set the focus switch to M (below left), and 2) Rotate the focus ring on the lens to "∞" (below right).

5) **Image Quality:** Desired setting = RAW. To adjust, press the "QUAL" button on the left control knob (below left), and rotate the primary wheel until "RAW" is displayed in the top LCD (below right).

6) **White Balance**: Desired setting = Auto. To adjust, press the "WB" button on the left control knob (below left), and rotate the primary wheel until "A" is displayed in the top LCD (below right).

7) **ISO (Sensor light sensitivity):** Desired setting = variable.

    a) To adjust ISO when shooting in Manual Mode (M), press the "ISO" button on the left control knob (below left), and rotate the secondary wheel until "ISO" is displayed (not ISO-auto), then rotate the primary wheel until the desired ISO is displayed.

    b) To set the camera to "ISO-auto" mode with maximum sensor sensitivity (i.e. ISO=Hi2), press the ISO button on the left control knob, rotate the primary wheel until "Hi2" is displayed, then rotate the secondary wheel until "ISO-auto" is displayed in the top LCD.

    c) The ISO settings discussed here may also be adjusted by pressing the "**Menu**" button, then navigating to "Shooting Menu → ISO sensitivity settings".

8) **Metering Mode:** Desired setting = Matrix Metering. To adjust, rotate the outer-ring of the "AE-L/AF-L" button to the center position (see below).

Settings Adjusted with the Playback Menu

1) **Playback display options:** Desired setting = show "RGB histogram" and "Overview". To adjust:

   a) Press the **Menu** button, and then use the **Multi-Selector** to navigate to "Playback Menu →
   Playback display options".

   b) Use the **Multi-Selector** to check the box next to "RGB histogram" and "Overview".

   c) Navigate to "Done" and press the **OK** button.

   d) With the options in (b) selected, it is possible to obtain file name and histogram information
   about each image taken. To view this information:

   i) Press the **Play** button (below).

   ii) Use the ◀ and ▶ keys on the **Multi-Selector** to select the desired image.

   iii) Press the ▲ and ▼ keys on the **Multi-Selector** to bring up the "Overview" and "RGB
   histogram" information (below left, below right, respectively).

Settings Adjusted with the Shooting Menu

1) **File Naming:** Desired setting = DXX, where XX = the NEON Domain #. Press **Menu**, and select "Shooting Menu → File naming". Enter the appropriate alpha-numeric characters. When finished, the display should look like the image below: note "D10" is displayed instead of "DSC".


2) **Color Space:** Desired setting = sRGB. Press **Menu**, and select "Shooting Menu → Color space". Select "sRGB" and press the **OK** button.

3) **High ISO Noise Reduction (NR):** Desired setting = normal. Press **Menu**, and select "Shooting Menu → High ISO NR". Select "Normal" and press the **OK** button.

4) **ISO sensitivity settings:** Desired setting = Minimum shutter speed = 1/30. The other settings can be controlled with physical buttons as described above.
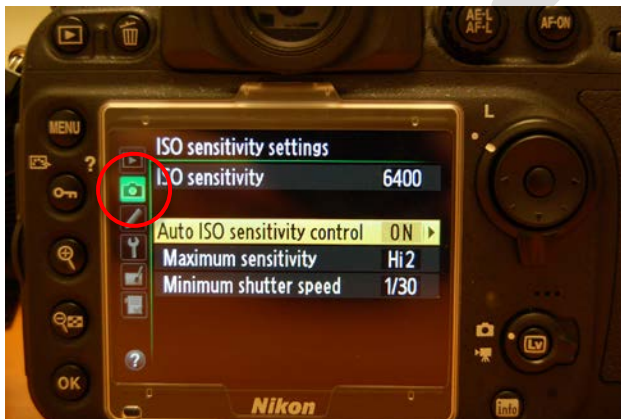
Settings Adjusted with the Setup Menu

1) **Time Zone and Date:** Desired settings =

    a) Correct time zone

    b) Correct local time and date

    c) Date format = Y/M/D

    d) Correct Daylight Savings Time – i.e. ON/OFF depending on time of year.

2) **Image comment:** Desired setting = current **plot_ID** where photos are being taken in the field.

    a) Press **Menu**, select "Setup Menu → Image comment"

    b) Select "Input comment" and erase the old **plot_ID.** Use the **Trash** button to delete characters at the cursor position.

    c) Use the specified keys to enter the current **plot_ID**.

    d) Select "Attach comment", then select "Done" and press the **OK** button.

Customizing My MENU

Any of the above menu options can be added to the customizable "My MENU" screen. The menu option that will be accessed most frequently is the "Image comment" setting. To add the "Image comment" settings to "My MENU":

1) Press **Menu**, then select "My MENU → Add items".

2) Scroll through the "Setup Menu" until you find "Image comment". Press the **OK** button.

3) Press **OK** again. The "My MENU" screen should now look like the image below.

APPENDIX B   LAI FIELD QC DATASHEET

This datasheet is provided for internal review and revision tracking purposes only. Do not print and use for data collection in the field.

Name:			Site:		
Plot ID:			Date:		
Start time:		End time:		Time zone:	

Below, "Point ID" is derived from the cardinal plot axes (N, S, E, W) and the distance from the plot center to the photo-point in meters.

Point ID	Camera orientation	Camera height	Image type	Image file name	Notes
N2	Upward		Canopy or Understory	DSC_0001	E.g.: Foliage too close to lens, moved 1 m to right of point.