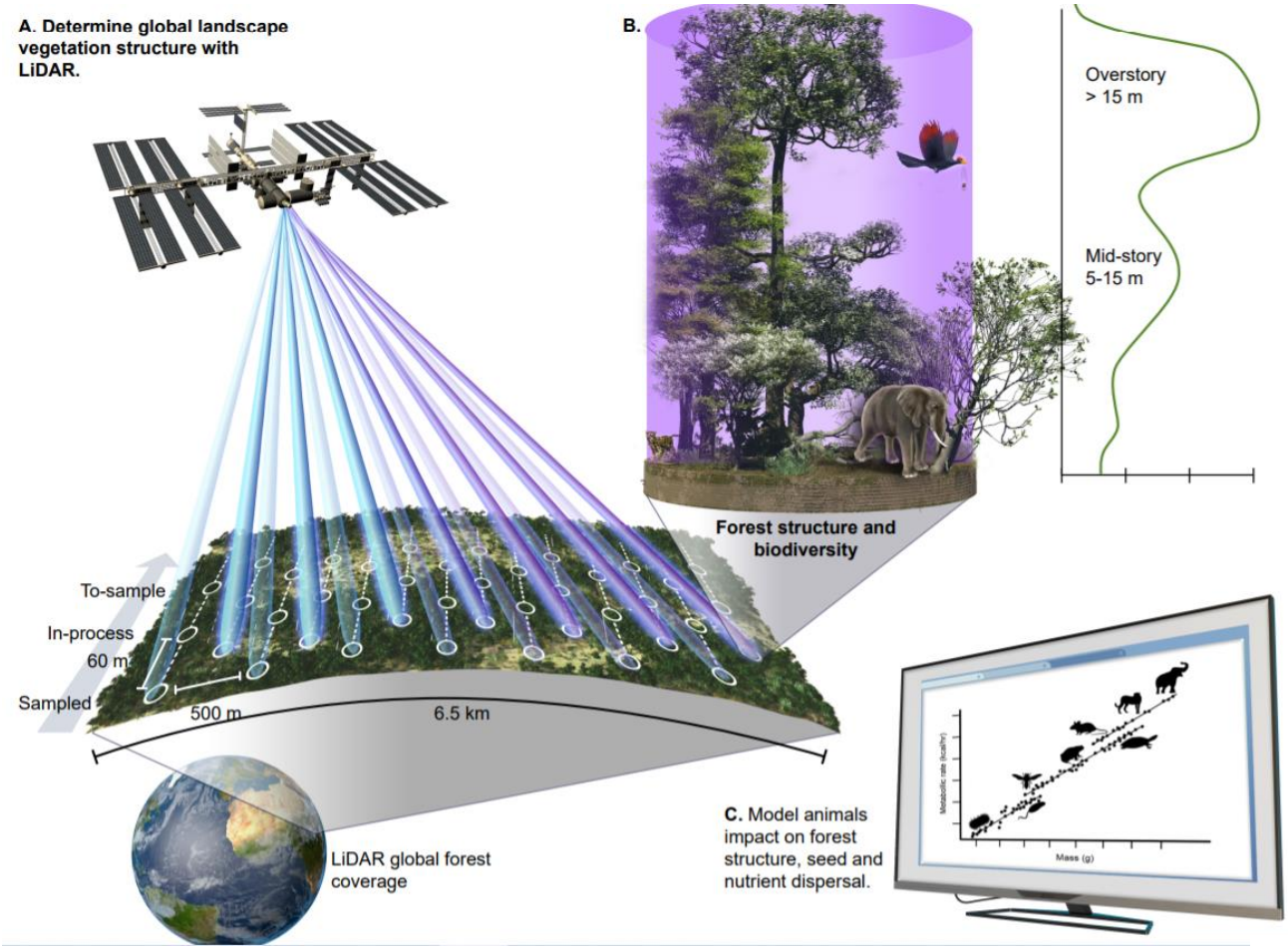
Putting animals into Earth System Science



Chris Doughty[1], Camille Gaillard[1], Jenna Keany[1], Andrew Abraham[1], Scott Goetz[1], Patrick Jantz[1], Patrick Burns[1], Toby Jackson[2], Luca Santini[3], Mike Harfoot[4],

Northern Arizona University[1], Cambridge[2], Sapienza University [3], *UNEP-WCMC[4]*

NAU Northern Arizona University

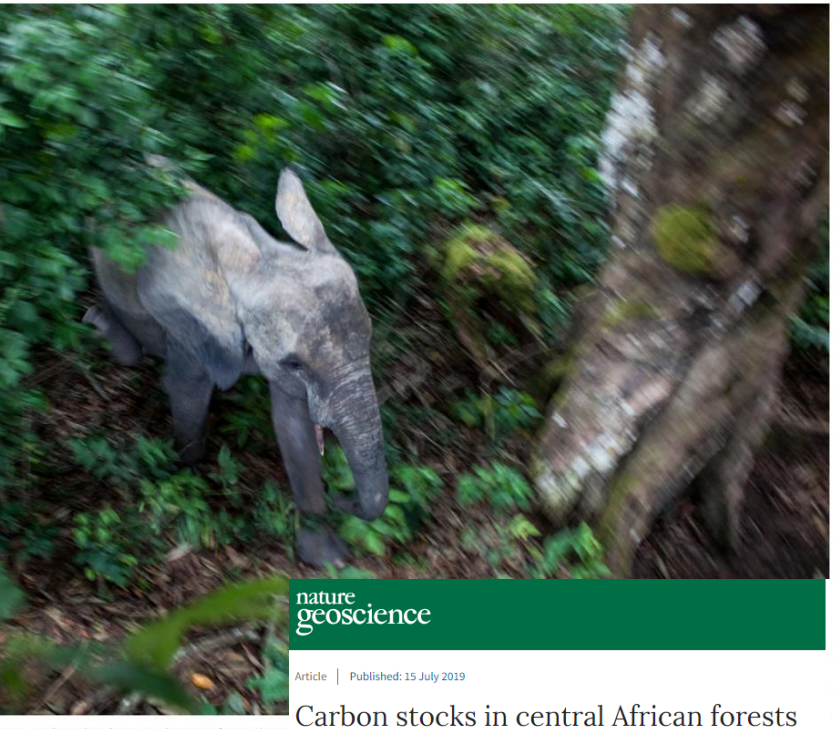
Ecological and Environmental Informatics

The Madingley Model

Animals impact global nutrient and carbon cycles

The Thick Gray Line: Forest Elephants Defend Against Climate Change

If the species is wiped out by poachers, Africa's vast rain forest will lose 7 percent of its carbon storage ability, scientists estimate.



Reserve in Gabon in 2012. There are fewer than 1 abon. Tyler Hicks/The New York Times

