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USDA LTAR Common Experiment measurement: PhenoCam for Green Chromatic Coordinate

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We use this protocol and it's working

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Abstract

Phenology is the study of seasonal dynamics and how environmental conditions such as temperature and rainfall influence it over different time periods. In the case of plants, phenology is a primary control of productivity. Phenology can be studied through color-based image analysis using a digital camera (**PhenoCam**) most commonly mounted on a tower that captures time-lapse photographs of vegetation canopies. Metrics of canopy greenness can be calculated from PhenoCam imagery as a continuous record of canopy and surface greenness. The most commonly used greenness metric is the green chromatic coordinate (G_{CC}), which is similar to the normalized difference vegetation index derived from satellite remote sensing. PhenoCam images provide unique insights into vegetation dynamics at a daily time step and the associated ecosystem metrics affected by management and climate change.

Protocol

30m

1 Camera installation, operation, and maintenance

1.1 A Stardot camera (model NetCam-SC-IR) is installed at meteorological and flux tower locations at an appropriate height above the vegetation canopy, facing north to minimize sun angle effects throughout the year.

1.2 When selecting the location to install a camera (if not on an established tower), the best practice is to ensure the landscape the camera is focused on (i.e., the field of view) represents the surrounding landscape across which measurements are made.

1.3 Landscape views are most common and work well with flux tower applications. Some (relatively few) smaller-scale, experimental PhenoCam installations focus on small plots or individual plants. These installations are prone to challenges with shadows and limit extrapolation of results.

1.4 For a given installation, the camera is oriented approximately 15° off the horizon so that more foreground than sky is in the field of view, i.e., a small portion of the sky is viewed at the top of an image.

1.5 The camera is connected to a laptop PC, and the PhenoCam installation tool (**PIT**) is run to automatically capture red–green–blue (RGB) and IR images every 30 minutes.

1.6 Images and metadata files are transferred via secure protocol to the PhenoCam Network at Northern Arizona University.

1.7 Clean the glass on the housing with a lint-free cloth and distilled or deionized water. Do not wipe the glass surface when dry. After removing dirt from the glass with water, clean the glass with 95% ethanol and clean lint-free cloth. Complete the cleaning process by removing the remaining dust or lint with a can of compressed air. Repeat this cleaning procedure quarterly or as needed, particularly after field operations such as planting and harvesting.

2 Image metadata

2.1 Image metadata include camera name, camera type, datetime, and camera temperature. The PhenoCam Network populates metadata. The investigator provides additional metadata, such as primary species and latitude and longitude, when the site is established.

3 Calculations

3.1 The camera captures the RGB additive color seen by the human eye. The color and brightness of a given pixel are recorded as a digital number (DN).

3.2 The green chromatic coordinate (GCC) is calculated as the quotient of the intensity of green relative to the total intensity of red, green, and blue:
$G_{CC} = G_{DN} / (R_{DN} + G_{DN} + B_{DN})$ [1]
where G_{DN}, R_{DN}, and B_{DN} are the digital numbers (DN) of green, red, and blue, respectively summarized for DN values within the region of interest (ROI).

3.3 The PhenoCam Network or site scientist can annotate the ROIs.

3.4 An ROI's G_{CC} is calculated as part of the PhenoCam Network data production protocol.

4 Quality assessment and quality control

4.1 Images are evaluated by QA/QC test per PhenoCam Network protocols.

4.2 Protocols established by the PhenoCam Network automatically notify site contacts after three, five, and ten days without receiving image data. Site scientists or field personnel should evaluate and remedy field conditions in this case. Site personnel are encouraged to check the status of the image time series on the PhenoCam Network regularly (daily or weekly) for streaming and image quality. The latest images are shown here: **https://phenocam.nau.edu/webcam/sites/sitename/**, where "sitename" is the PhenoCam site name. Site cameras can be found by searching the site name here: https://phenocam.nau.edu/webcam/network/search/.

5 Image archiving

5.1 The PhenoCam Network currently sustains the Long-Term Agricultural Research (LTAR) network PhenoCam image archive, metadata, and data products using two strategies: redundancy and backup. The primary archive is housed in a climate-controlled and access-restricted machine room, and a mirrored backup is maintained on NAU's Monsoon cluster.

5.2 In addition, LTAR has established a mirror of image data and derived data products from the PhenoCam Network to the USDA SCINet Juno servers as a secure backup and archive, backed up every two days.

