NASA Biodiversity and Ecological Forecasting Team Meeting 2022

Understanding seed disperser movements and their consequences across rainforest gradients of structural and phenological diversity

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1-University of California, Los Angeles, 2-Jet Propulsion Laboratory, Pasadena, CA, 3-University of California, Davis, 4- University of Konstanz, Germany, 5-Max Plank Institute, Germany, 6-University of Queensland, Australia, 7-Congo Basin Institute, Cameroon, 8-Institute of Research and Development, France

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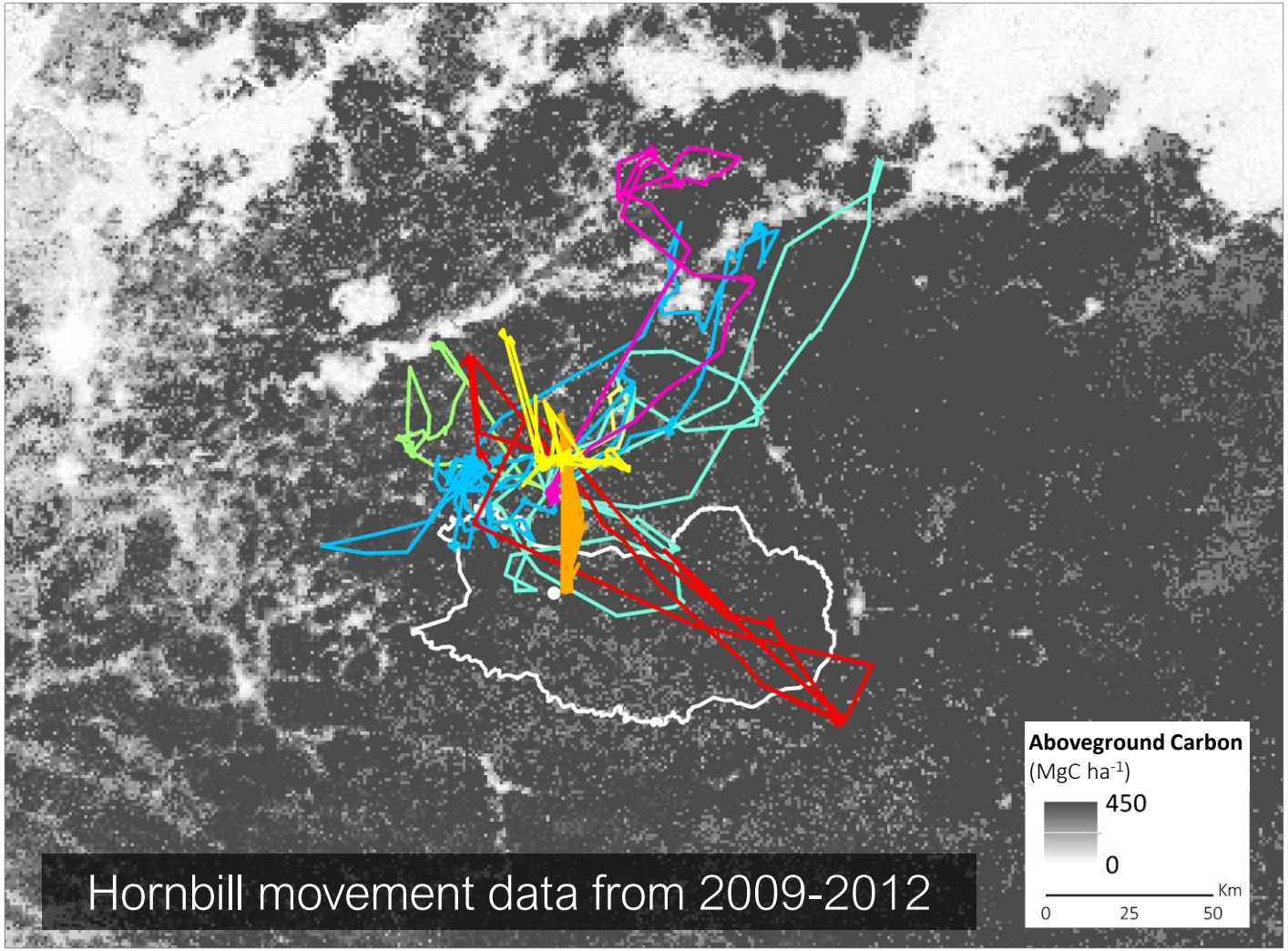
Seed dispersers play a critical role in tropical forest function

- **Primates disperse:** 125 species of trees, lianas and shrubs, equivalent to ~34% of the known tree flora.

- **Hornbills disperse:** 59 tree and liana species, and likely provided dispersal for 56 of them; ~22% of the known tree flora at the site

Whitney et al. 1998; Poulsen et al. 2001

Travel far distances, across intact and degraded forests



Large hornbills:

- Show large scale movements
- Track fruit resources seasonally
- Are important seed dispersers in primary and secondary forests

Whitney & Smith 1998; Holbrook & Smith 2000

Motivation

- Seed dispersers are critical for maintenance of forest function and structure
- Little is known about relationship between seed dispersing animals and ecosystem structure and function

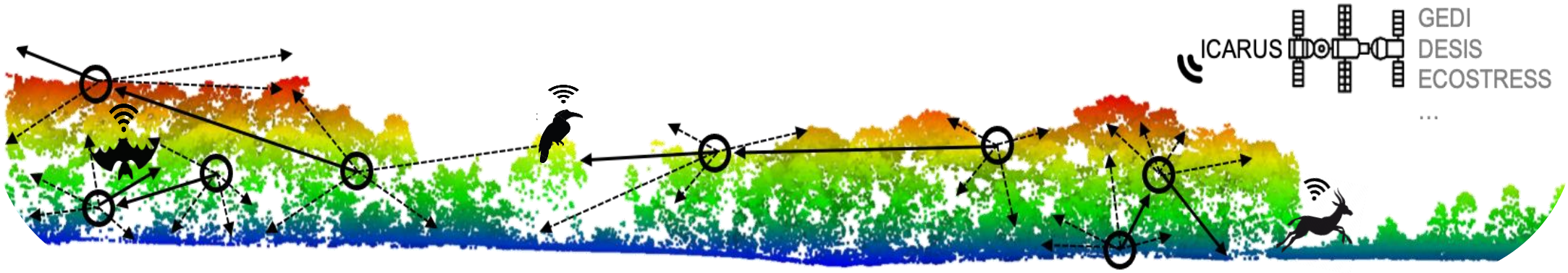
Questions have been difficult to answer for two reasons:

1. Quantifying precise locations of individuals in space and time is difficult
2. A lack of methods and technical tools for analyzing the feedbacks between large-scale ecosystem properties and seed dispersal

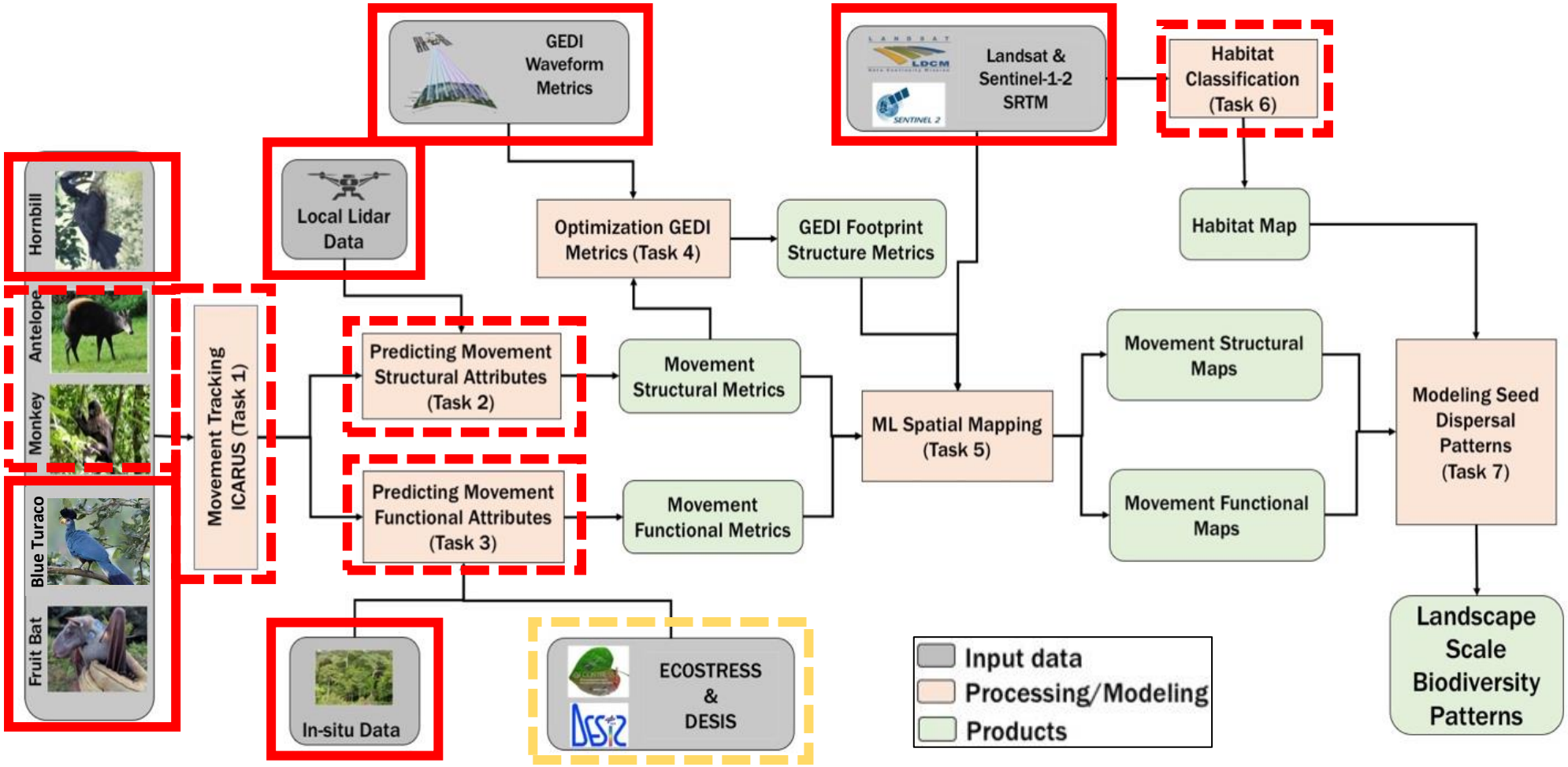
Project overview

Goals:

1. Understand how movements of seed-dispersing taxa with contrasting life histories, behaviors, and home ranges are shaped by vegetation structure and phenology.
2. Explore possible feedback loops between animal seed dispersal and forest structure and diversity.
3. Examine how forest fragmentation and disturbance may influence seed dispersal by vertebrates and forest recovery.



Project workflow



Study taxa

Birds

Bats

Duiker

Primate

ICARUS tag

Pennisi 2022 *Science*

Study taxa

Birds

Bats

Duiker

Primate

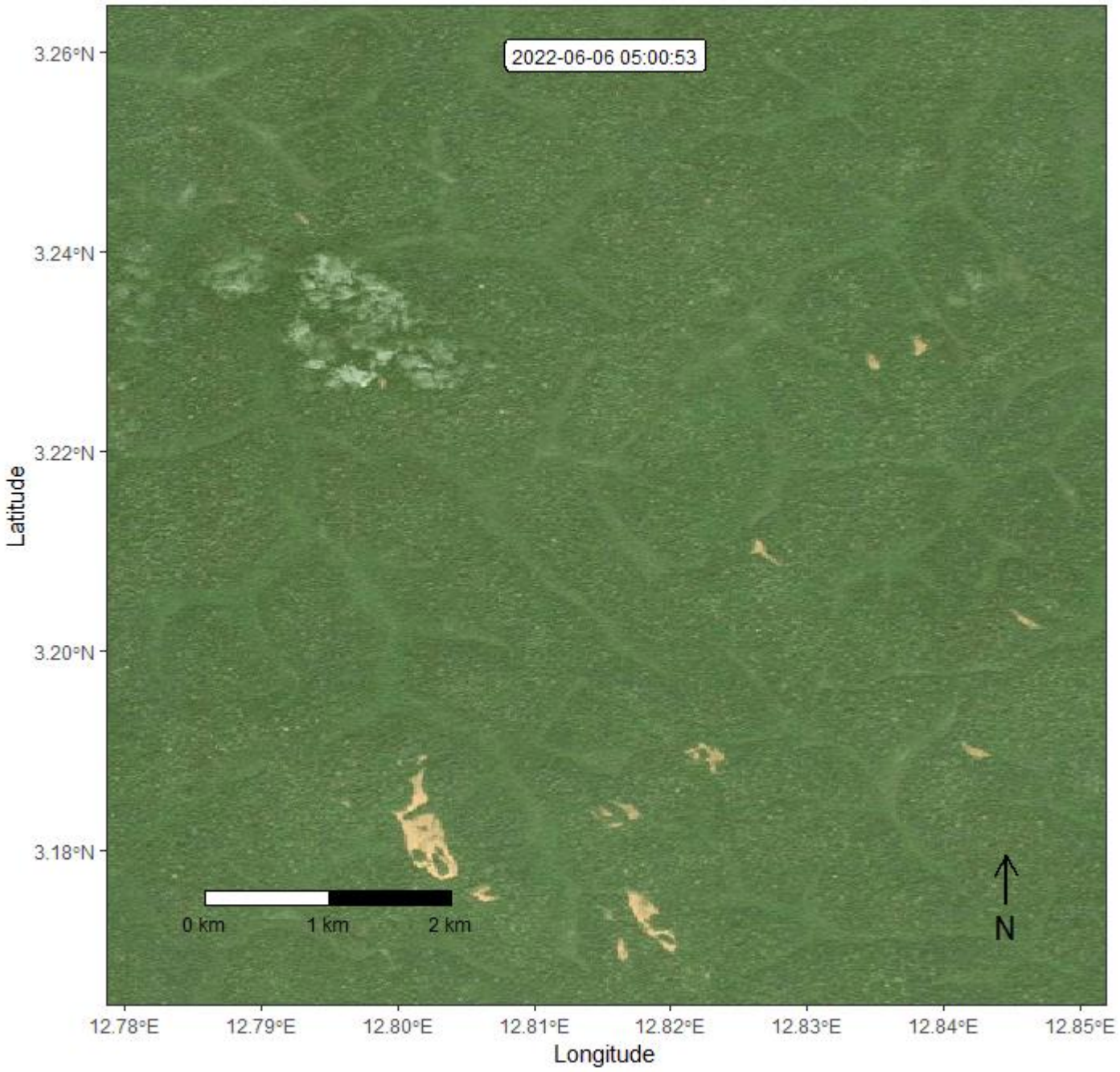
Lots of Tagging

Progress

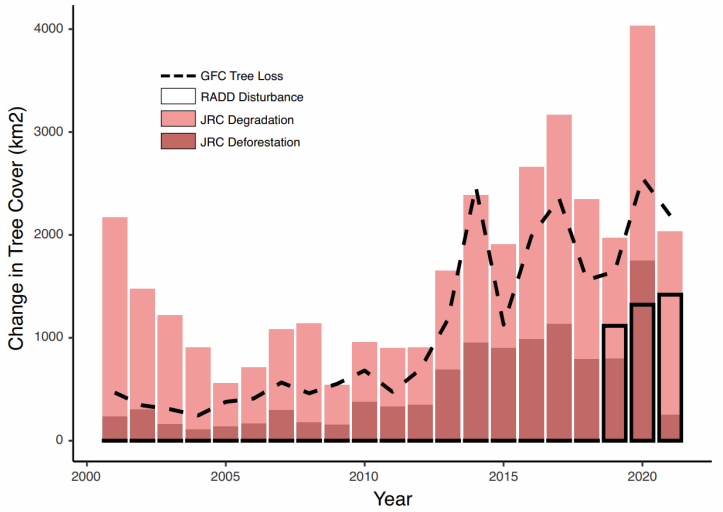
- 14 birds captured since April 2022
  - 10 black-casqued hornbill
  - 2 white-thighed hornbill
  - 2 great blue turaco
- GPS locations collected every 5-30 minutes for most individuals
- Acceleration data collected every 10 mins
- 5 hammer headed fruit bats
- 94 grey-cheeked mangabeys follows
- 791 indirect and direct observations of primates
  - 308 visual sightings, 454 vocalisations