By Rachel Nuwer

Aug. 19, 2019

nature geoscience

Article | Published: 15 July 2019

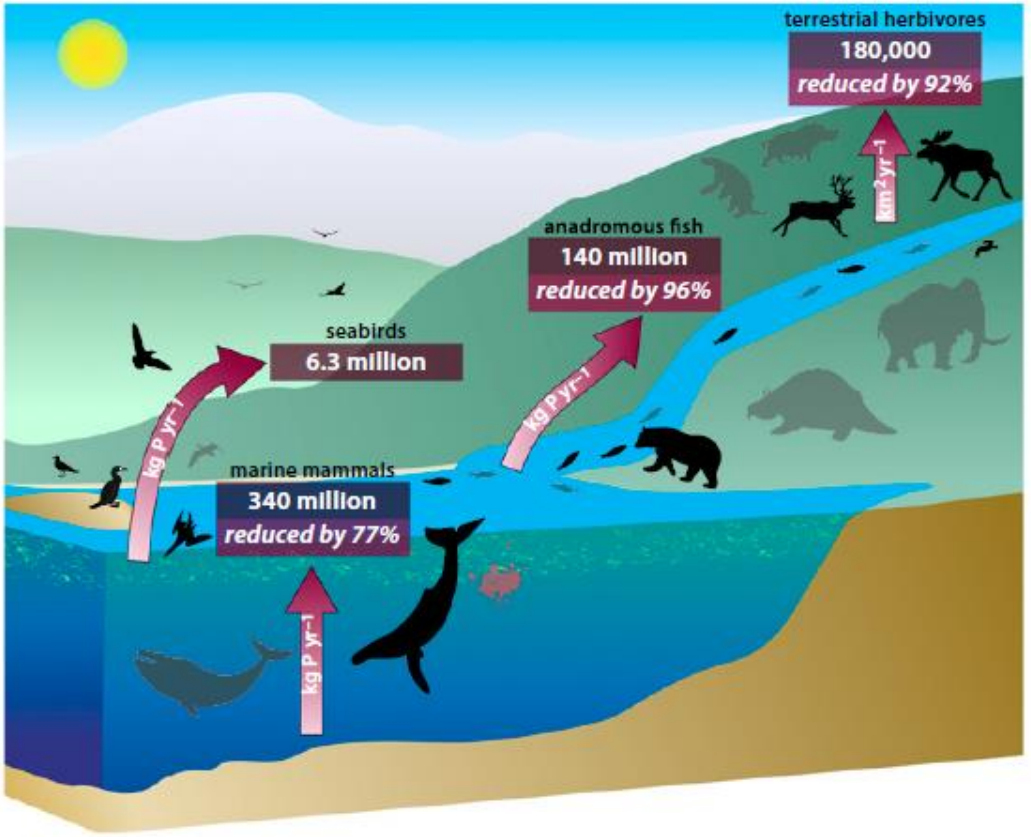
Carbon stocks in central African forests enhanced by elephant disturbance

Fabio Berzaghi, Marcos Longo, Philippe Ciais, Stephen Blake, François Bretagnolle, Simone Vieira, Marcos Scaranello, Giuseppe Scarascia-Mugnozza & Christopher E. Doughty

Nature Geoscience (2019) | Download Citation

Global nutrient transport in a world of giants

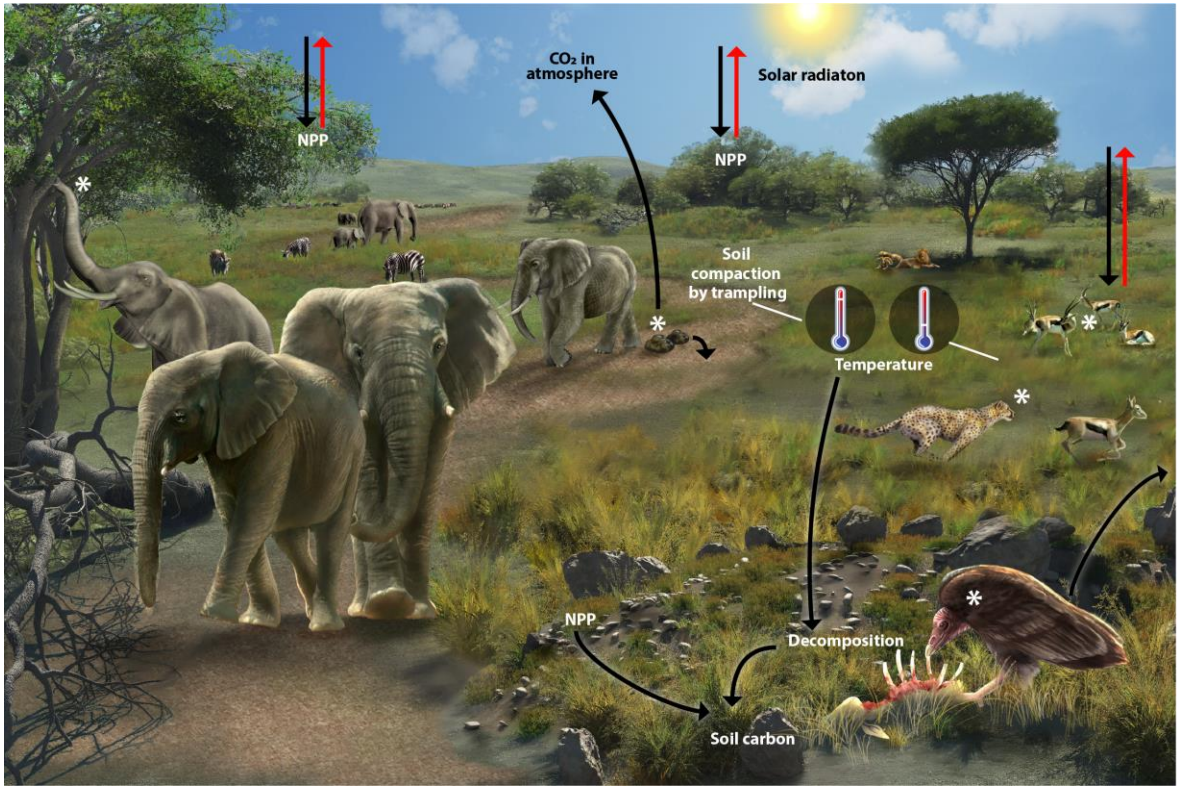
Christopher E. Doughty[a,1], Joe Roman[b,c], Søren Faurby[d], Adam Wolf[e], Alifa Haque[a], Elisabeth S. Bakker[f], Yadvinder Malhi[a], John B. Dunning Jr.[g], and Jens-Christian Svenning[d]



- What about:
- Landscapes of fear?
- Human influences?
- Climate change?
- The combined influences?

- We need a global mechanistic model

- Predation influences movement and biogeochemical patterns.
- Humans impact movement patterns.
- Temperature impact ecto and endotherms differently.



Schmitz et al. (2018), *Science*

The Madingley Model

Madingley General Ecosystem Model

OPEN ACCESS Freely available online

PLOS | BIOLOGY

Emergent Global Patterns of Ecosystem Structure and Function from a Mechanistic General Ecosystem Model

Michael B. J. Harfoot[1,2☯*], Tim Newbold[1,2☯], Derek P. Tittensor[1,2,3☯], Stephen Emmott[2], Jon Hutton[1], Vassily Lyutsarev[2], Matthew J. Smith[2], Jörn P. W. Scharlemann[1,4], Drew W. Purves[2]

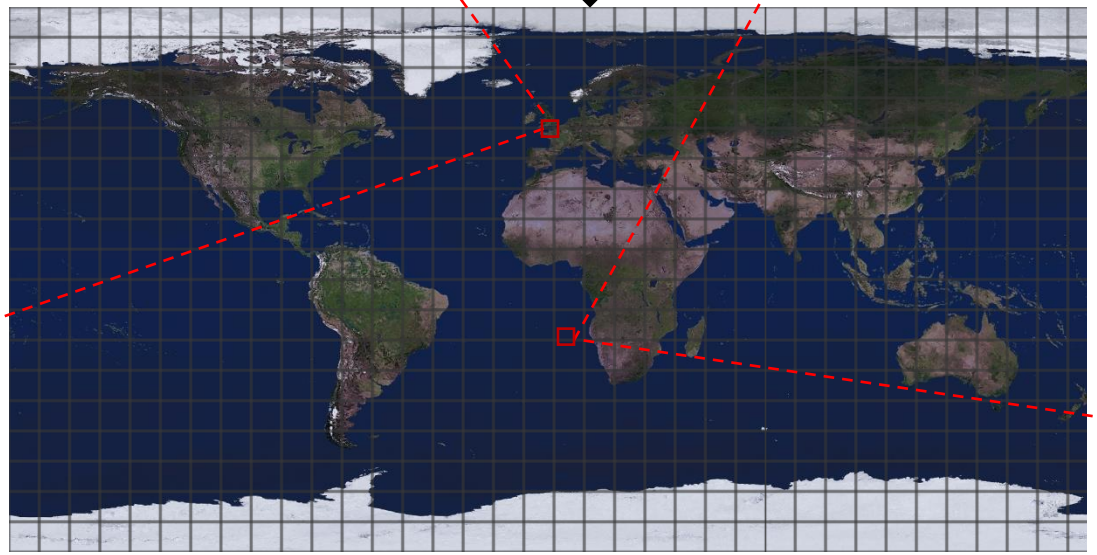
April 2014 | Volume 12 | Issue 4 | e1001841