Illustrative Information

6 Primary productivity (photosynthesis) and G_{CC} are strongly correlated among ecosystems, including forests, shrublands, and grasslands (Fig. 6; Richardson, 2023b). In conjunction with eddy covariance measurements, G_{CC} can be used to predict water and carbon fluxes as influenced by contrasting management practices within and across agroecosystems (Browning et al., 2021).

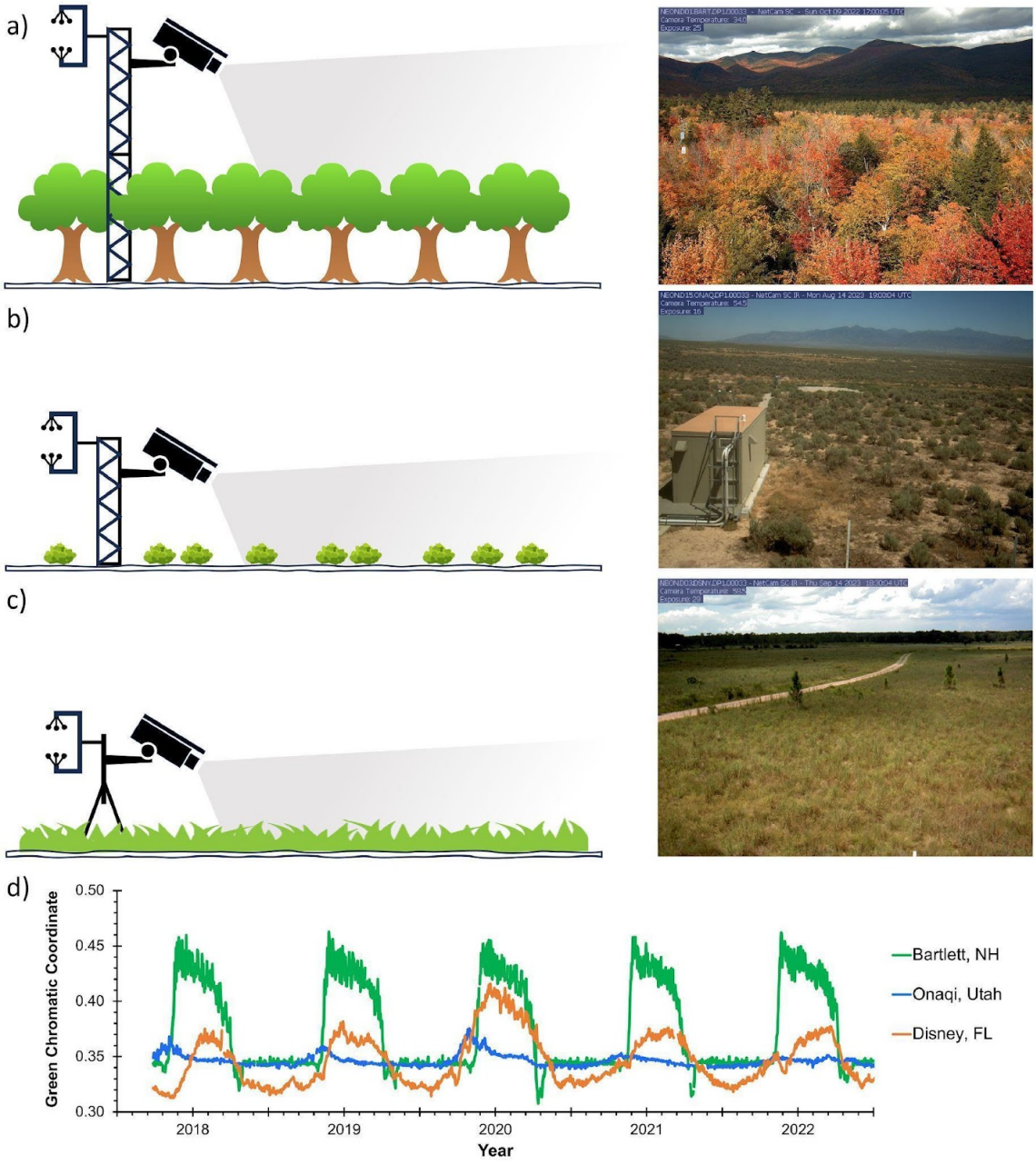

Figure 1. Examples of PhenoCam installations in three ecosystem types: a) a 30+ m tower above forest canopy (Bartlett, NH), b) a 10+ m tower in desert shrubland (Onaqi, UT), and c) a 3+ m tripod in temperate grassland (Disney, FL). d) Green chromatic coordinate (G_{CC}) data during a five-year period illustrate the differences in timing, magnitude, and regularity of phenology across ecosystem types (adapted from Richardson, 2023b).