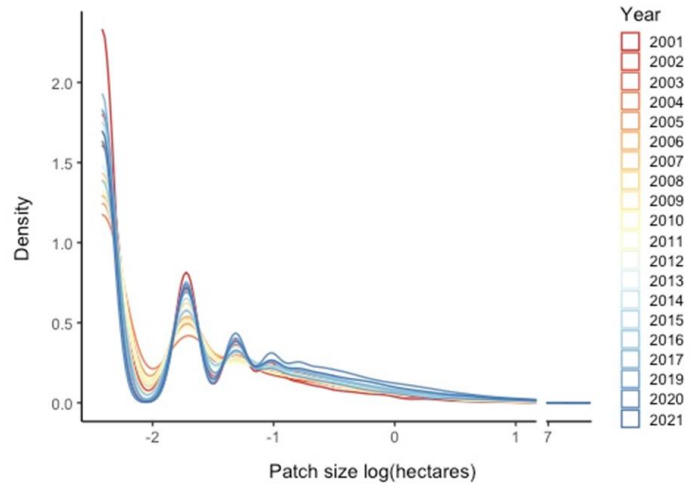
Preliminary results

- General preference for taller canopies
- Strong individual variation in movement behavior
  - Encamped and exploratory behaviors observed
- Long distance movements (>10 km) observed in two black-casqued hornbills



Forest disturbance and its drivers





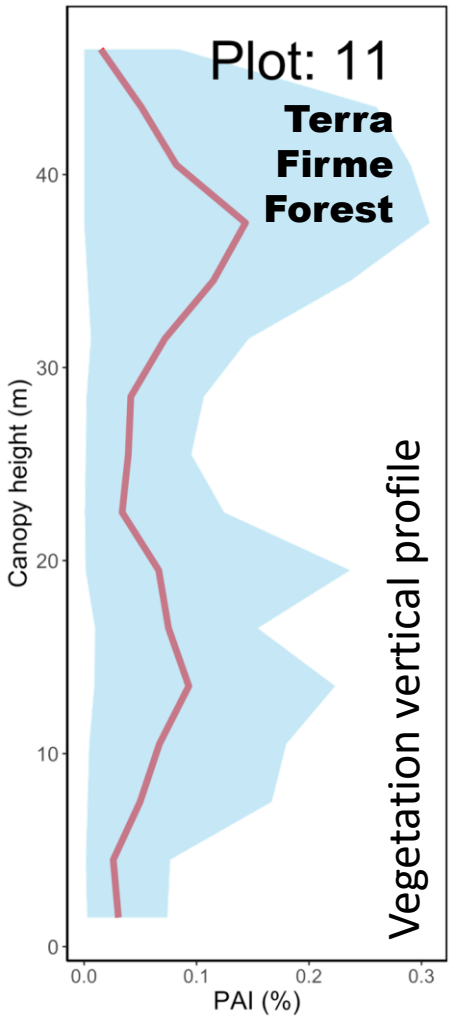
SkySat image collection over plantation near Dja Reserve

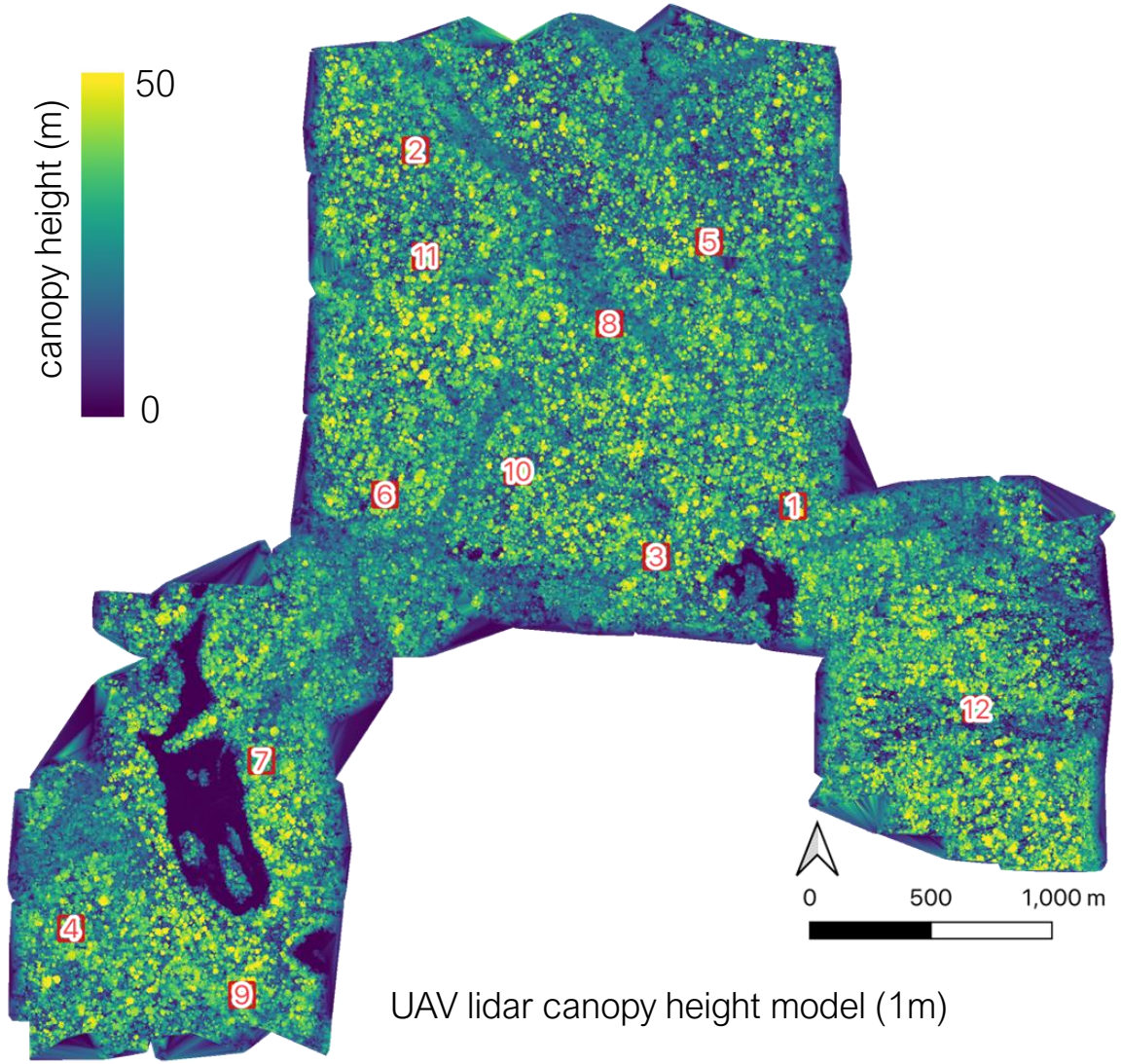
Forest disturbance due to flooding of Dja river.