The Madingley Model

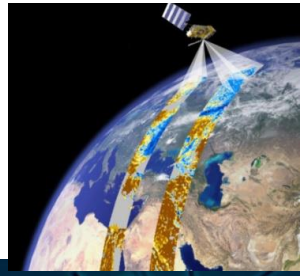
Terrestrial: data constrained carbon model (Smith *et al.*, 2013 Biogeosciences)

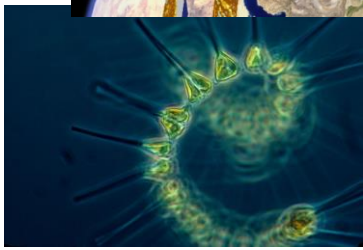
Realistic geography, ocean circulation, environmental conditions (air & ocean temperature, precipitation)

+

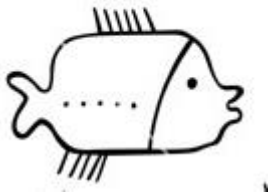


Marine: remotely sensed phytoplankton concentration

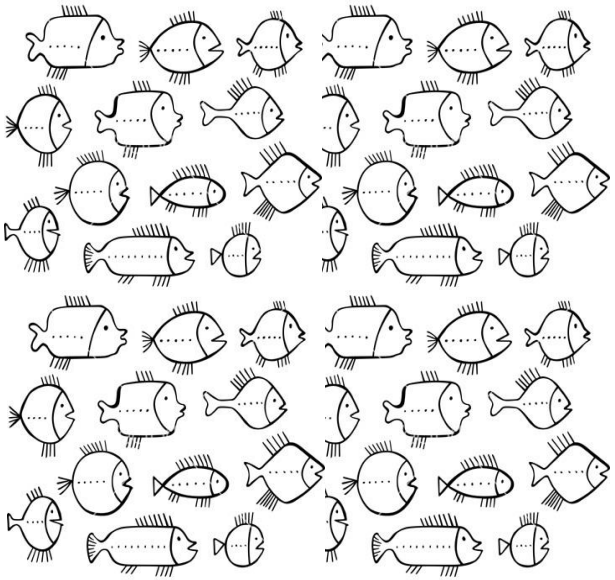




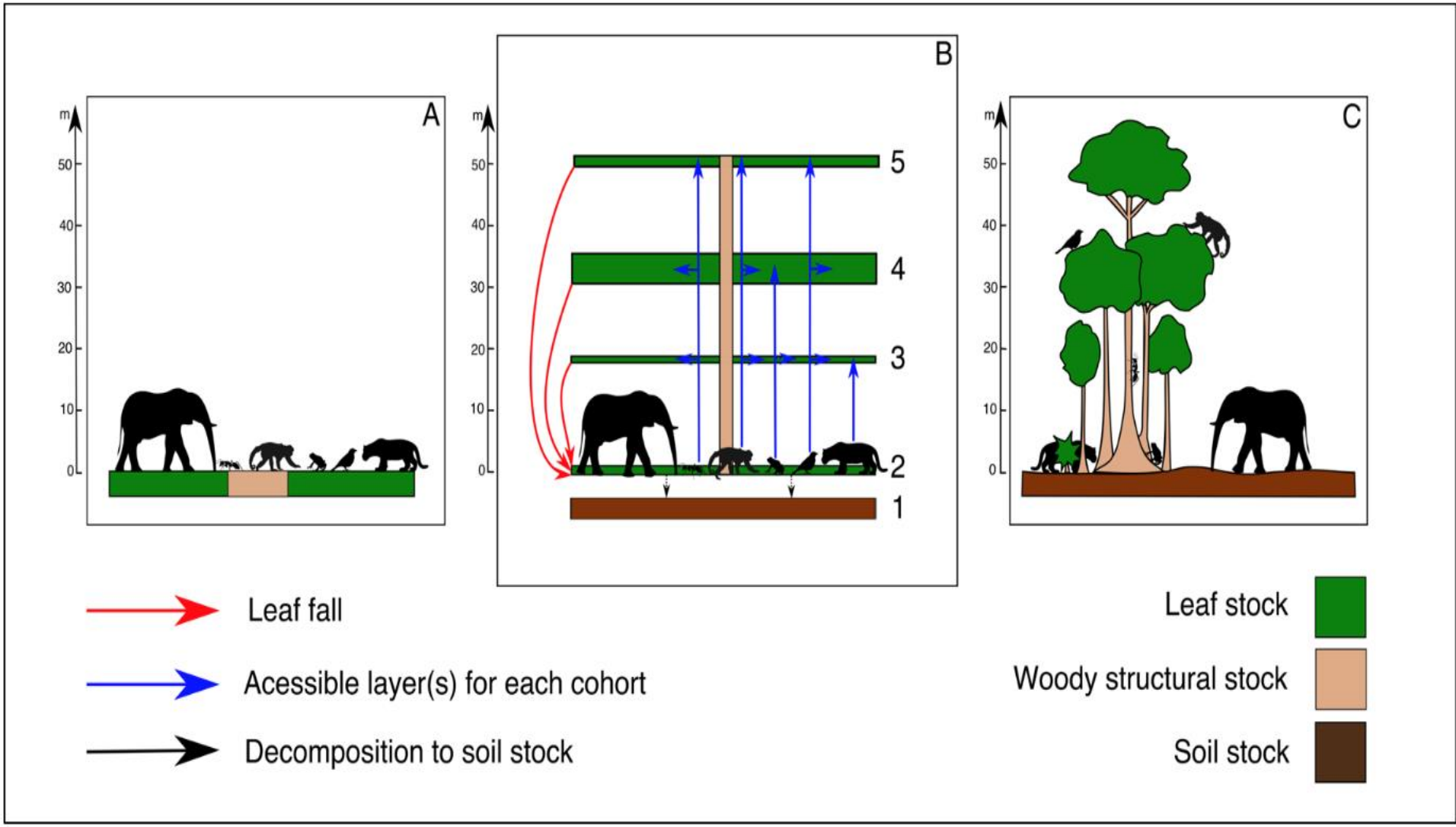
Animals – cohort-based approach



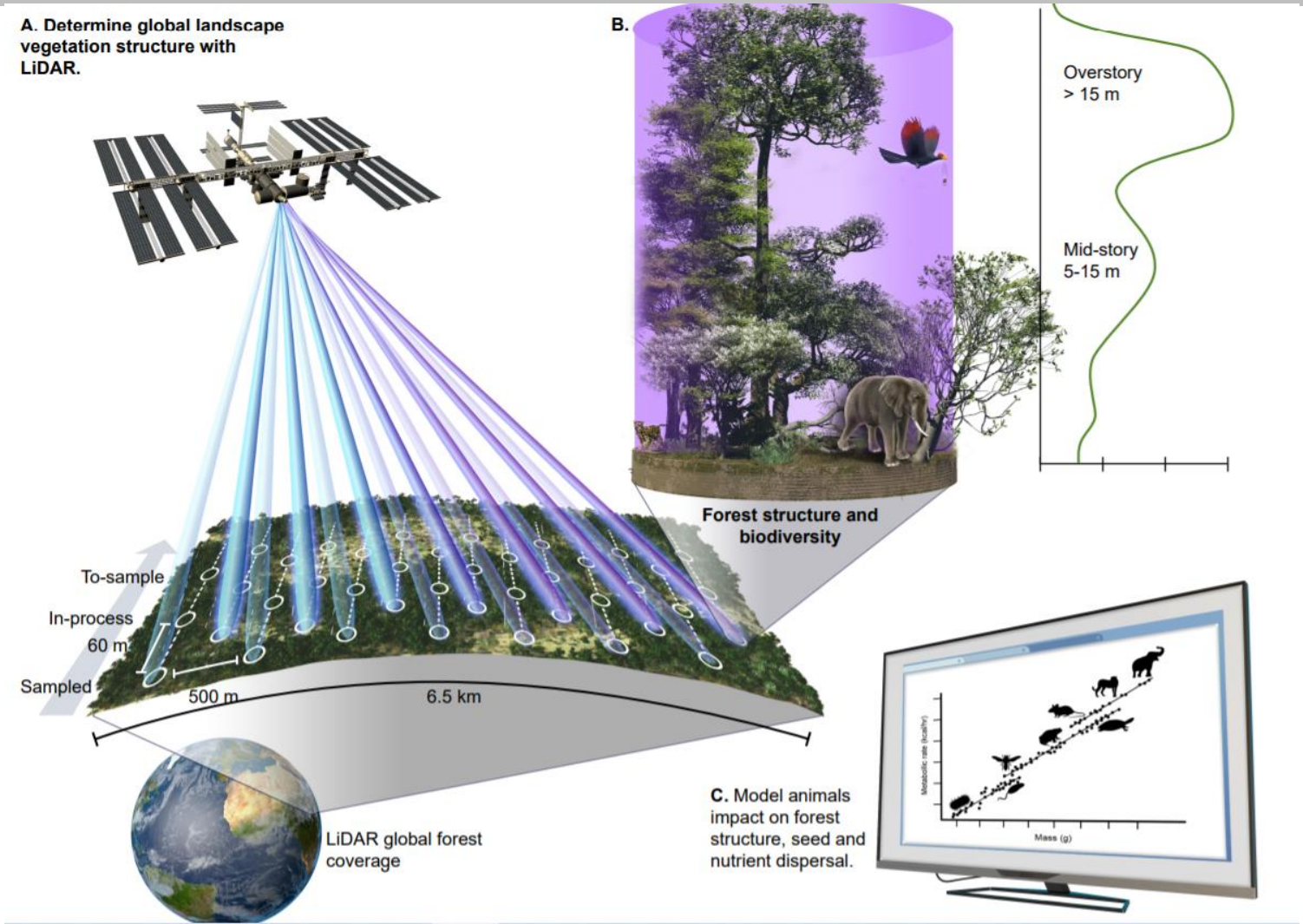
Herbivore / omnivore / carnivore
Ecotherm / Endotherm
Active disperser / passive disperser
Iteroparous / semelparous
Adult body mass
Juvenile body mass
Current body mass



Herbivore / omnivore / carnivore
Ecotherm / Endotherm
Active disperser / passive disperser
Iteroparous / semelparous
Adult body mass
Juvenile body mass
Current body mass
Abundance

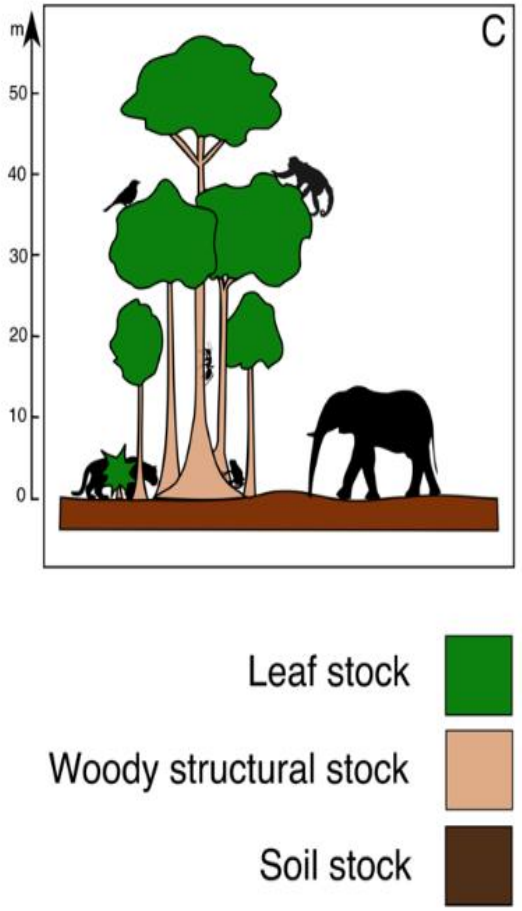

A
B
C
m