Accessing PhenoCam Data

7

- **Version 2** of the PhenoCam dataset has been published (Seyednasrollah et al., 2019).
- Richardson (2023a) describes a very detailed **tutorial** on how to access PhenoCam data.

- Daily G_{CC} and other products are accessed through a "**Gallery**" of PhenoCam sites; a site is searched and found by geography (map) or name.
- Within a site's webpage is a link to the "ROI Timeseries" that is selected (mouse-clicked) to view a graph of daily G_{CC}, as exemplified in Fig. 7.
- Selecting/clicking the link to "Provisional Data" opens a dialog to download a compressed file (*provisional_data*.zip) containing data folders and documentation (README.txt and fair use policy).
- The National Ecological Observatory Network (**NEON**) also provides access to PhenoCam provisional data.

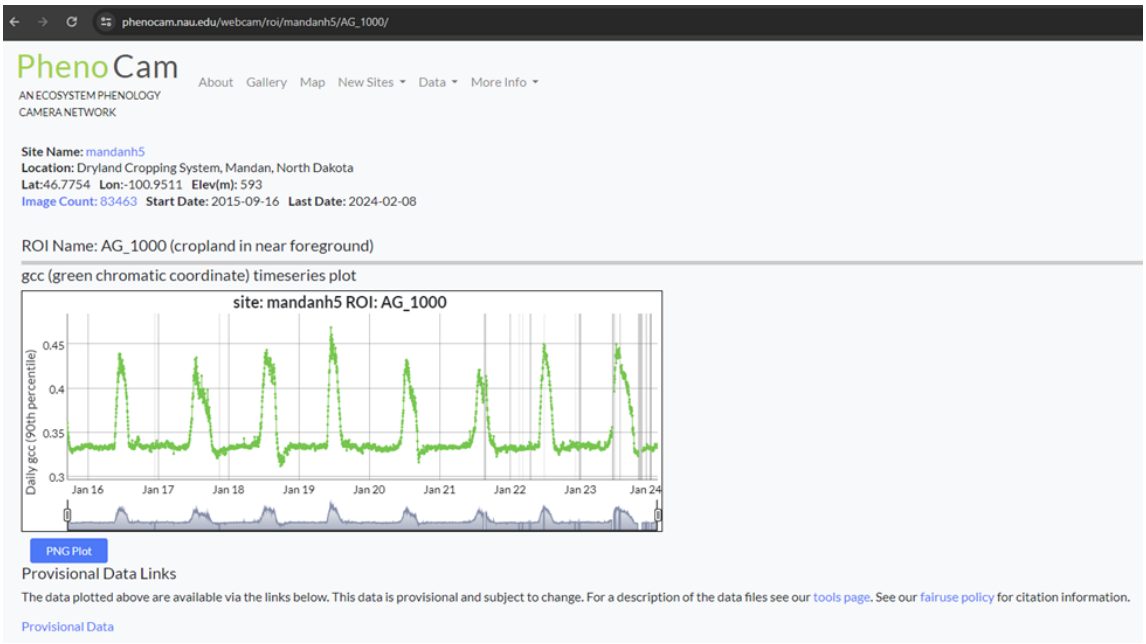

Figure 2. Screenshot of a webpage for an LTAR site ("mandani2") displaying daily G_{CC} (green line-dots). The link for "Provisional Data" in the lower left corner provides access to daily PhenoCam data, including G_{CC} for the entire duration of a PhenoCam site.

Recommendations for data collection

8 Table 1. Summary of recommendations for measurement of PhenoCam attributes.

	A	B	C	D
	Attribute	Preferred	Minimum	Comments
	Spatial scale	Plot or field; field of view or region of interest (ROI); the camera height determines the size of the ROI; a higher c	The camera height must be at least 2 m above the vegetation canopy	

	A	B	C	D
		amera height implies a greater ROI or field of view		
	Frequency	Photograph taken every 30 minutes in daytime and uploaded to the PhenoCam Network	Photograph taken every 30 minutes in daytime and uploaded to the PhenoCam Network via cellular service and router (PIT)	Other methods for transmitting images using a data logger are available here.
	Covariate metrics	Soil moisture; eddy covariance sensors to measure fluxes of CO2 and H2O or latent heat, sensible heat; above-ground biomass, leaf area index, and canopy height	Meteorological station within 1 km to include precipitation, air temperature, and relative humidity	Meteorological station within 3 km at a minimum