Biswas et al. *in prep*

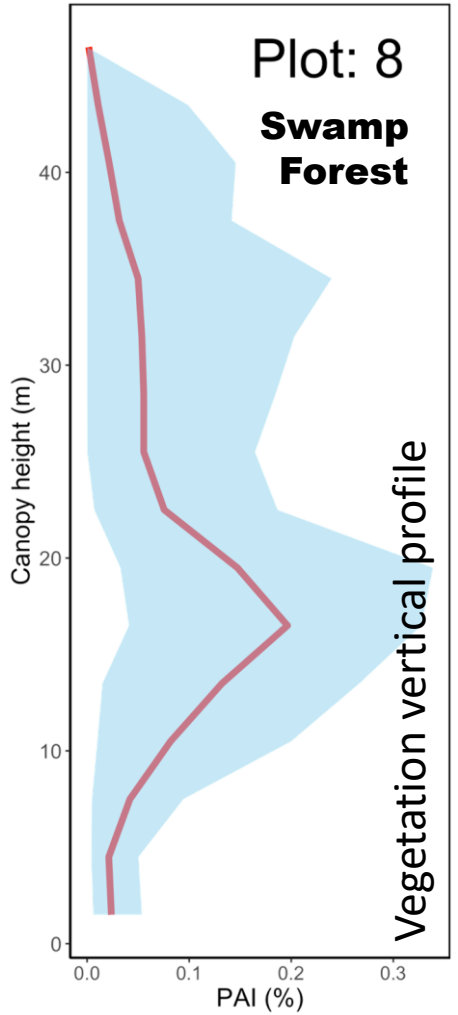
Variation in forest structure

GEDI & Drone Lidar

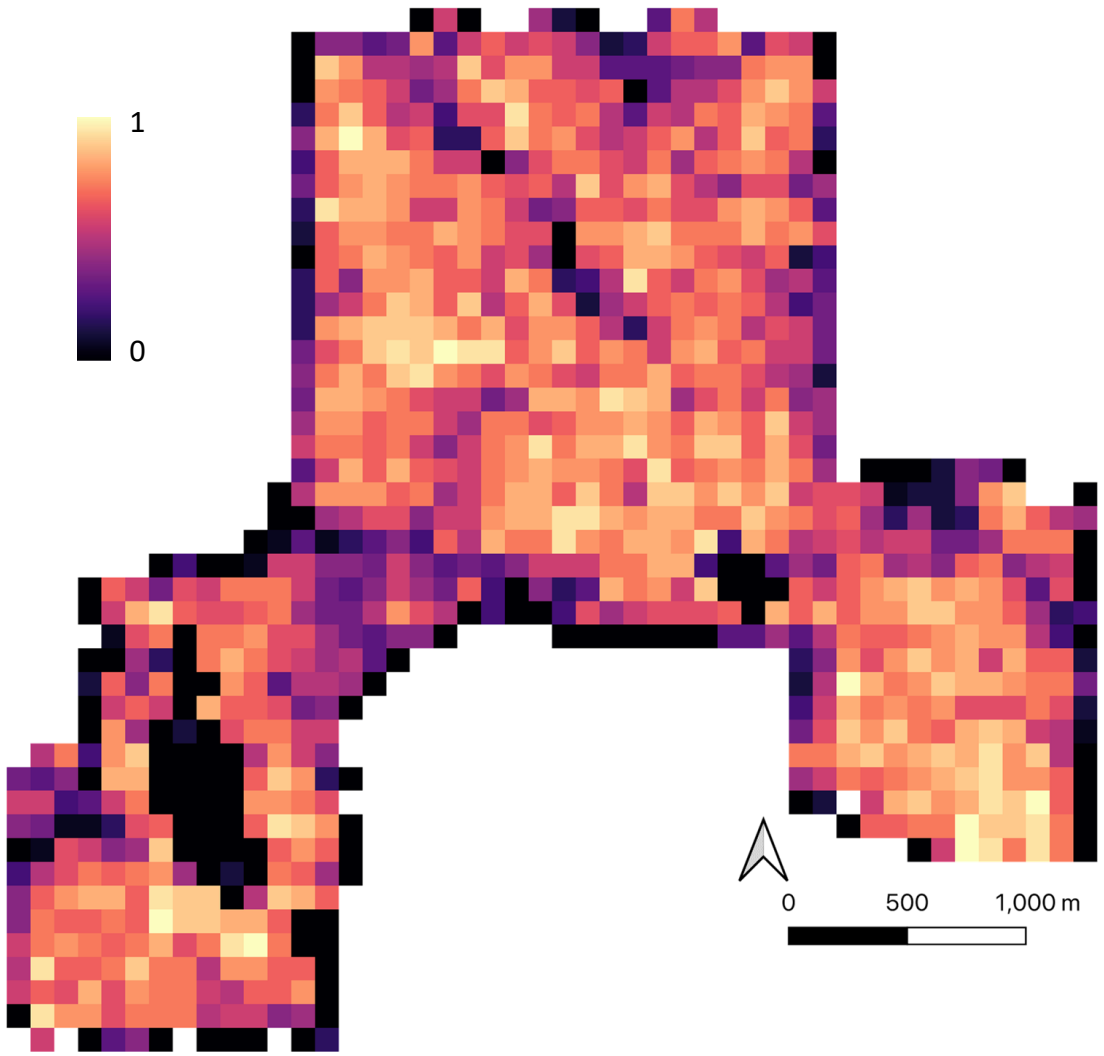




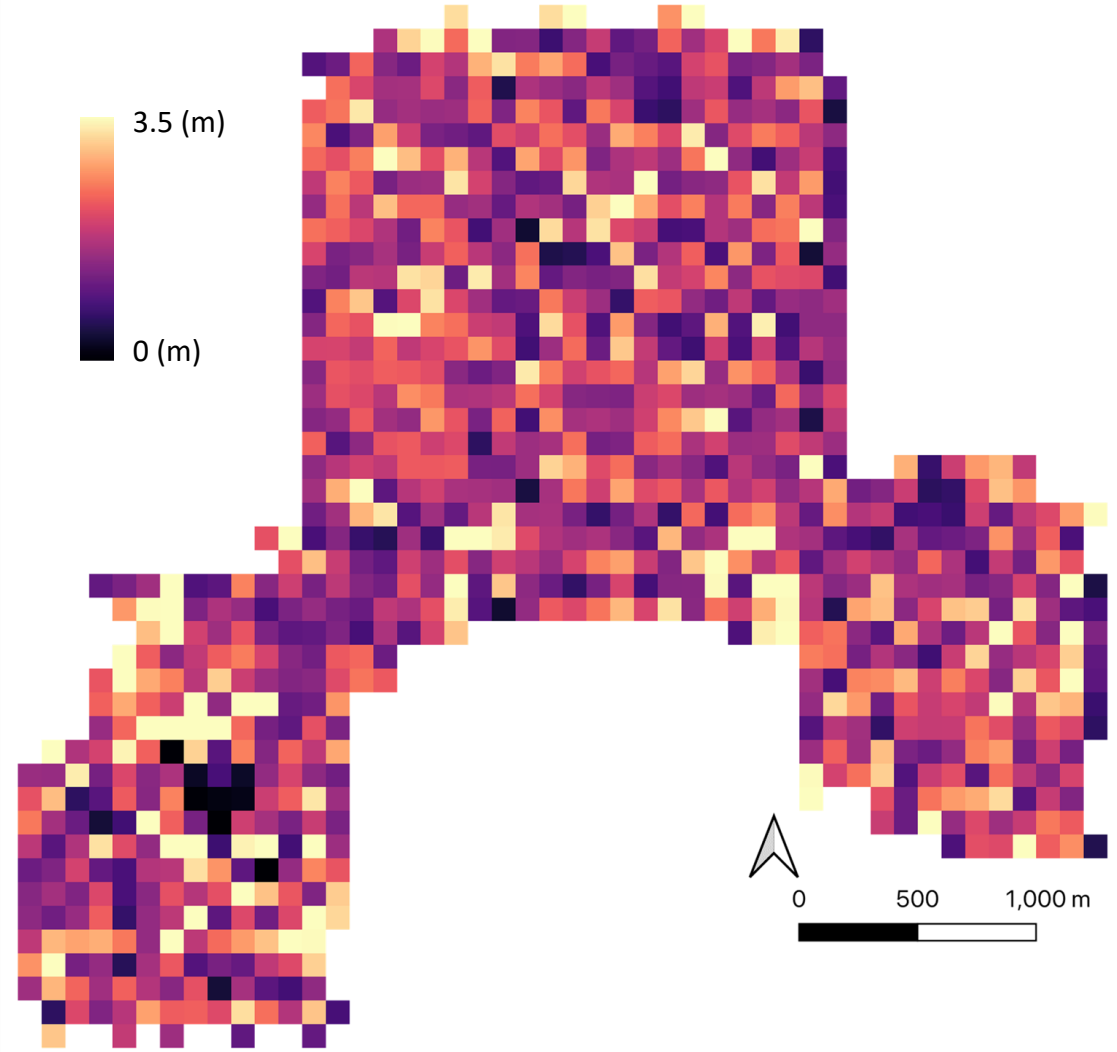
UAV lidar canopy height model (1m)



Normalized foliage height diversity (1 ha)

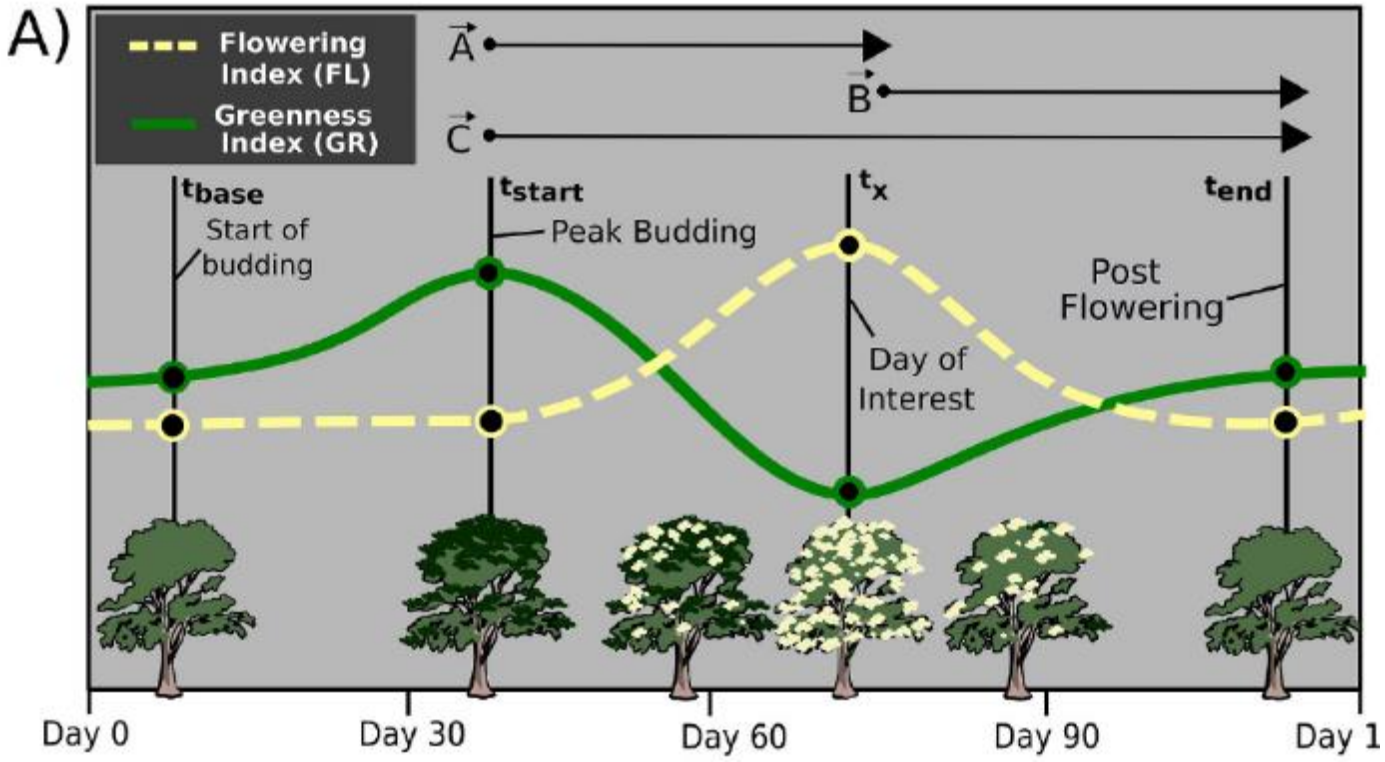


Canopy height complexity (1 ha)

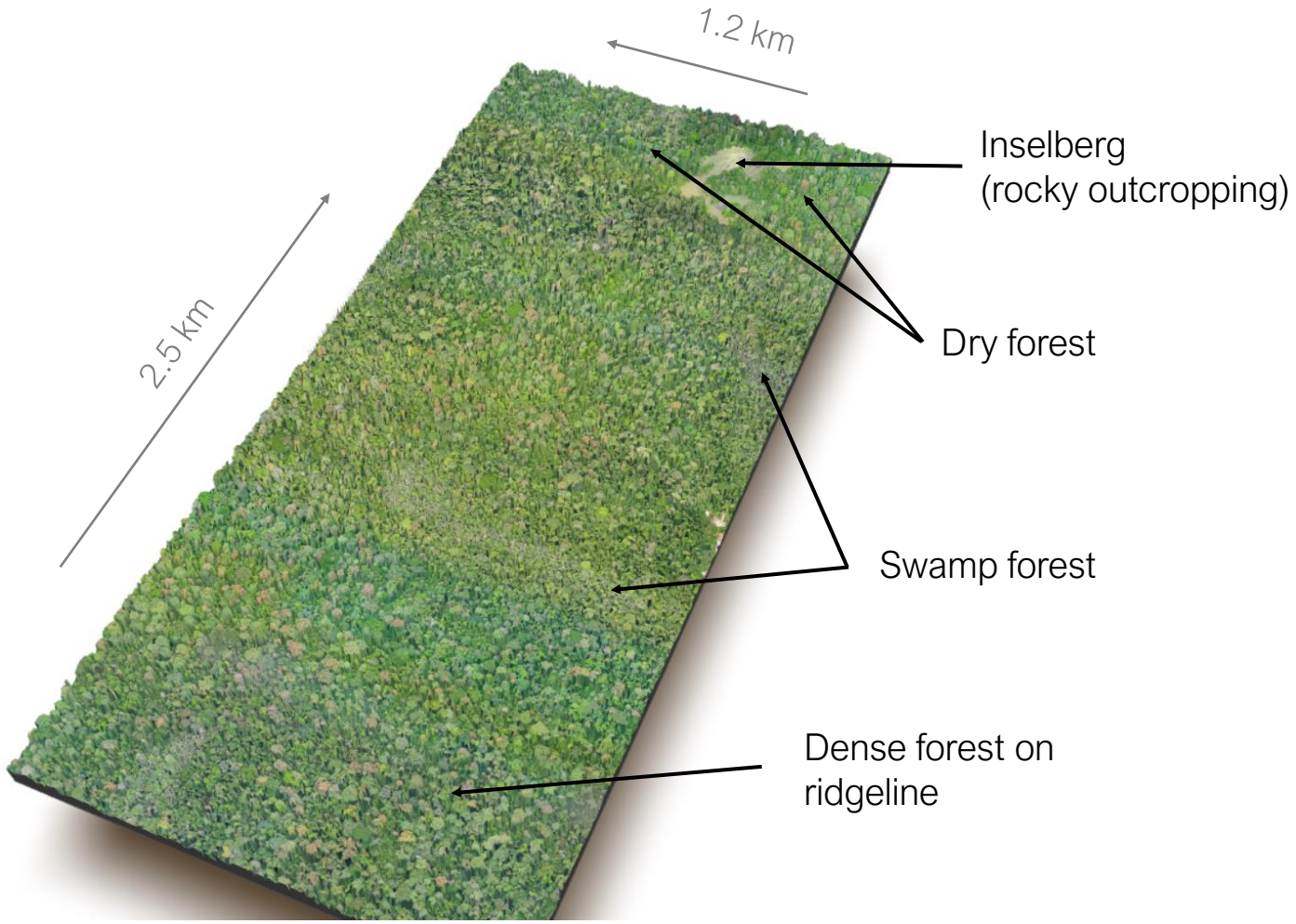


Phenology

PlanetScope, HLS, Drone RGB, In situ



Dixon et al. 2021 *RSE*


1.2 km
2.5 km
Inselberg
(rocky outcropping)
Dry forest
Swamp forest
Dense forest on
ridgeline

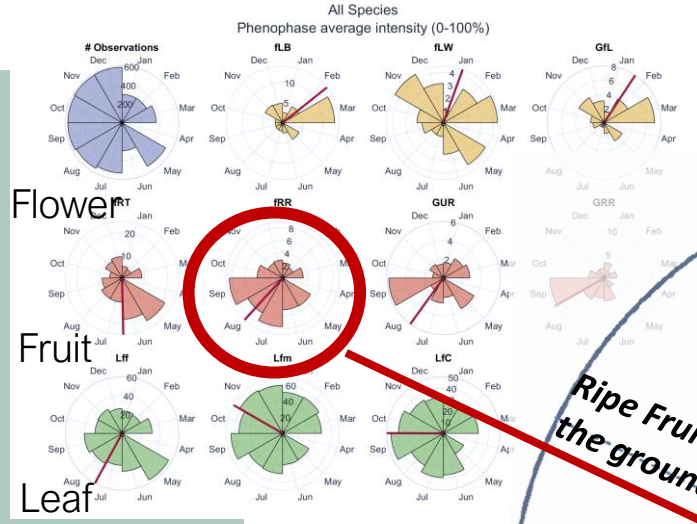

27-04-2022
11-05-2022


Paracou_20201124_RGB3cm_mosa_rect.tif

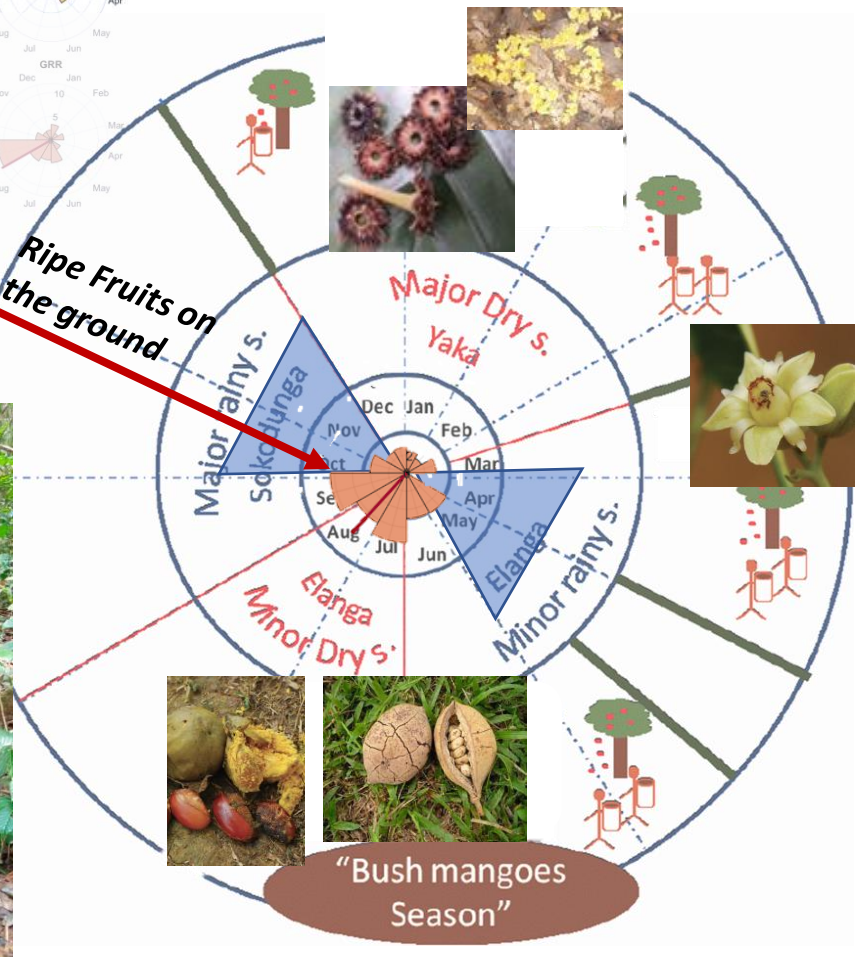
Phenology ground observations and indigenous knowledge transfer

CBI's School for Indigenous & Local Knowledge (SILK)

Facilitate transmission of Traditional Ecological Knowledge (TEK) through collaborative research in national parks with local Baka Indigenous communities