50
40
30
20
10
0
5
4
3
2
1
Leaf fall
Acessible layer(s) for each cohort
Decomposition to soil stock
Leaf stock
Woody structural stock
Soil stock

Adding space-based vegetation structure measurements to a global ecosystem model to simulate tropical forest animal communities and their role in ecosystem function

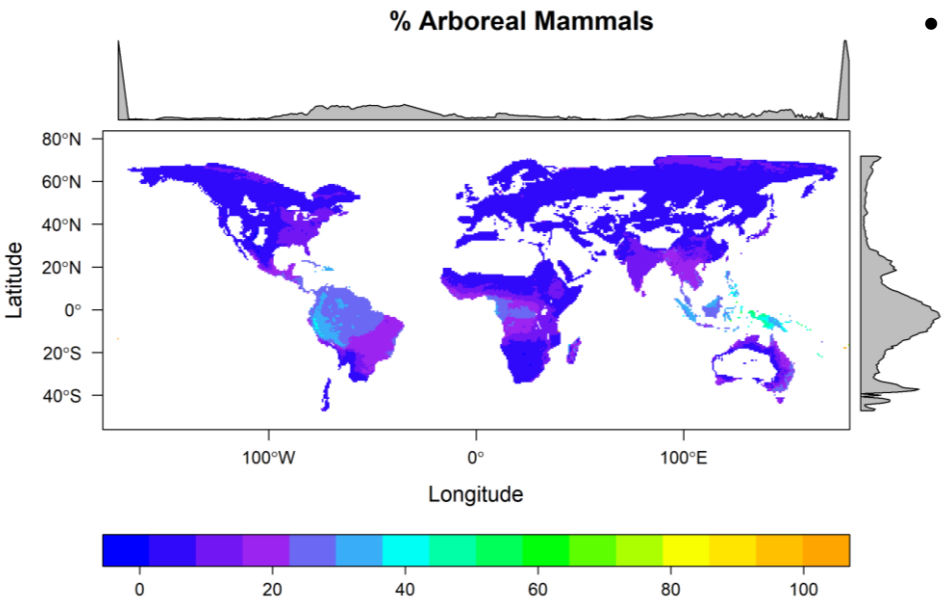


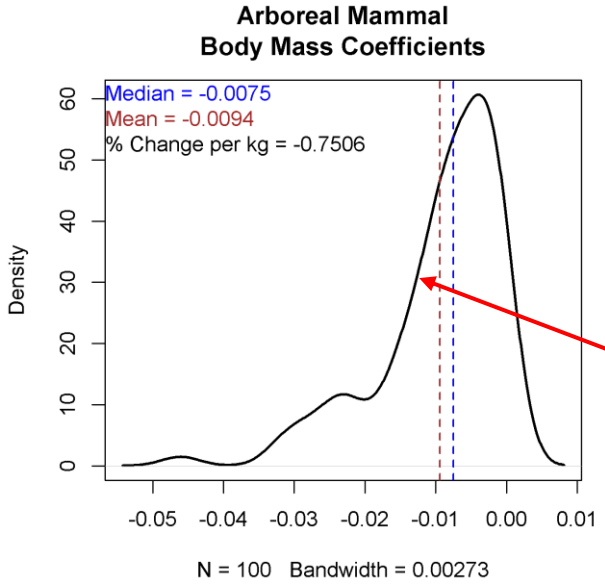
Project goals

- Add climbing cohort and GEDI data to Madingley.
- Add ecosystem engineer cohort to Madingley.
- Understand role of forest structure on composition.
- Provide RCP scenarios and EBVs to key stakeholders in Gabon, Peru, and Brazil



What traits are important for arboreality?





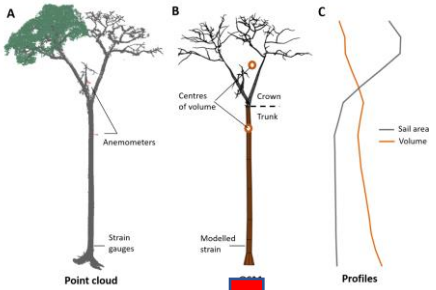
- % nectar and fruit in diet are most important functional traits positively associated with arboreal mammals.
- Less important, but positive is predation pressure.
- ~1% decrease in arboreality per kg increase in body mass.