Protocol references

1. Browning, D.M., E.S. Russell, G.E. Ponce-Campos, N. Kaplan, A.D. Richardson, B. Seyednasrollah, S. Spiegal, N. Saliendra, J.G. Alfieri, J. Baker, C. Bernacchi, B.T. Bestelmeyer, D. Bosch, E.H. Boughton, R.K. Boughton, P. Clark, G. Flerchinger, N. Gomez-Casanovas, S. Goslee, N.M. Haddad, D. Hoover, A. Jaradat, M. Mauritz, G.W. McCarty, G.R. Miller, J. Sadler, A. Saha, R.L. Scott, A. Suyker, C. Tweedie, J.D. Wood, X. Zhang, S.D. Taylor. 2021. Monitoring agroecosystem productivity and phenology at a national scale: A metric assessment framework. Ecological Indicators 131, 108147. **10.1016/j.ecolind.2021.108147**

2. NEON (National Ecological Observatory Network). Phenology images (DP1.00033.001), provisional data. Dataset accessed from **https://data.neonscience.org/data-products/DP1.00033.001** on February 12, 2024.

3. Richardson, A. 2023a. How to access PhenoCam data and imagery: A tutorial, 47 pp. https://phenocam.nau.edu/education/PhenoCam_Access_Guide.pdf

4. Richardson, A.D. 2023b. PhenoCam: An evolving, open-source tool to study the temporal and spatial variability of ecosystem-scale phenology. Agricultural and Forest Meteorology 342, 109751. https://doi.org/10.1016/j.agrformet.2023.109751

5. Seyednasrollah, B., A.M. Young, K. Hufkens, T. Milliman, M.A. Friedl, S. Frolking, A.D. Richardson, M. Abraha, D.W. Allen, M. Apple, M.A. Arain, J. Baker, J.M. Baker, D. Baldocchi, C.J. Bernacchi, J. Bhattacharjee, P. Blanken, D.D. Bosch, R. Boughton, E.H. Boughton, R.F. Brown, D.M. Browning, N. Brunsell, S.P. Burns, M. Cavagna, H. Chu, P.E. Clark, B.J. Conrad, E. Cremonese, D. Debinski, A.R. Desai, R. Diaz-Delgado, L. Duchesne, A.L. Dunn, D.M. Eissenstat, T. El-Madany, D.S.S. Ellum, S.M. Ernest, A. Esposito, L. Fenstermaker, L.B. Flanagan, B. Forsythe, J. Gallagher, D. Gianelle, T. Griffis, P. Groffman, L. Gu, J. Guillemot, M. Halpin, P.J. Hanson, D. Hemming, A.A. Hove, E.R. Humphreys, A. Jaimes-Hernandez, A.A. Jaradat, J. Johnson, E. Keel, V.R. Kelly, J.W. Kirchner, P.B. Kirchner, M. Knapp, M. Krassovski, O. Langvall, G. Lanthier, G.l. Maire, E. Magliulo, T.A. Martin, B. McNeil, G.A. Meyer, M. Migliavacca, B.P. Mohanty, C.E. Moore, R. Mudd, J.W. Munger, Z.E. Murrell, Z. Nesic, H.S. Neufeld, T.L. O'Halloran, W. Oechel, A.C. Oishi, W.W. Oswald, T.D. Perkins, M.L. Reba, B. Rundquist, B.R. Runkle, E.S. Russell, E.J. Sadler, A. Saha, N.Z. Saliendra, L. Schmalbeck, M.D. Schwartz, R.L. Scott, E.M. Smith, O. Sonnentag, P. Stoy, S. Strachan, K. Suvocarev, J.E. Thom, R.Q. Thomas, A.K. Van den berg, R. Vargas, J. Verfaillie, C.S. Vogel, J.J. Walker, N. Webb, P. Wetzel, S. Weyers, A.V. Whipple, T.G. Whitham, G. Wohlfahrt, J.D. Wood, S. Wolf, J. Yang, X. Yang, G. Yenni, Y. Zhang, Q. Zhang, and D. Zona. 2019. PhenoCam Dataset v2.0: Vegetation Phenology from Digital Camera Imagery, 2000-2018. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1674

Illustrative Media

PhenoCam – An Ecosystem Phenology Camera Network (**https://phenocam.nau.edu/webcam/**)

- PhenoCam tutorial available under ‘More Info’ tab.