40 Frugivorous tree species

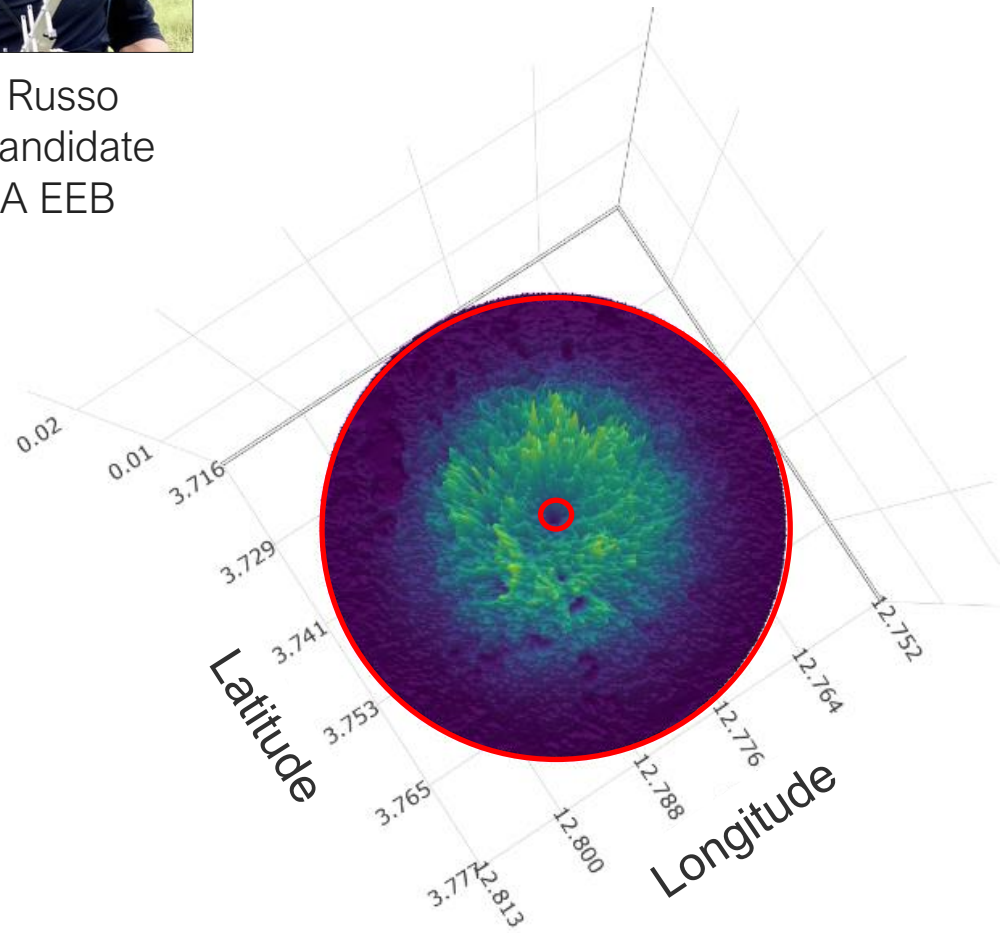


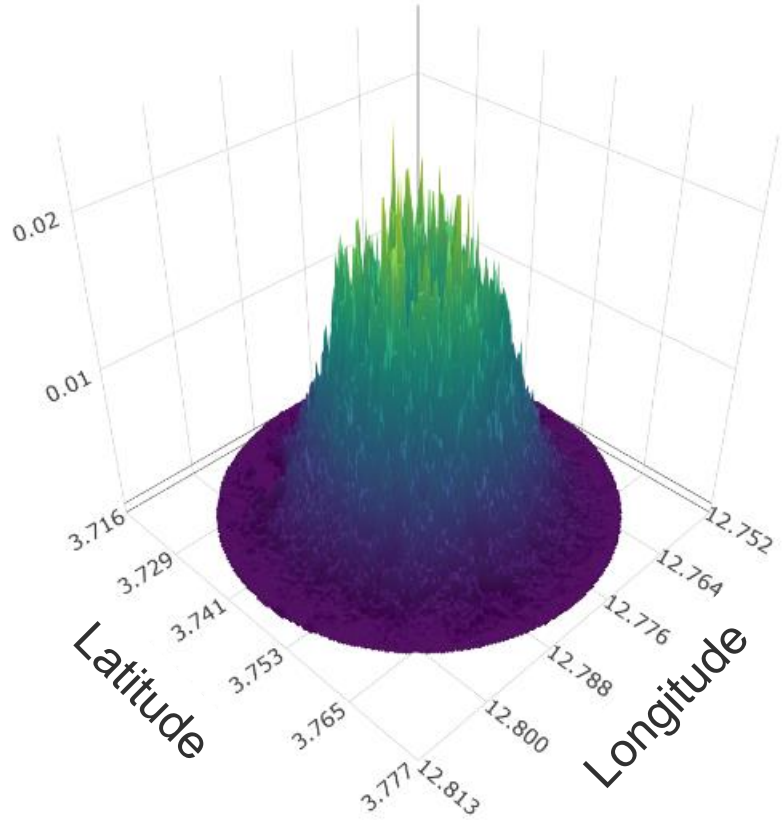
- **Ground observations:** Monthly tree phenology monitoring at Bouamir Research Station (men) and in the village forest (women)
- **Capacity building:** Training Baka youth in research data collection: tree phenology, mangabey habituation, hornbill, bat & duiker studies

Nick Russo
PhD Candidate
UCLA EEB

Tying it all together:

Spatially Explicit Seed Shadow

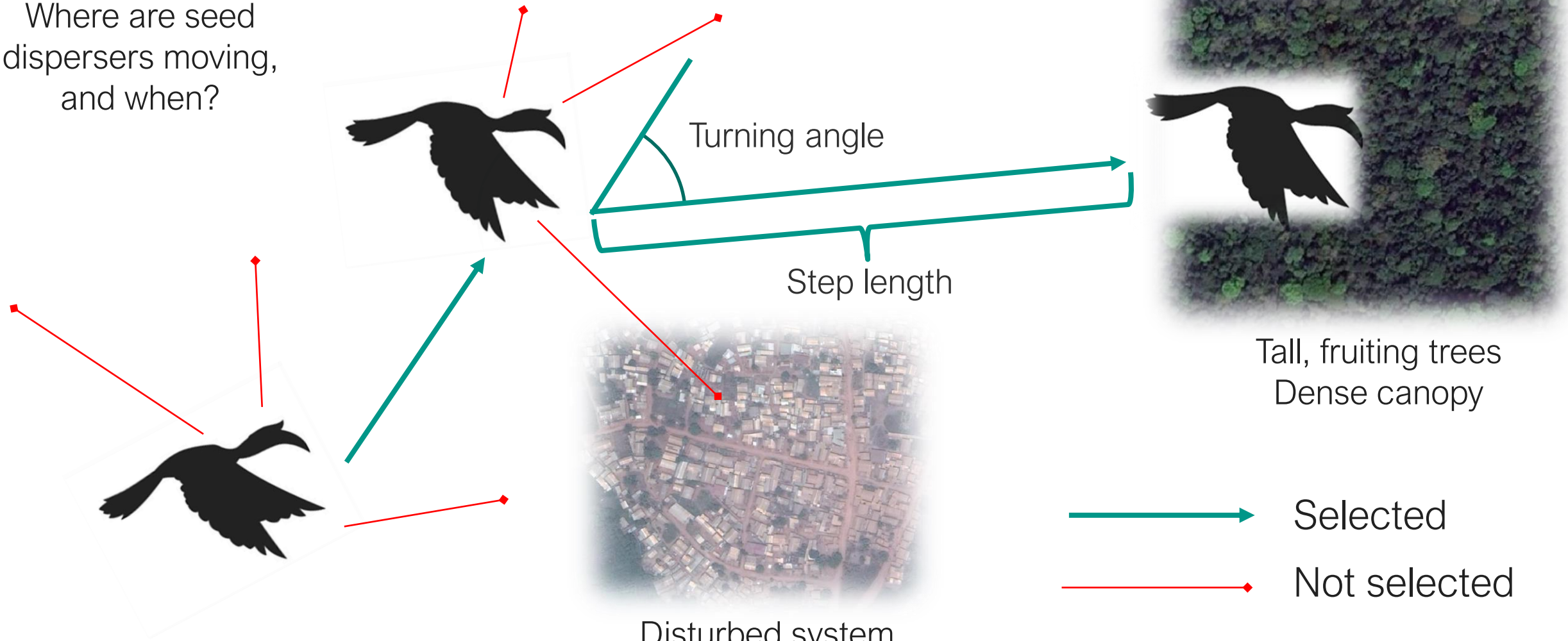




Dispersal Probability

Step Selection Functions

Where are seed dispersers moving, and when?



Training opportunities in Cameroon

- 3 students and 3 forest guides trained in canopy netting and animal tracking
- Phenology analyses and Turaco data contribute to Master's thesis of Antoine Tékam
- 2 students trained in statistical analyses in R
- 5 students and techs trained in drone data collection and processing
- 3-day Google Earth Engine workshop offered at Cameroon's National Observatory on Climate Change

Acknowledgments

UCLA / Congo Basin Institute
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Bonaventure Sonké, Le Bienfaiteur Sagang, Libalah Moses

Cameroonian Students
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IRD
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Max Planck Institute
Martin Wikelski, Meg Crofoot

UMR AMAP
Gaëlle Viennois

Field Collaborators & Support
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UCLA

Institut de Recherche pour le Développement FRANCE

NASA

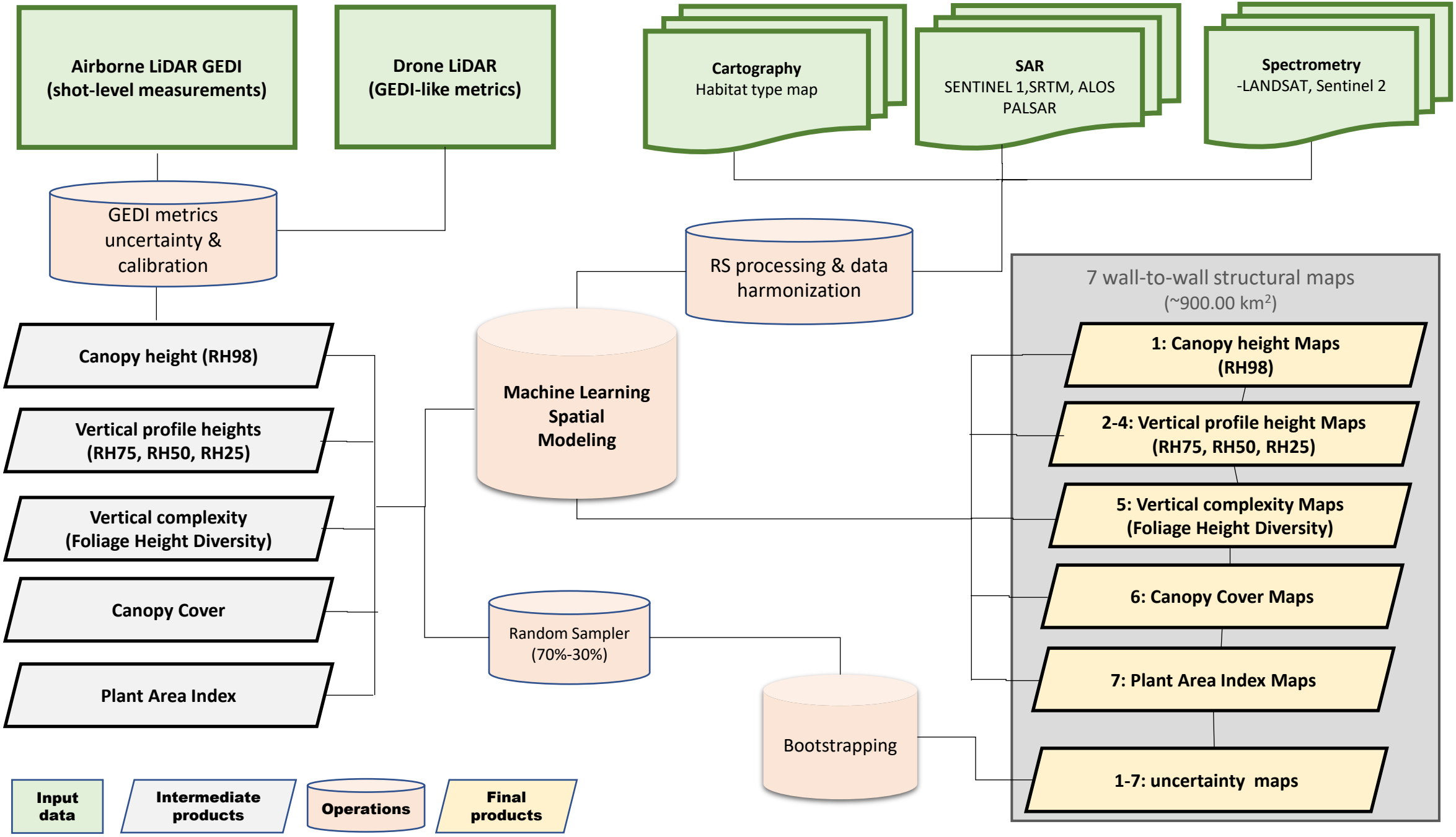
MAX PLANCK INSTITUTE OF ANIMAL BEHAVIOR

CBI CONGO BASIN INSTITUTE

AMAP lab botAnique et Modélisation de l'Architecture des Plantes et des végétations

NASA Jet Propulsion Laboratory California Institute of Technology

Additional Information


Airborne LiDAR GEDI
(shot-level measurements)
Drone LiDAR
(GEDI-like metrics)
Cartography
Habitat type map
SAR
SENTINEL 1,SRTM, ALOS
PALSAR
Spectrometry
-LANDSAT, Sentinel 2
GEDI metrics
uncertainty &
calibration
RS processing & data
harmonization
7 wall-to-wall structural maps
(~900.00 km²)
Canopy height (RH98)
Vertical profile heights
(RH75, RH50, RH25)
Vertical complexity
(Foliage Height Diversity)
Canopy Cover
Plant Area Index
Machine Learning
Spatial
Modeling
Random Sampler
(70%-30%)
Bootstrapping
1: Canopy height Maps
(RH98)
2-4: Vertical profile height Maps
(RH75, RH50, RH25)
5: Vertical complexity Maps
(Foliage Height Diversity)
6: Canopy Cover Maps
7: Plant Area Index Maps
1-7: uncertainty maps
Input
data
Intermediate
products
Operations
Final
products