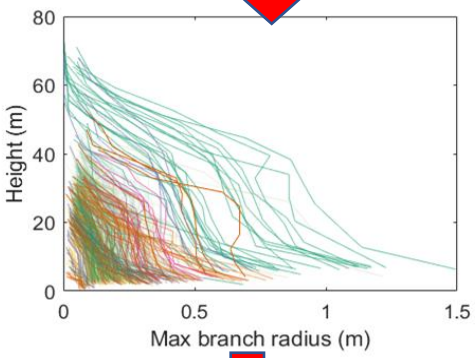
Jantz et al for SI ERE

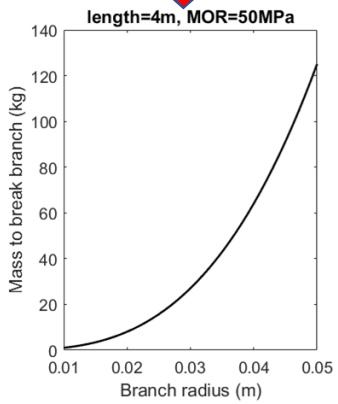
Add climbing cohort and GEDI data to Madingley.

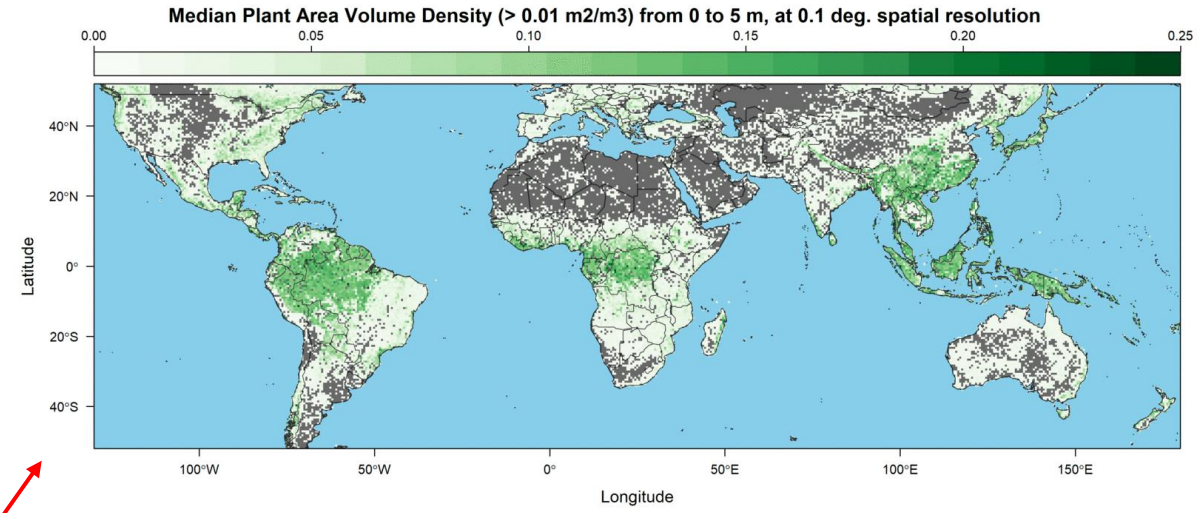
Linking vegetation height to branch strength

