Tropical leaf phenology characterization by using an ecologically-constrained deep learning model with PlanetScope satellites

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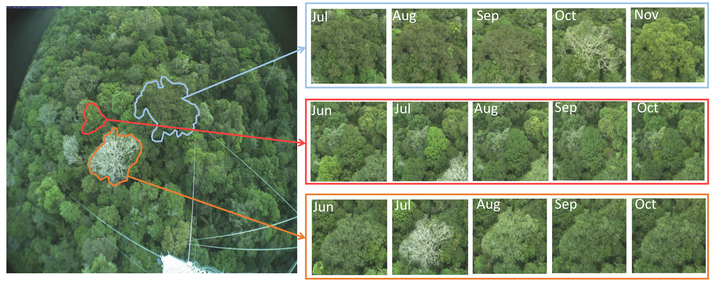
Introduction

- The tropical forest shows an evergreen landscape with strong internal dynamics.
- Phenocams help characterize such internal dynamics but with limitations (i.e. limited sites and small coverages).

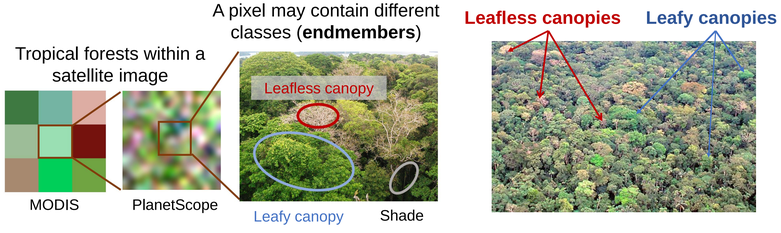


Source: Phenocam data (2013-2014) at a central Amazonian rainforest, Credit: Bruce Nelson

- PlanetScope offers opportunities to monitor internal dynamics (tropical deciduousness phenology) across pan-tropics

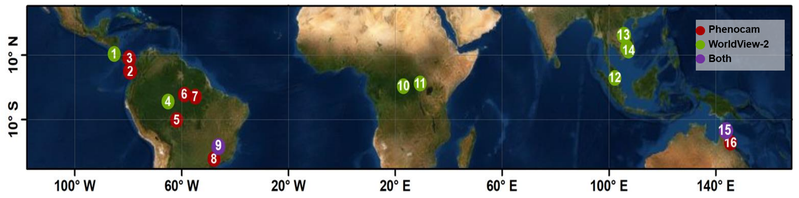
Knowledge gaps

- Using spectral unmixing to monitor tropical deciduousness with PlanetScope data.
  - $Pixel\ Reflectance = \mathbf{D\%} \times \mathbf{R_{leafless}} + \mathbf{E\%} \times \mathbf{R_{leafy}} + \mathbf{S\%} \times \mathbf{R_{Shade}}$
  - $\mathbf{D\%}$: the abundance of leafless abundance, $\mathbf{R_{leafless}}$: the reflectance of leafless pixel
- **Spectral variability** within each endmember across tropics.



Study sites & Materials

- 16 tropical forest sites across different continents
  - Across large rainfall gradient from 1470 to 2819 mm y^{-1}

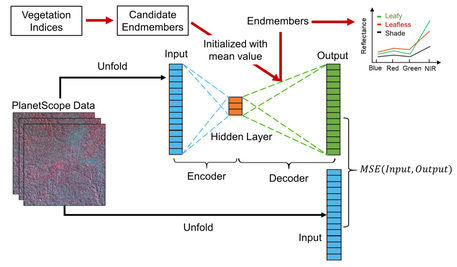


- Benchmark data
  - Time-series phenocam observations
  - WorldView-2 image (0.5m; 5km*5km)
- PlanetScope
  - The closet years as benchmark data
  - 5km*5km

Method & Evaluation

- **IG-ECAE Model** (two-step unsupervised deep learning model)

(1) Model Structure



(2) Process procedures

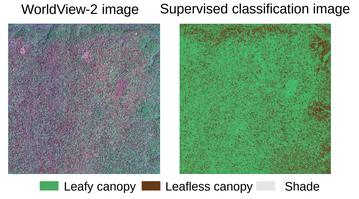
Step1: screen candidate endmembers using vegetation indices (EVI, NDVI etc.)

Step 2: determine "true" endmembers with a deep-learning method (i.e. autoencoder that minimizes the difference between input and approximate output)

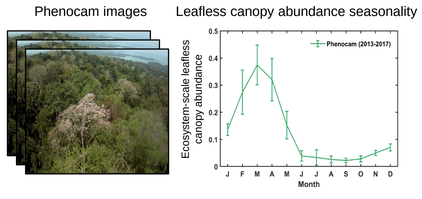
Ecological Constraints
- The rule of leafy, leafless and shade spectra e.g. NIRe > NIRd > NIRs)
- Refine endmembers within the spectral range of all candidate endmembers

- Evaluating the PlanetScope-derived deciduousness with WorldView-2 and phenocam-derived deciduousness.

Spatial Evaluation



Temporal Evaluation



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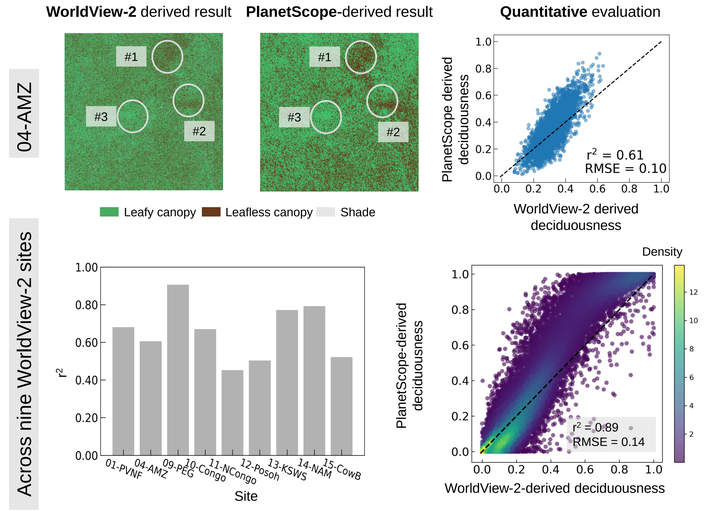
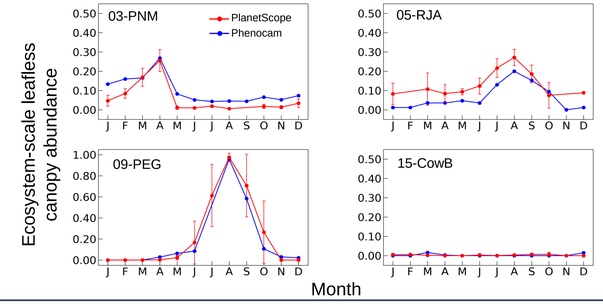
Results

- Deciduousness abundance derived from PlanetScope show a strong agreement with those derived from WorldView-2.



- PlanetScope-derived deciduousness captures the similar ecosystem-scale seasonality as those captured by phenocams.



Conclusion

- Within a forest, the IG-ECAE model can accurately capture spatial variability and ecosystem-scale seasonal trends in deciduousness.
- Across forests, the proposed integration can work consistently well across large environmental gradients.

Please refer to Wang#, Song#,et al, 2023, RSE, https://doi.org/10.1016/j.rse.2022.113429 for more information. *(# denotes equal contribution)*