PlanetScope Processing

PlanetScope

UDM/UDM2 masking

Additional Cloud masking

Calibrated PlanetScope

MODIS v6.1

Download

BRDF Correction

BRDF Corrected MODIS

Calibration

Surface Reflectance

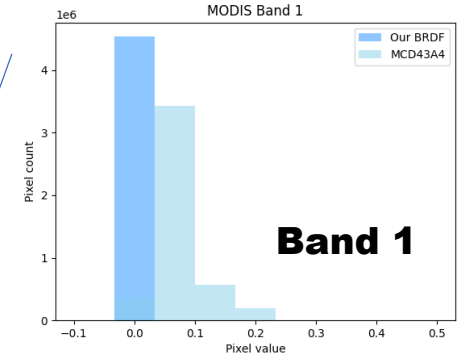
Phenological metrics

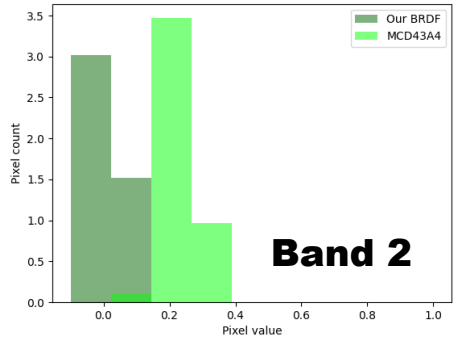
Texture metrics

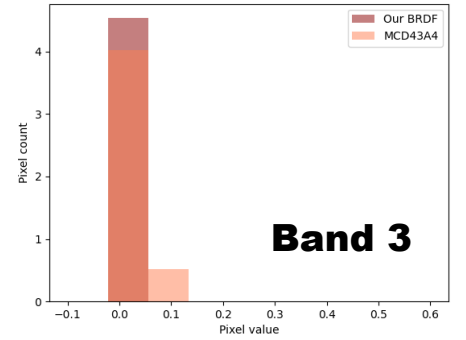
DL model

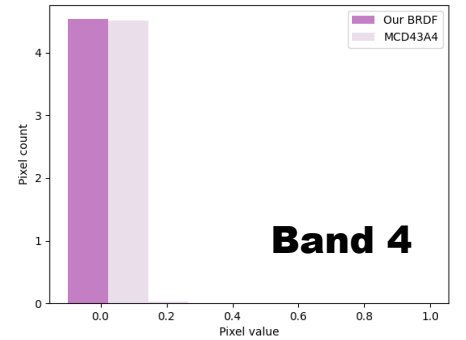
Outputs

1. Percent leaf
2. Percent flower









Preliminary results

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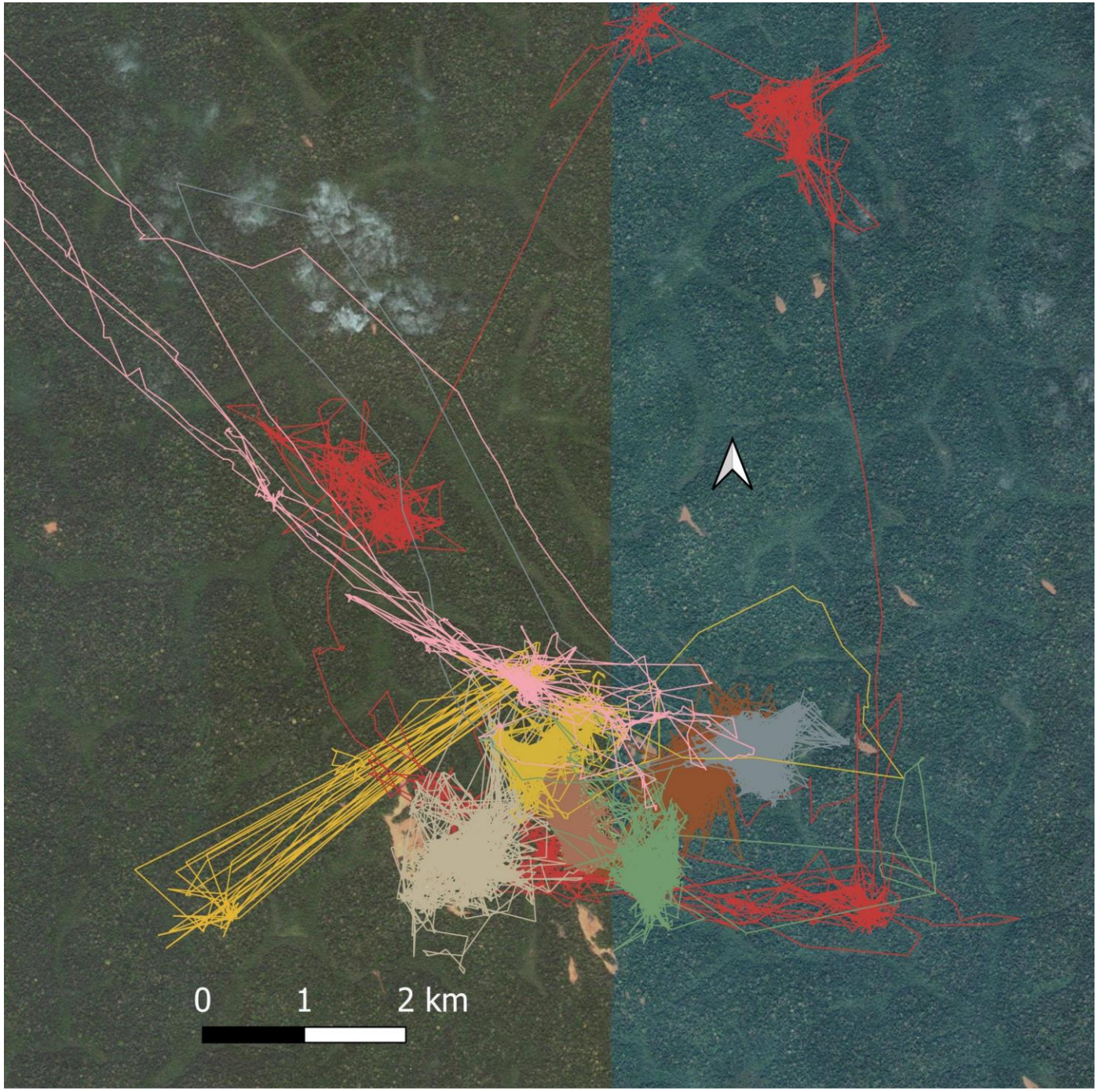
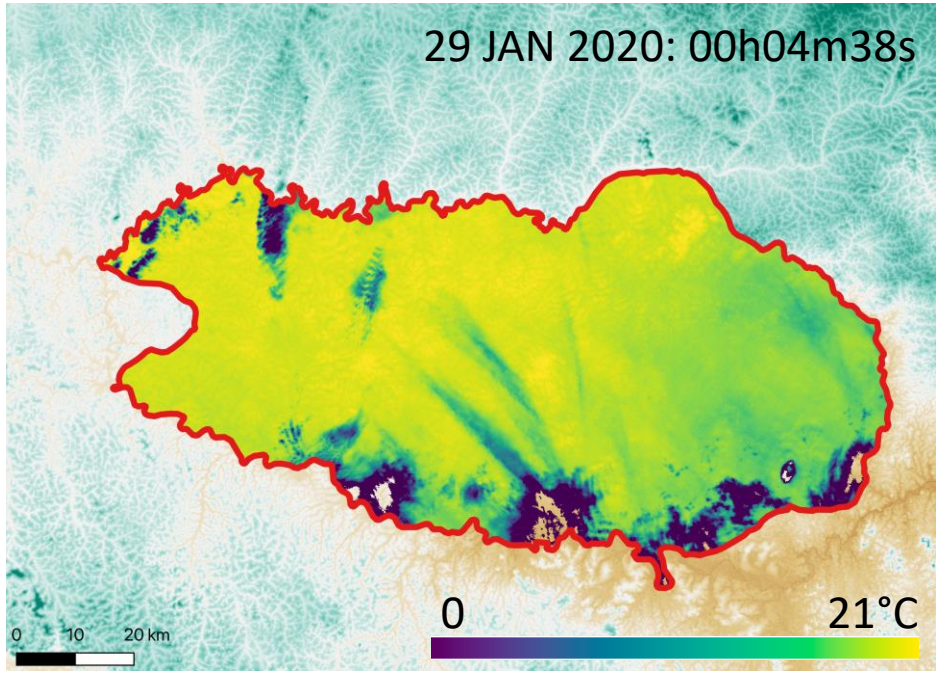
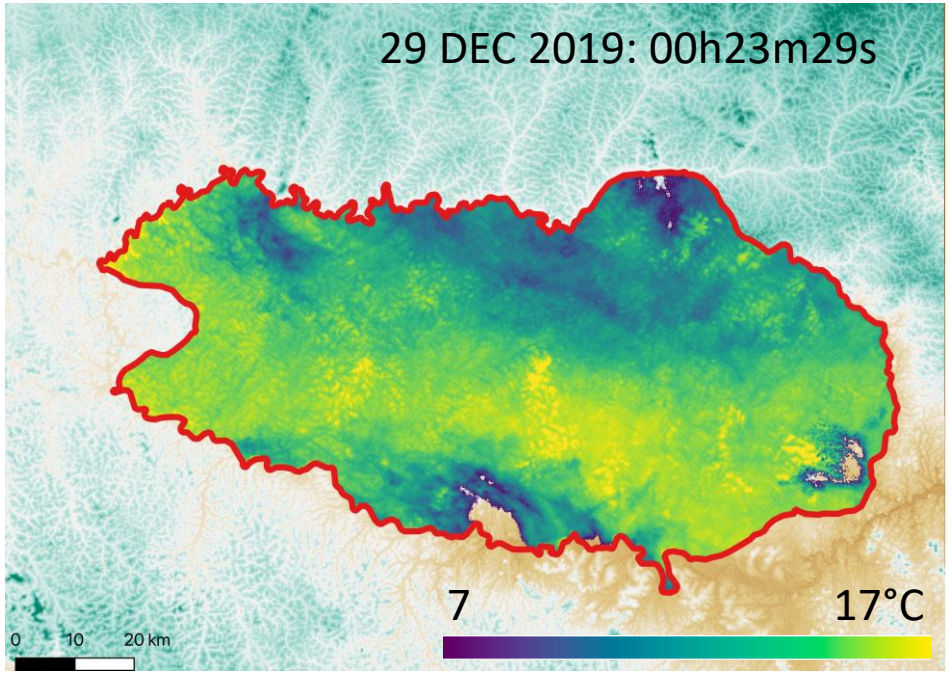
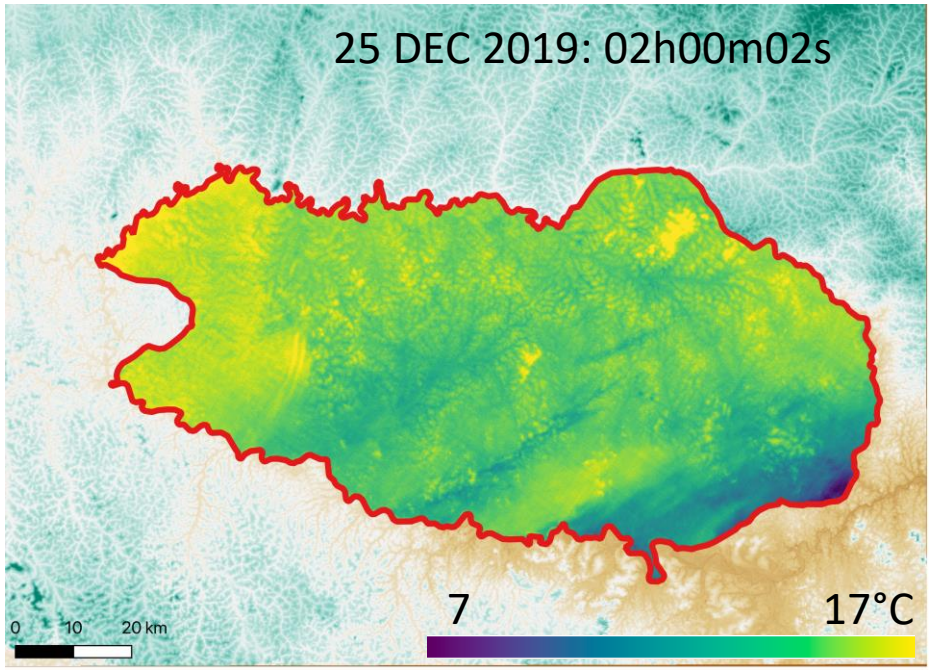
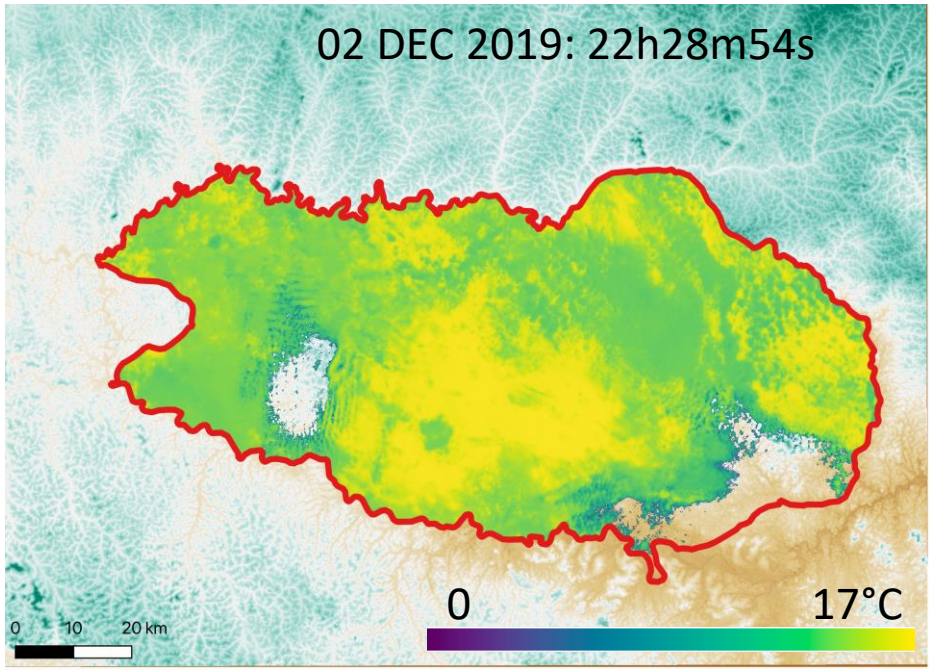