Terrestrial Lidar Scanning

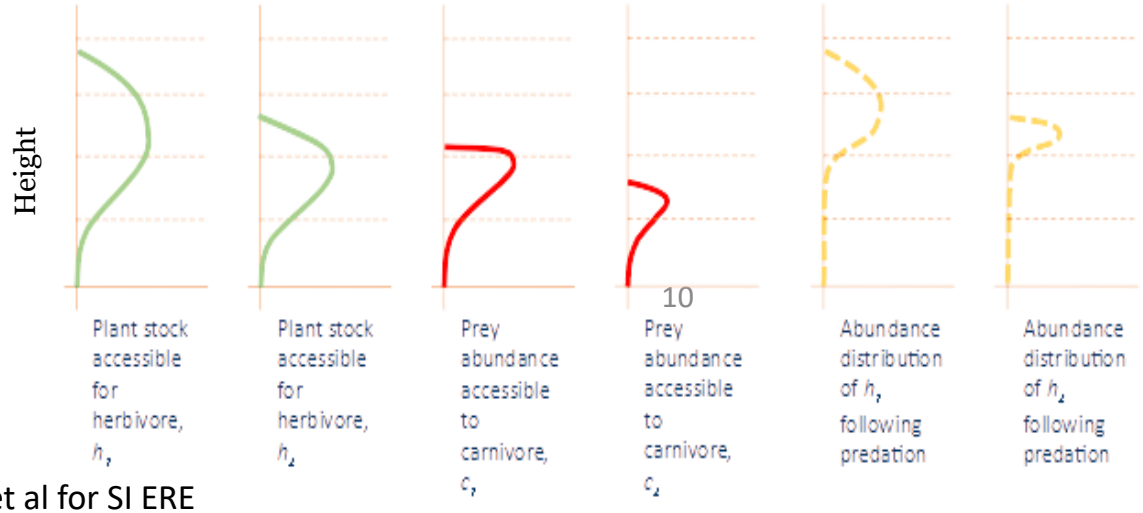






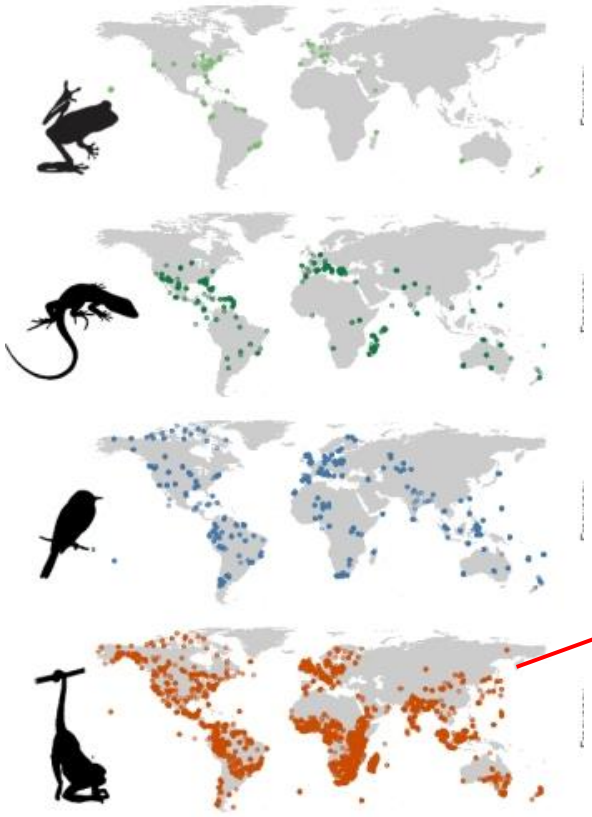


Links tree height to how accessible resources are to different sizes of organism



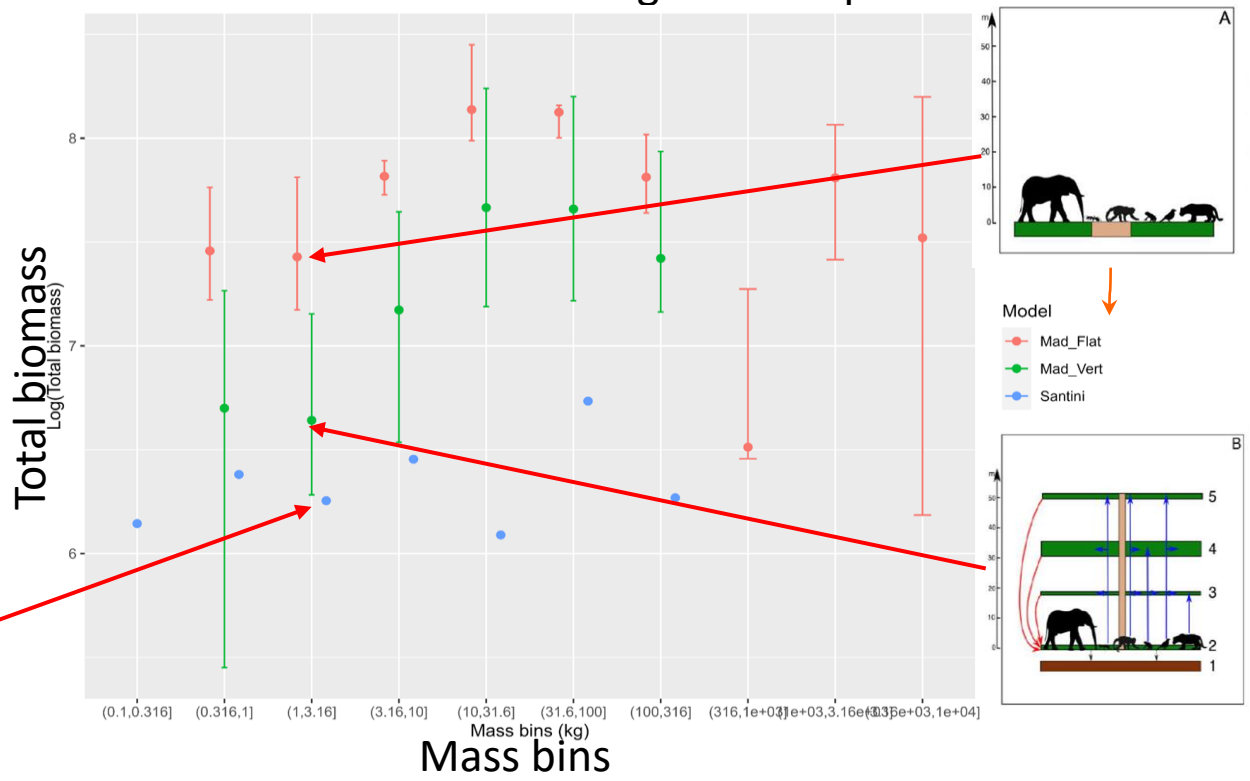
Gaillard et al for SI ERE

Simulation results



Tetradensity- Santini et al 2018

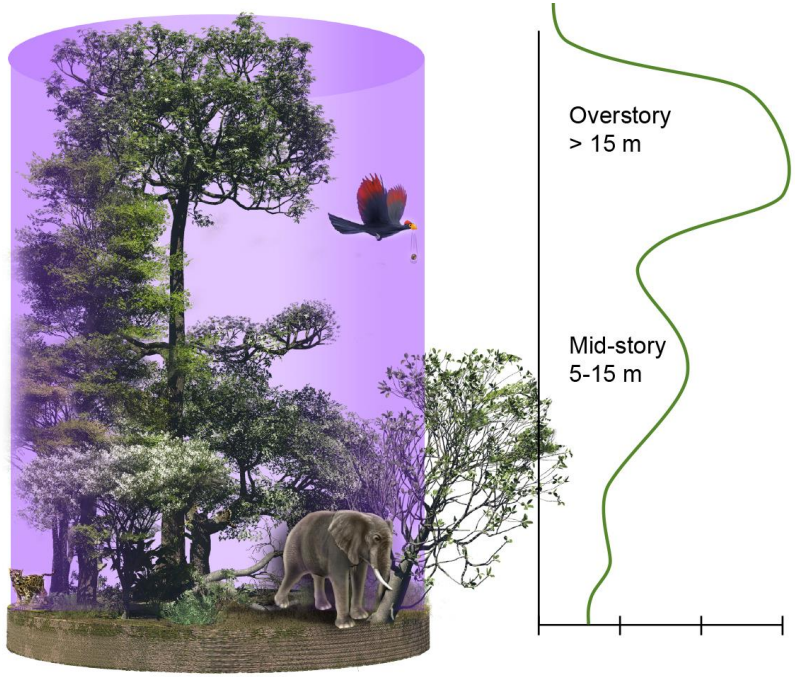
Cohorts are now using vertical space

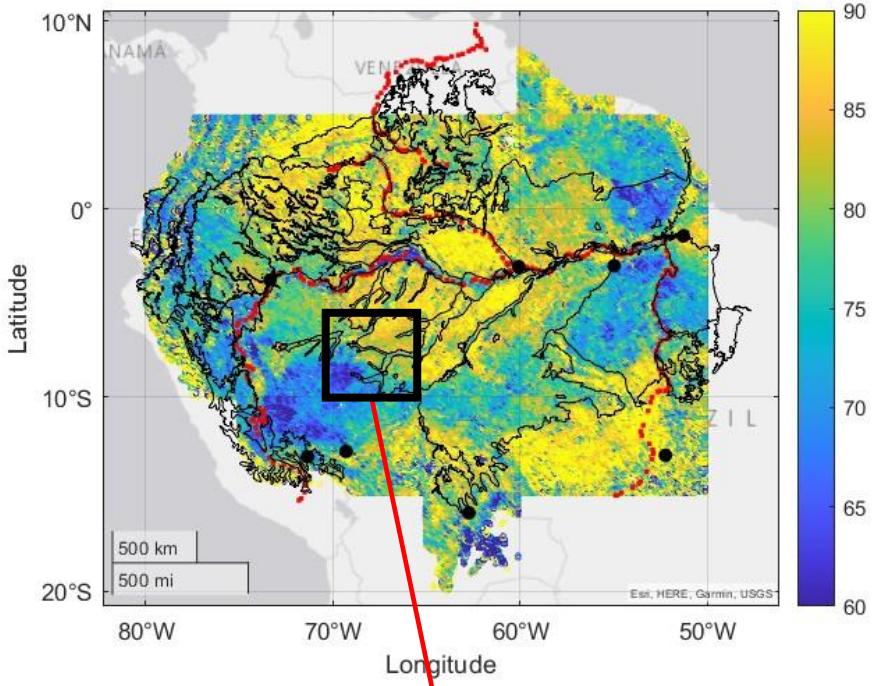


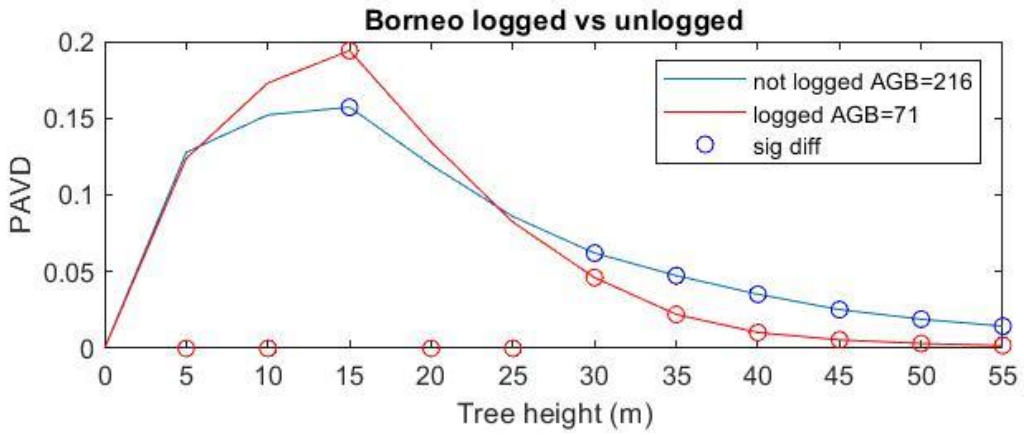
Adding vertical structure to Madingley gives more accurate total biomass estimates

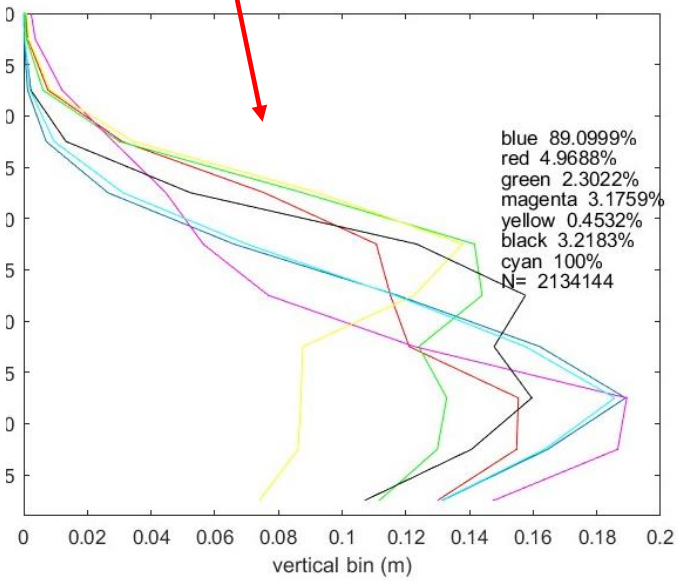
Gaillard et al for SI ERE and poster

How does tropical forest structure vary?