29 JAN 2020: 00h04m38s
0
21°C
0 10 20 km

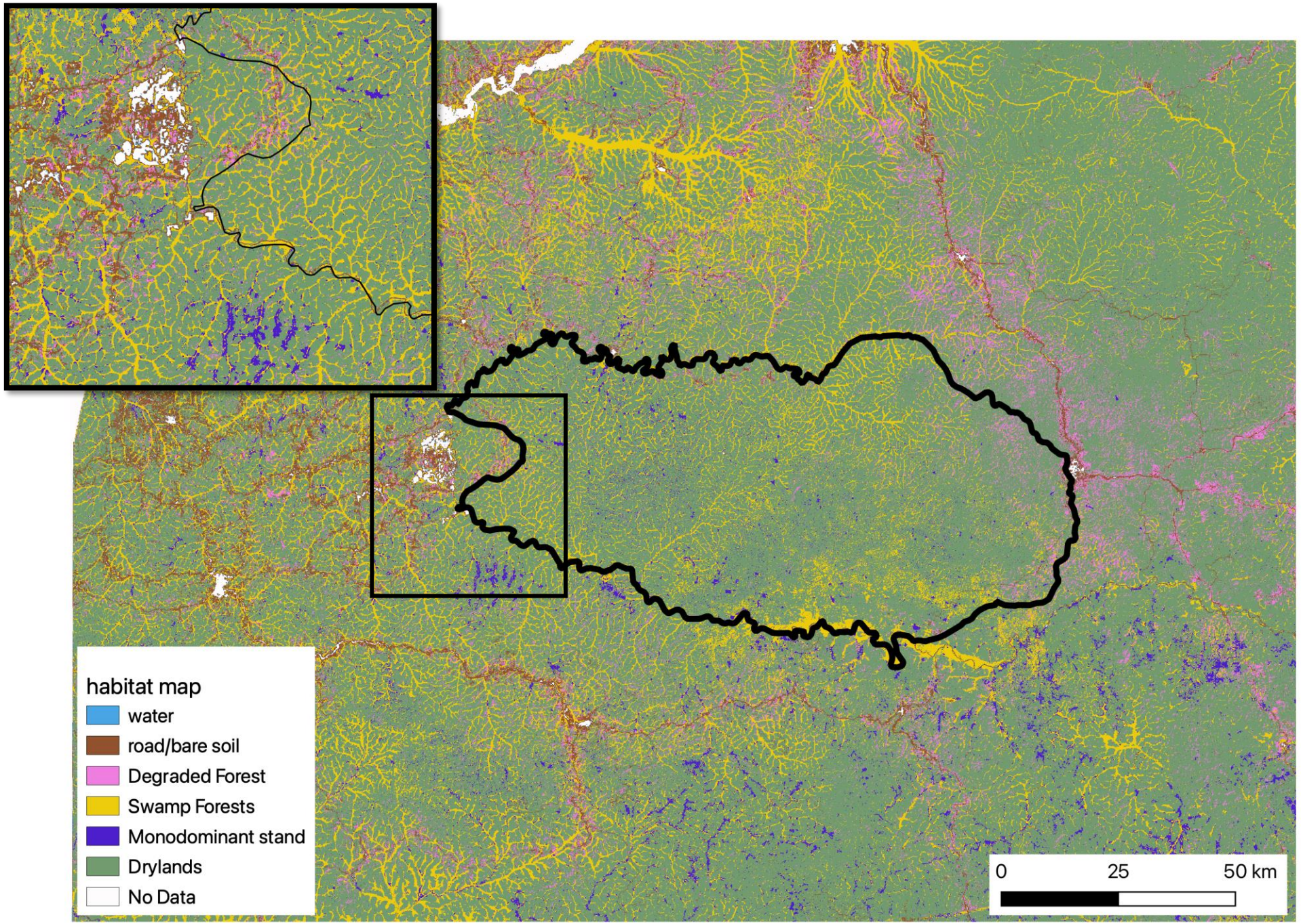

29 DEC 2019: 00h23m29s
7
17°C
0 10 20 km


25 DEC 2019: 02h00m02s
7
17°C
0 10 20 km

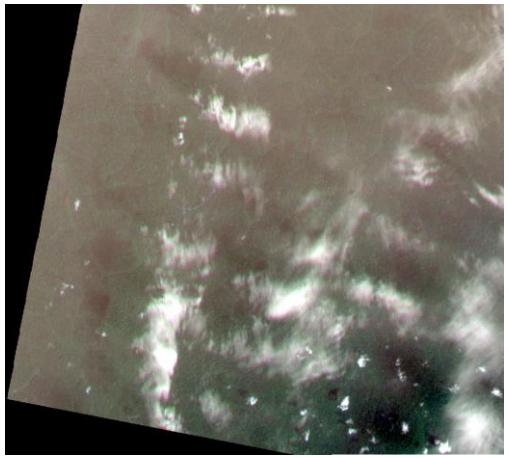

02 DEC 2019: 22h28m54s
0
17°C
0 10 20 km

Habitat map

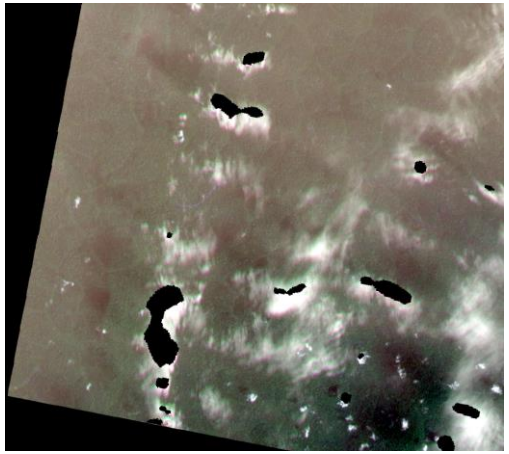
from Sentinel-2 multispectral measurements (10 m)



Cloud Masking



Original image



Udm2 mask applied-only ‘clear’ pixels selected

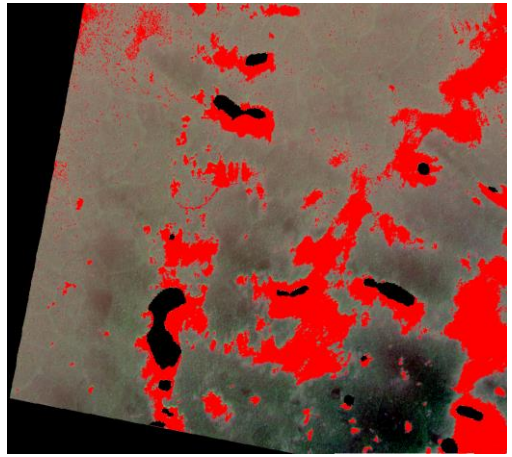


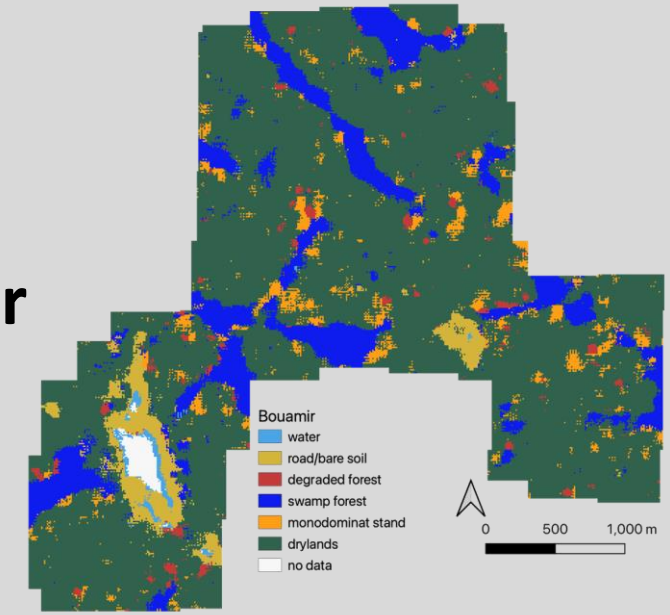
Image customized cloud mask applied- in progress

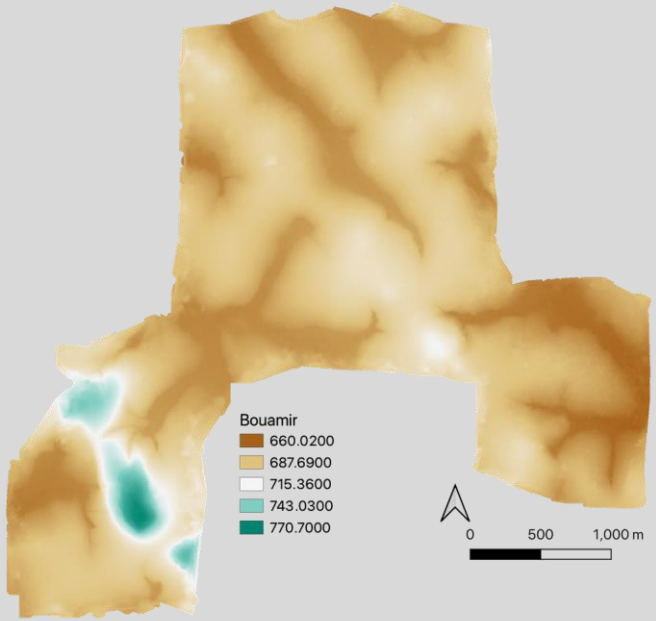
Sentinel 2 habitat map

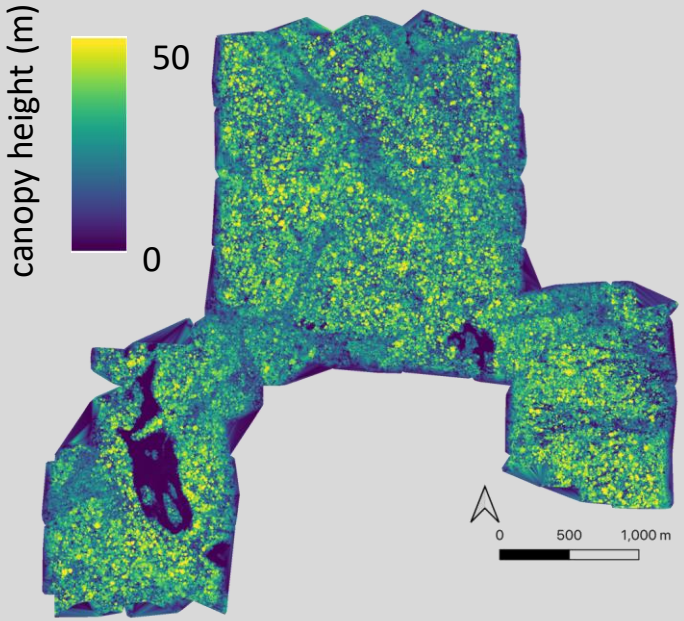
lidar terrain elevation

lidar canopy height model

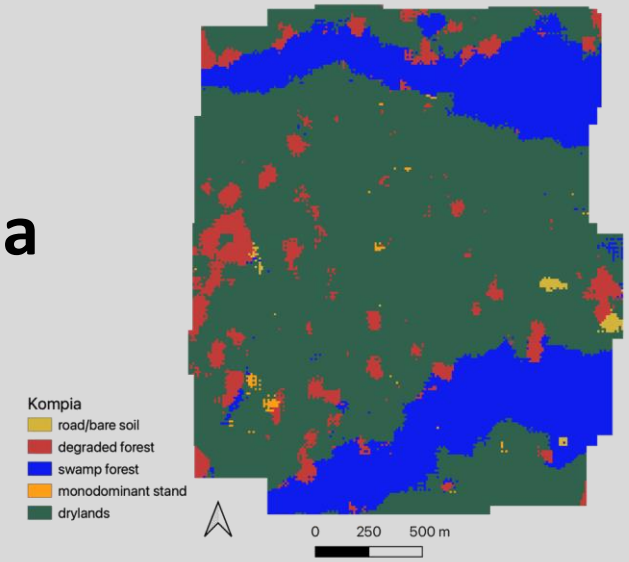
Bouamir

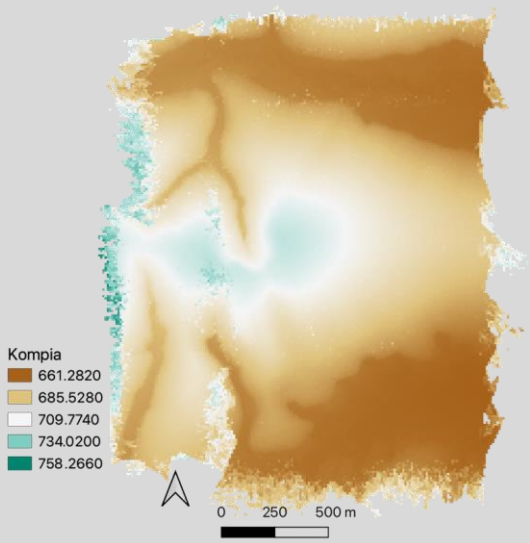


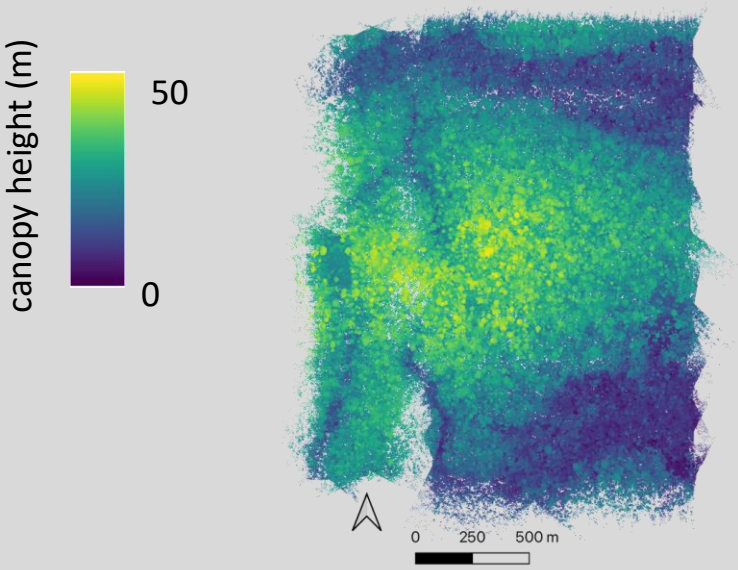




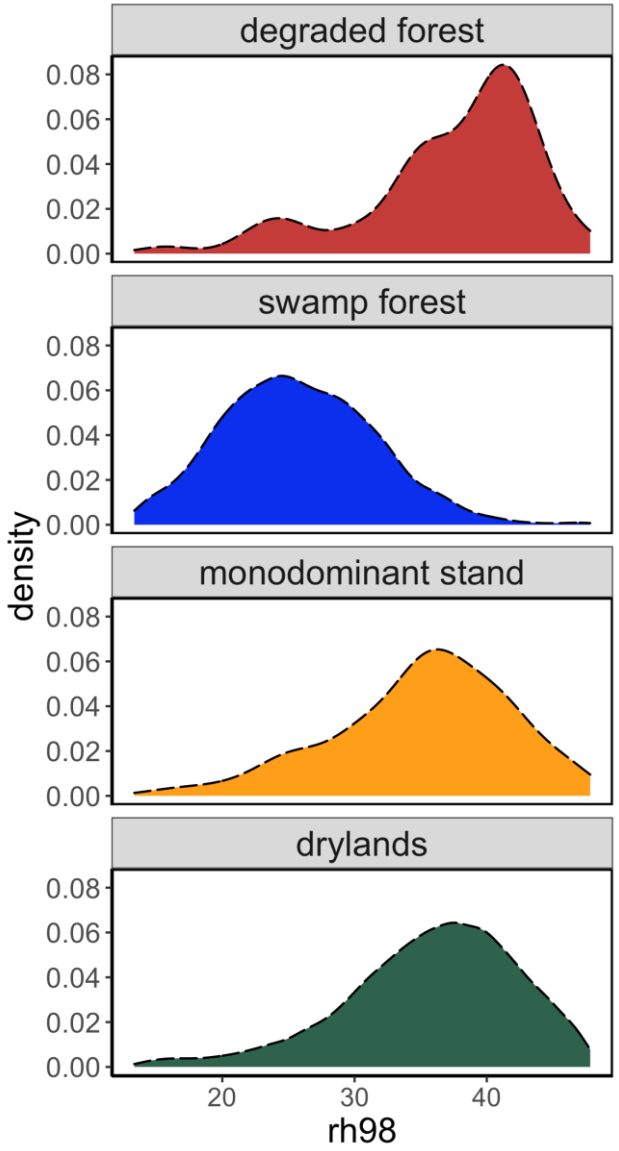
Kompia



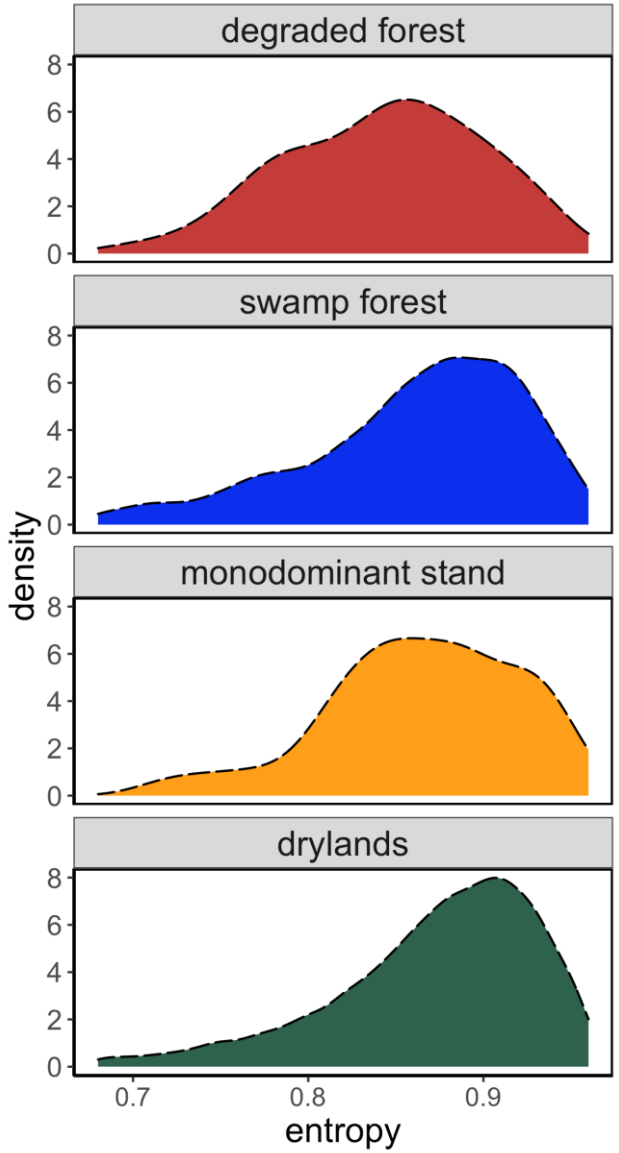




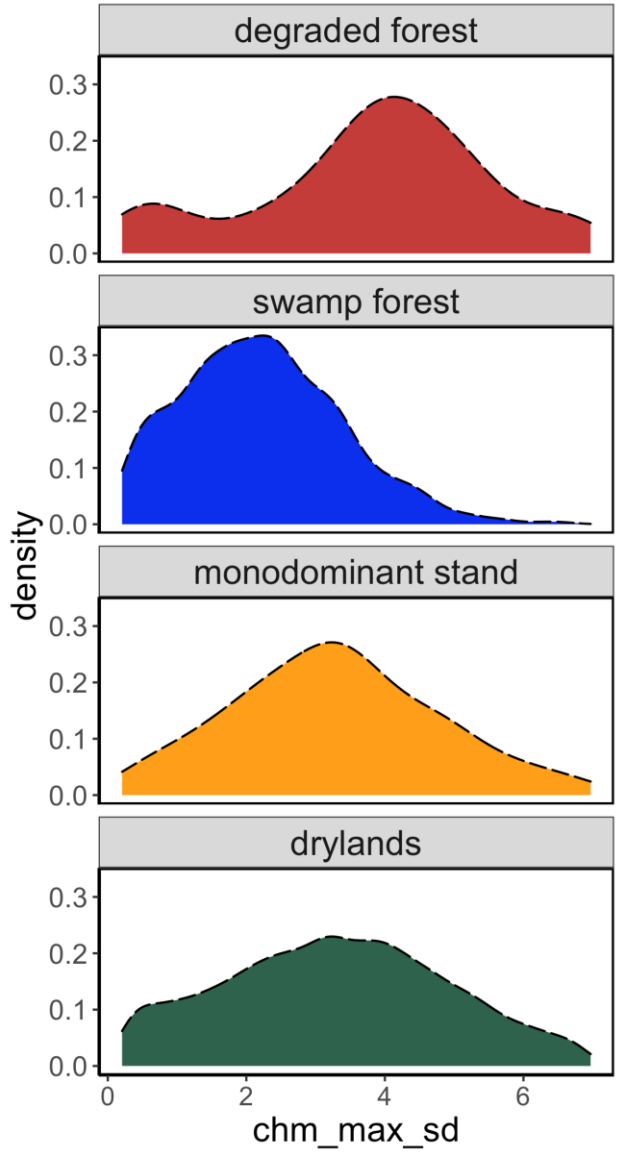
canopy height
(25 m resolution)



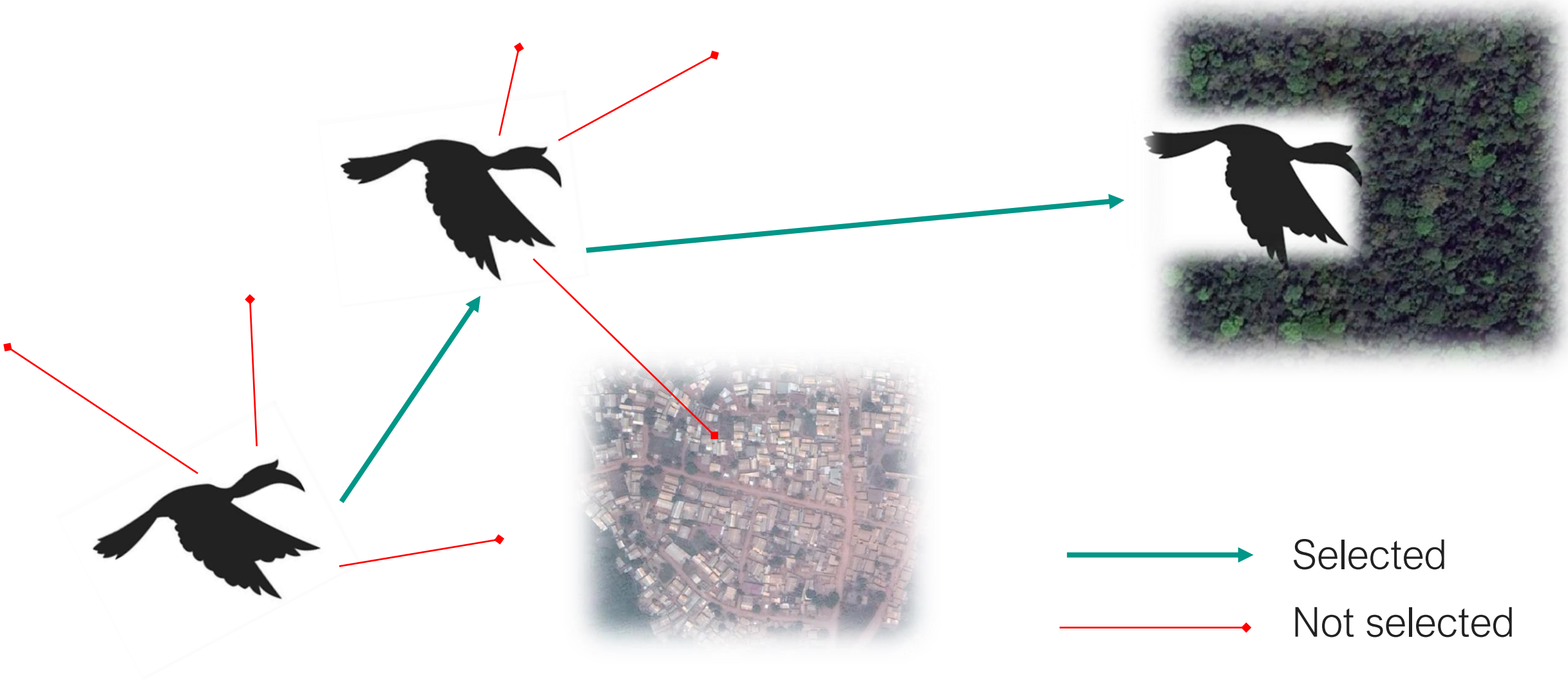
Normalized FHD
(25 m resolution)



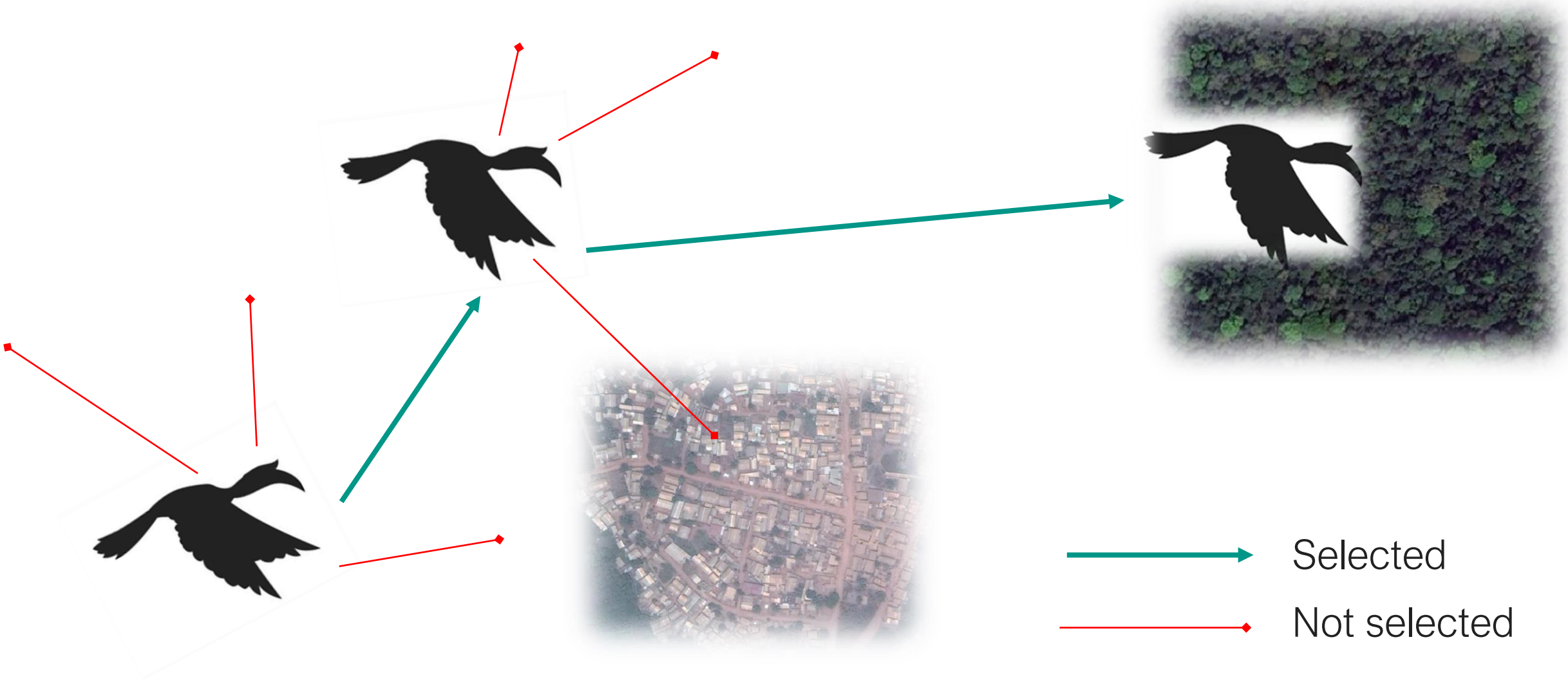
canopy roughness
(25 m resolution)