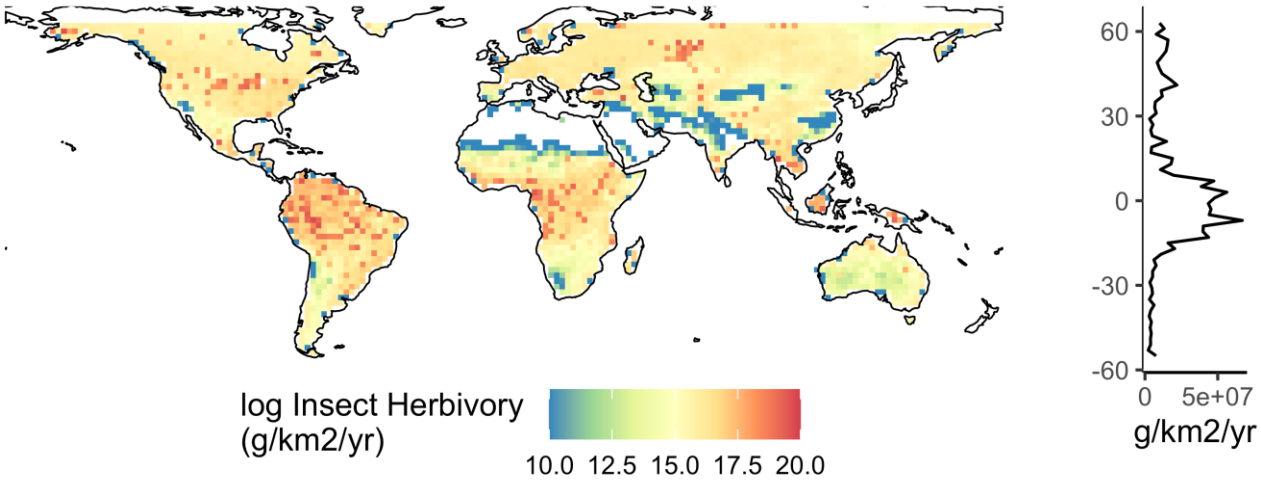


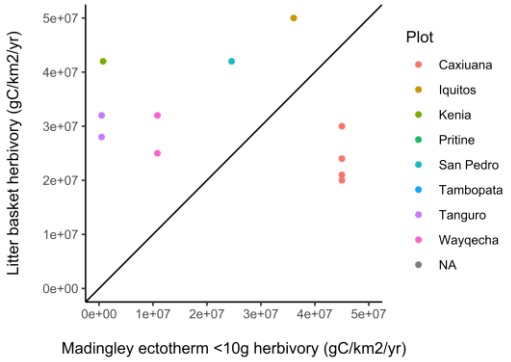




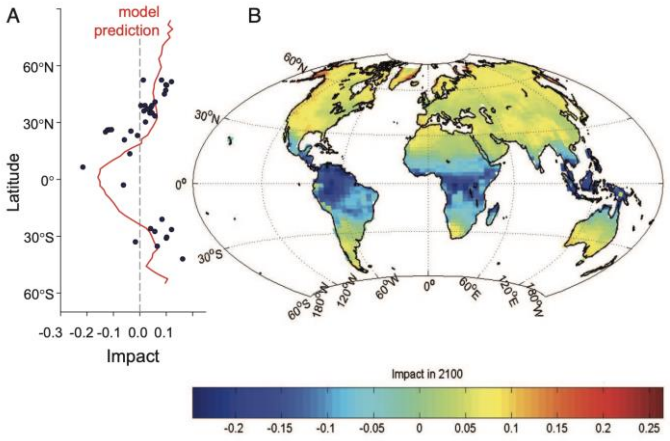
Doughty et al for SI ERE

Use Madingley to understand how changes to insect biomass may influence ecosystem composition globally



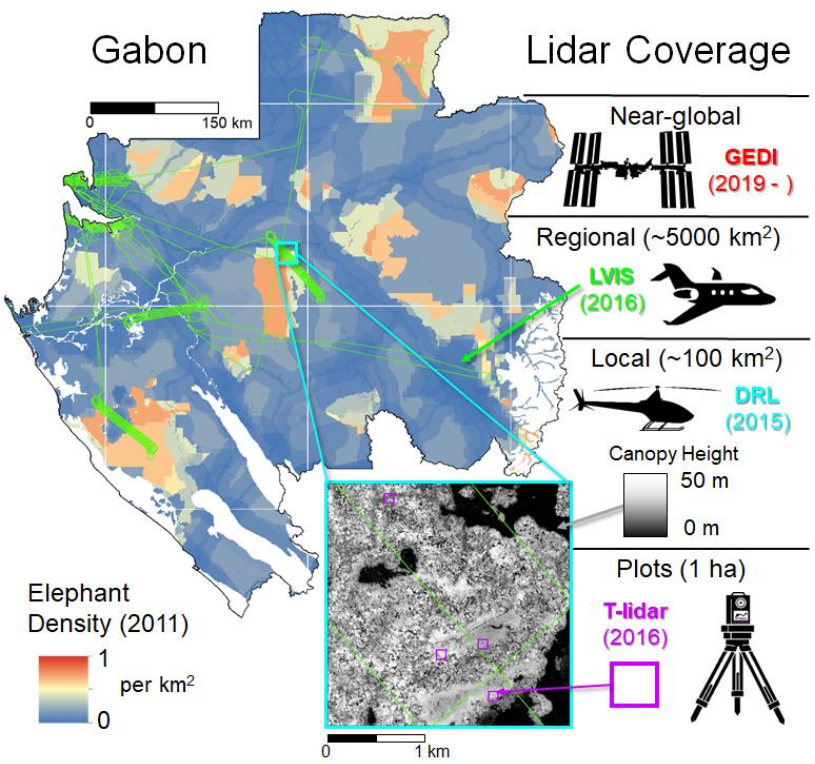


- Comparisons of Madingley to empirical data show that it correctly predicts decreasing insect herbivory from the tropics to the poles
- Next, we will modify insect abundance based on Deutsch et al. (2008)
- Assess ecosystem composition metrics globally in response to insect changes:
    - Total animal biomass
    - Functional diversity
    - Trophic skew



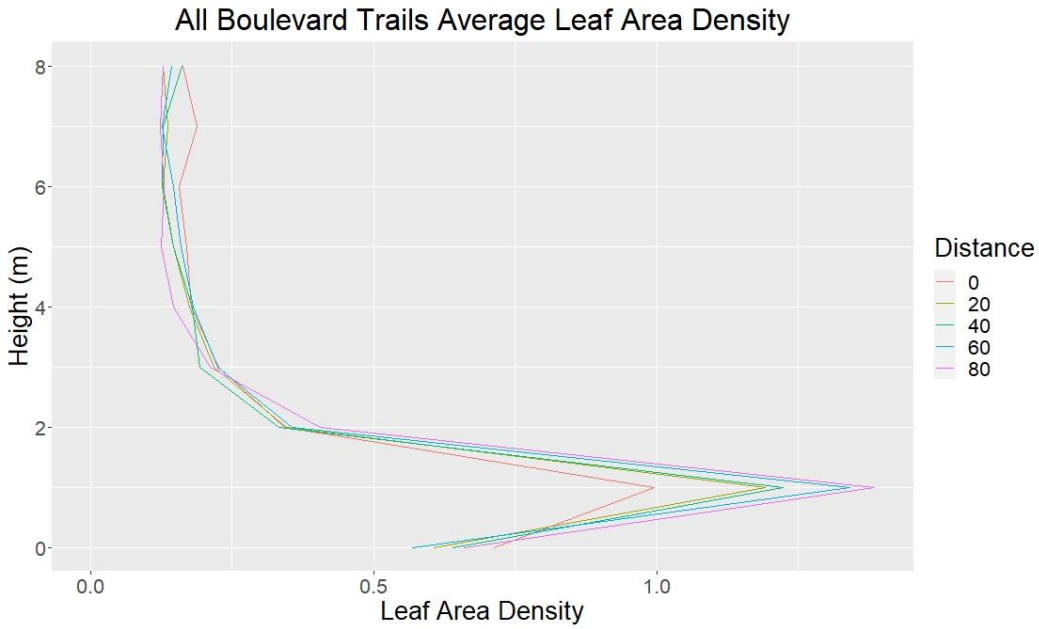
Abraham et al for SI ERE and poster

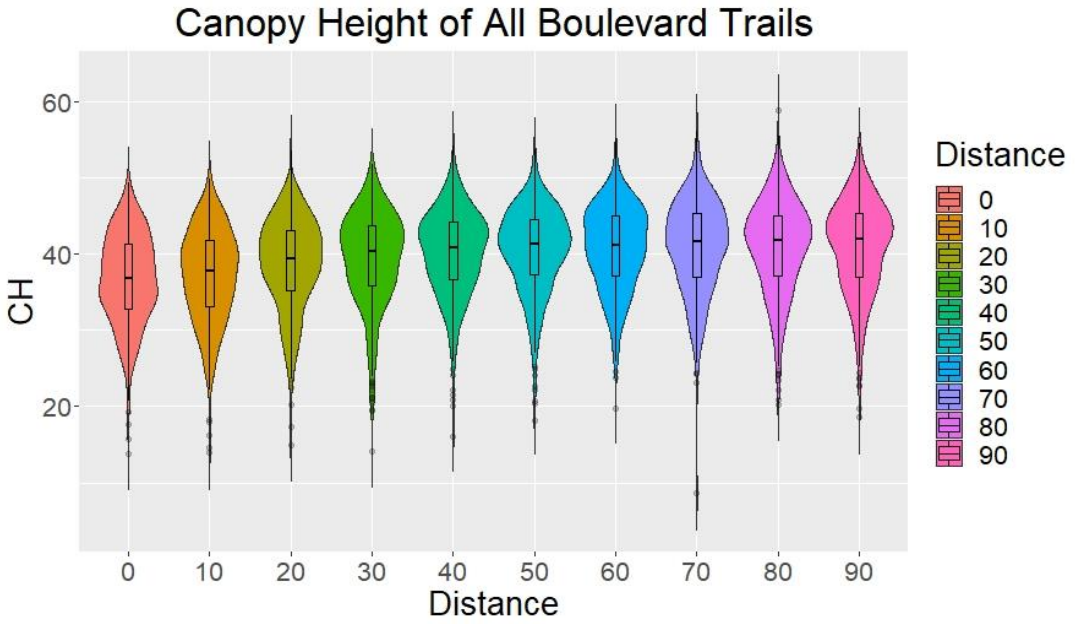
Add ecosystem engineers to Madingley



Lidar:

- Airborne DRL - 2015
- T-lidar – 2016
- Airborne LVIS – 2016
- GEDI - 2019 to presen





Keany et al for SI ERE and poster

Provide RCP scenarios and EBVs to key stakeholders in Gabon, Peru, and Brazil

- Scenario planning for climate change, selective logging, extinctions, trophic loss, land use change.
- EBV Madingley results available for scientists, the public or policy makers as a map and a time series PDF.
- Available in five languages

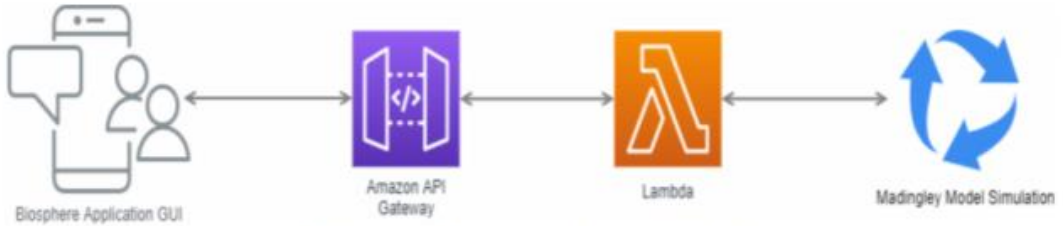
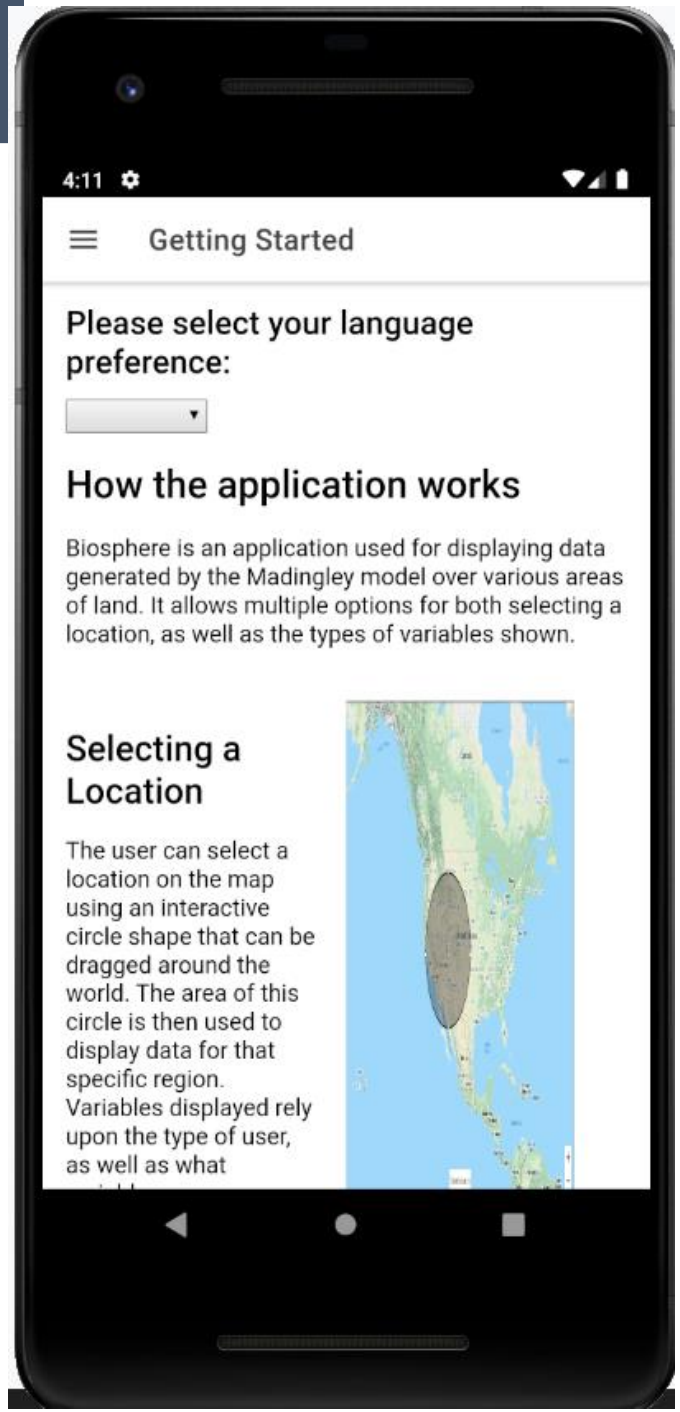


figure 4.1.3 - Application Data Flow Chart



This work was funded by NASA grant award number - 80NSSC19K0206

Questions?
Chris.doughty@nau.edu

NAU Northern Arizona University
Ecological and Environmental Informatics