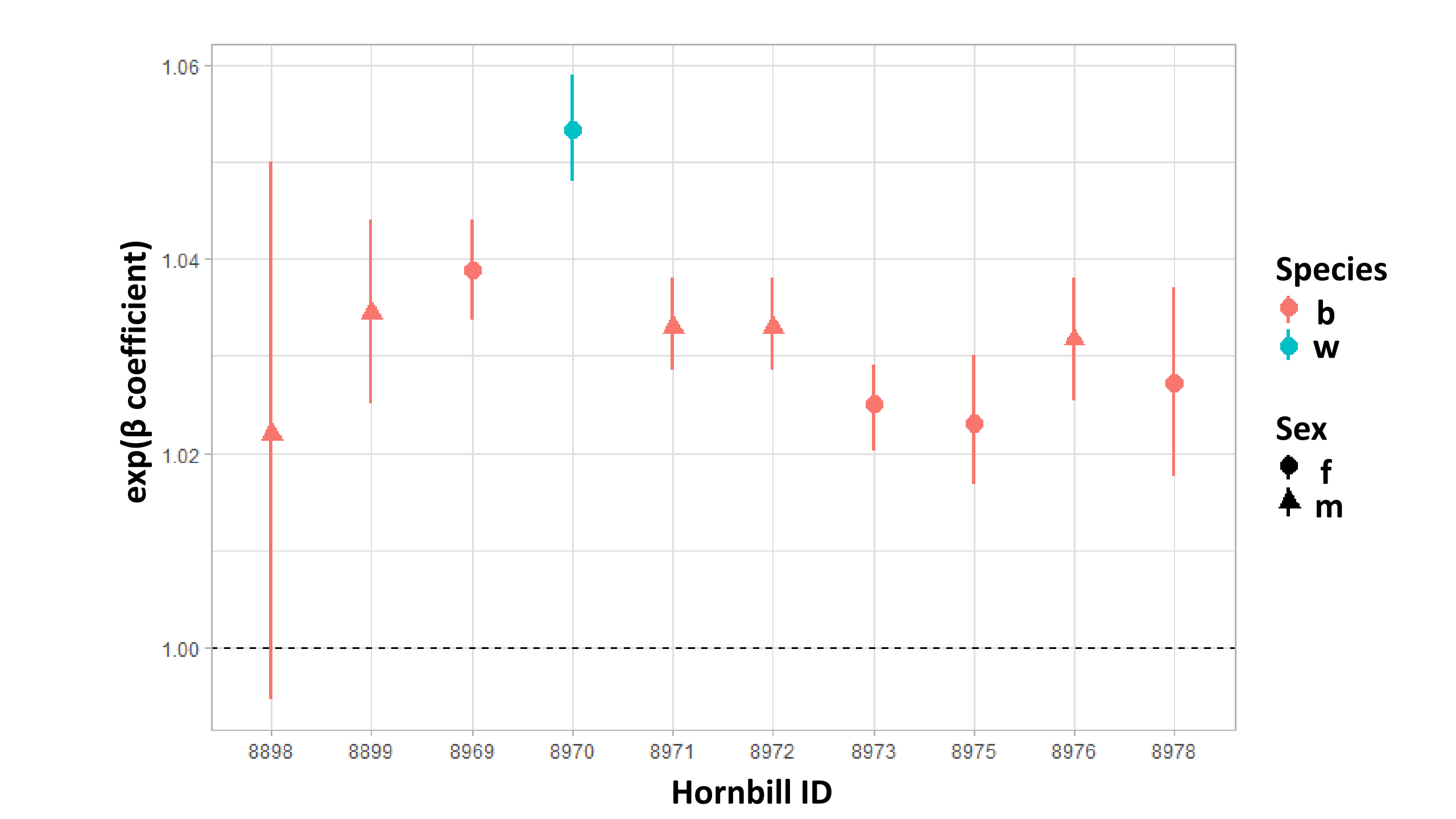


$$\breve{w}(x) = \exp(\beta_1 * \boldsymbol{canopy} + \beta_2 * \boldsymbol{NDVI} + \beta_3 * \boldsymbol{human\ influence})$$



$$\breve{w}(x) = \exp(\boldsymbol{\beta_1} * canopy + \boldsymbol{\beta_2} * NDVI + \boldsymbol{\beta_3} * human\ influence)$$




1.06
1.04
1.02
1.00
exp(β coefficient)
8898
8899
8969
8970
8971
8972
8973
8975
8976
8978
Hornbill ID
Species
b
w
Sex
f
m

Understanding seed dispersers movements and their consequences across rainforest gradients of structural and phenological diversity

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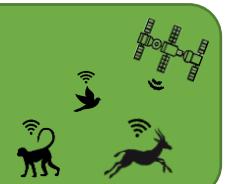
Motivation

- Congo Basin Tropical Rainforests are exposed to habitat degradation and biodiversity loss at an accelerating rate. Sustaining these forests depends on animal services
- Animals shape the structure, function and diversity of African tropical forests by dispersing the seeds of up to 90% of tree species (Osuri et al 2016)
- We have a poor understanding of how vegetation structure and function influence the movements of seed dispersing animals

We are investigating:

1) How forest structure, functional diversity, and phenology influence the movements of seed-dispersing animals, and
2) Differences in movement and seed dispersal patterns in intact and degraded forests to understand the role of species in forest biodiversity and resilience



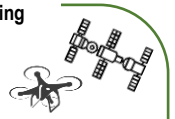
1: Study site

- **Dja Biosphere Reserve** (526,000 ha) and surrounding lowland tropical rainforest in Southern Cameroon
- The Dja Reserve harbors 100 mammal, 350 birds and 1500 plant species
- The Dja (**1a**) is exposed to forest degradation and conversion gradients (**2a**)

2: Habitat remote sensing

We use ISS, satellite and drone RS to characterize forest :

- Structural diversity
- Spectral diversity (proxy for plant biodiversity)
- Functional diversity and habitat types
- Phenological patterns (temporal and spatial)



Movement hypothesis	Sensors used	Products (examples)
Vertical structure	GEDI	Canopy height, cover, layering, understory density, tree crown size and shape, tree size distributions
	Drone LiDAR	
Landscape Structure	GEDI	Forest connectivity, forest degradation, forest morphological diversity, emergent crown density
	Drone LiDAR	
	Landsat 8	Habitat type (Baka-defined), Spectral beta diversity, thermal habitat niches
	Sentinel-1 & 2	
Forest function	SRTM	
	ECOSTRESS	
	DESIS	canopy- and tree-level spectral signatures of wilting, flowering and, flushing
Phenology	Sentinel-2	
	Planet Lab	

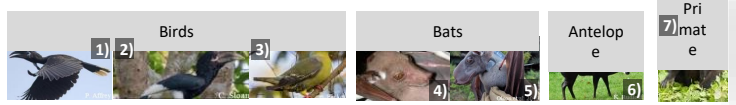
3: Animal movement tracking

a) We are tracking the movement of 7 key seed-dispersers using ICARUS tags transmitting their location to an antenna installed on the ISS

b) We are customizing ICARUS transmitters to maximize fix rate and location precision while keeping weight <5% animal mass

c) Collaborator Nicholas Russo recently tagged 3 hornbills in the Dja Biosphere Reserve.

1) Black-casqued hornbill
2) White-thighed hornbill
3) African green-pigeon
4) Franquet's epauleted fruit bat
5) Hammer-headed fruit bat
6) Yellow-backed duiker
7) Grey-cheeked mangabey

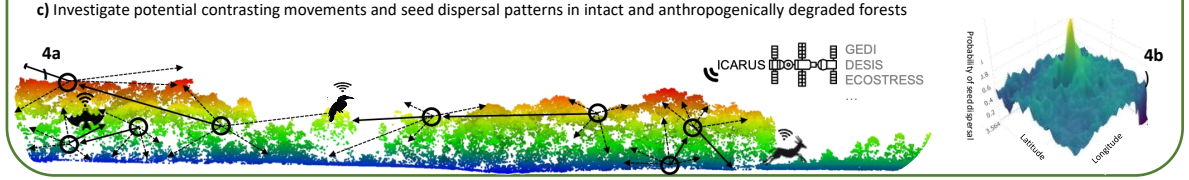


4: Integrating animal tracking and remote sensing to address science questions

a) Study the influence of forest characteristics (structure, function, phenology) on animal movements using Step Selection Functions (SSF's)

b) Modelling seed dispersal spatial patterns by considering animals movement, location of key fruiting/flowering trees and gut passage times

c) Investigate potential contrasting movements and seed dispersal patterns in intact and anthropogenically degraded forests

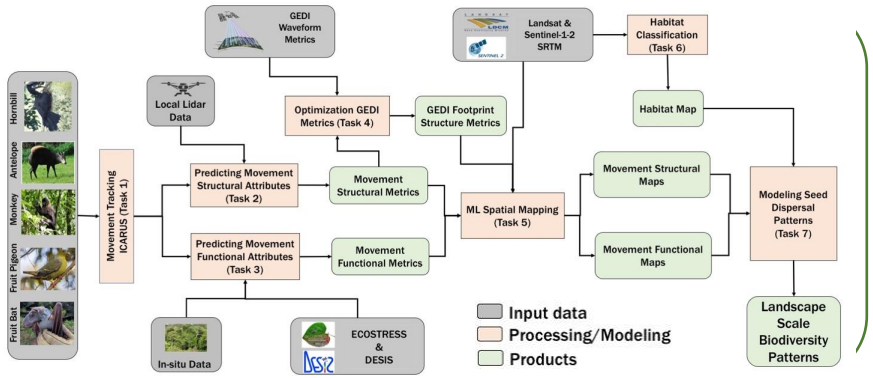


5: Overall method workflow

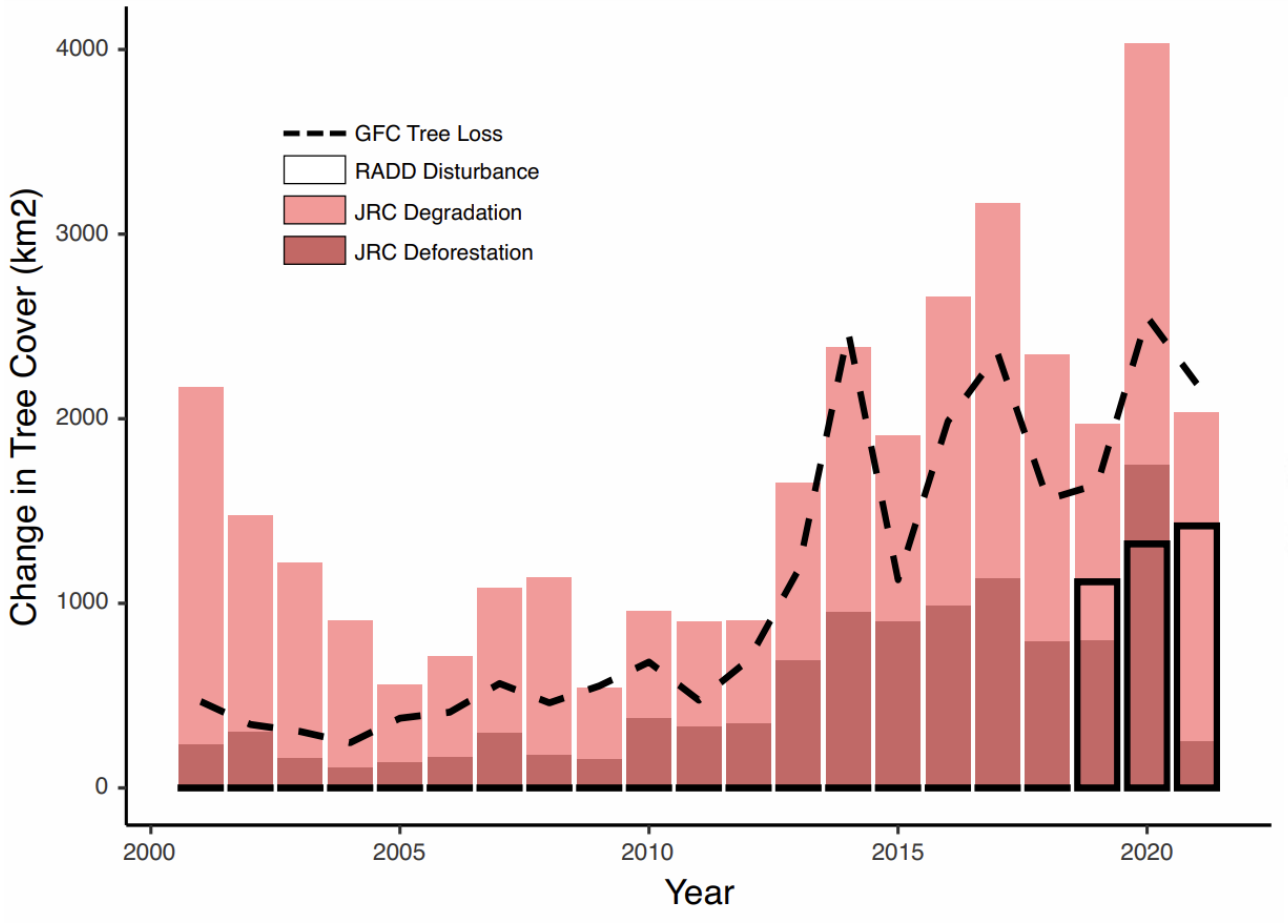
We developed a multi-scale approach to accommodate contrasting animal home ranges.

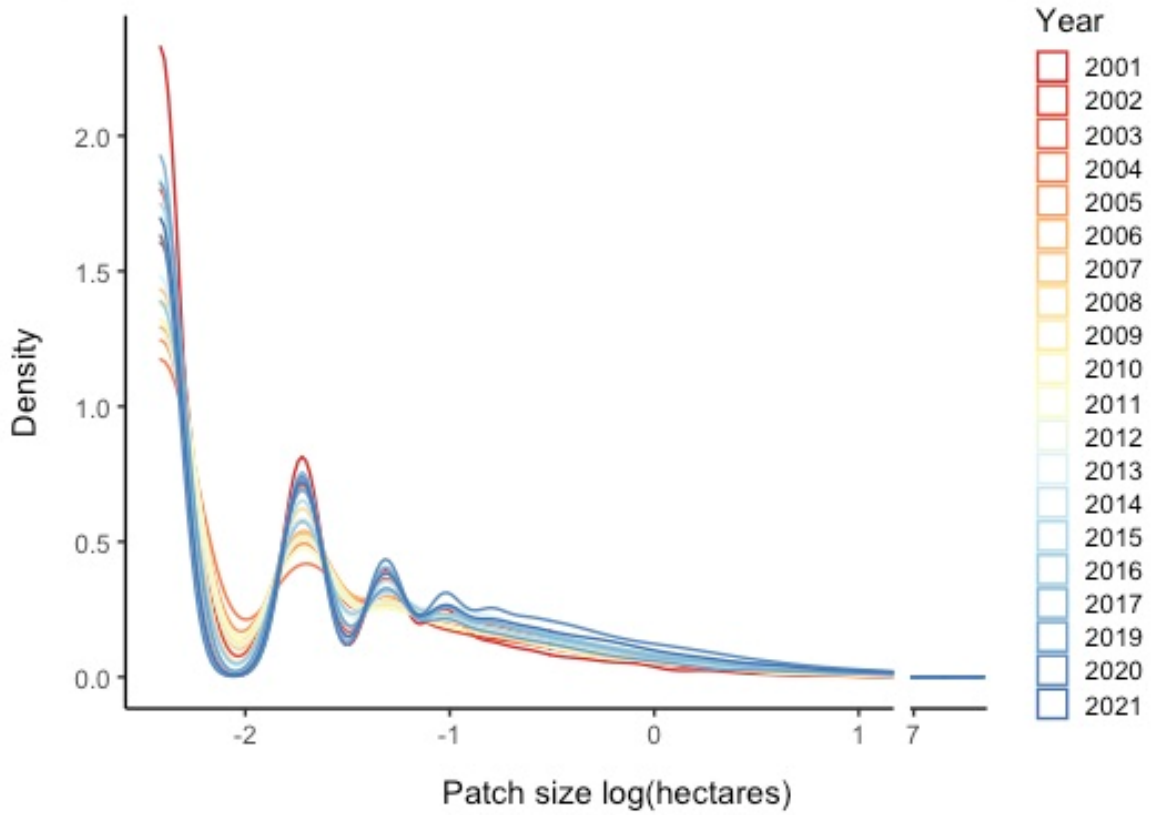
The local-scale forest characterization from drone and high-resolution imagery is used to study the movement of short-range animals (e.g., primates)

The landscape-scale characterization from spaceborne measurements is used to study movements of large-range animals (e.g., hornbills > 600km) and to extrapolate local-scale predictions to the entire study site.



Increasing forest disturbance





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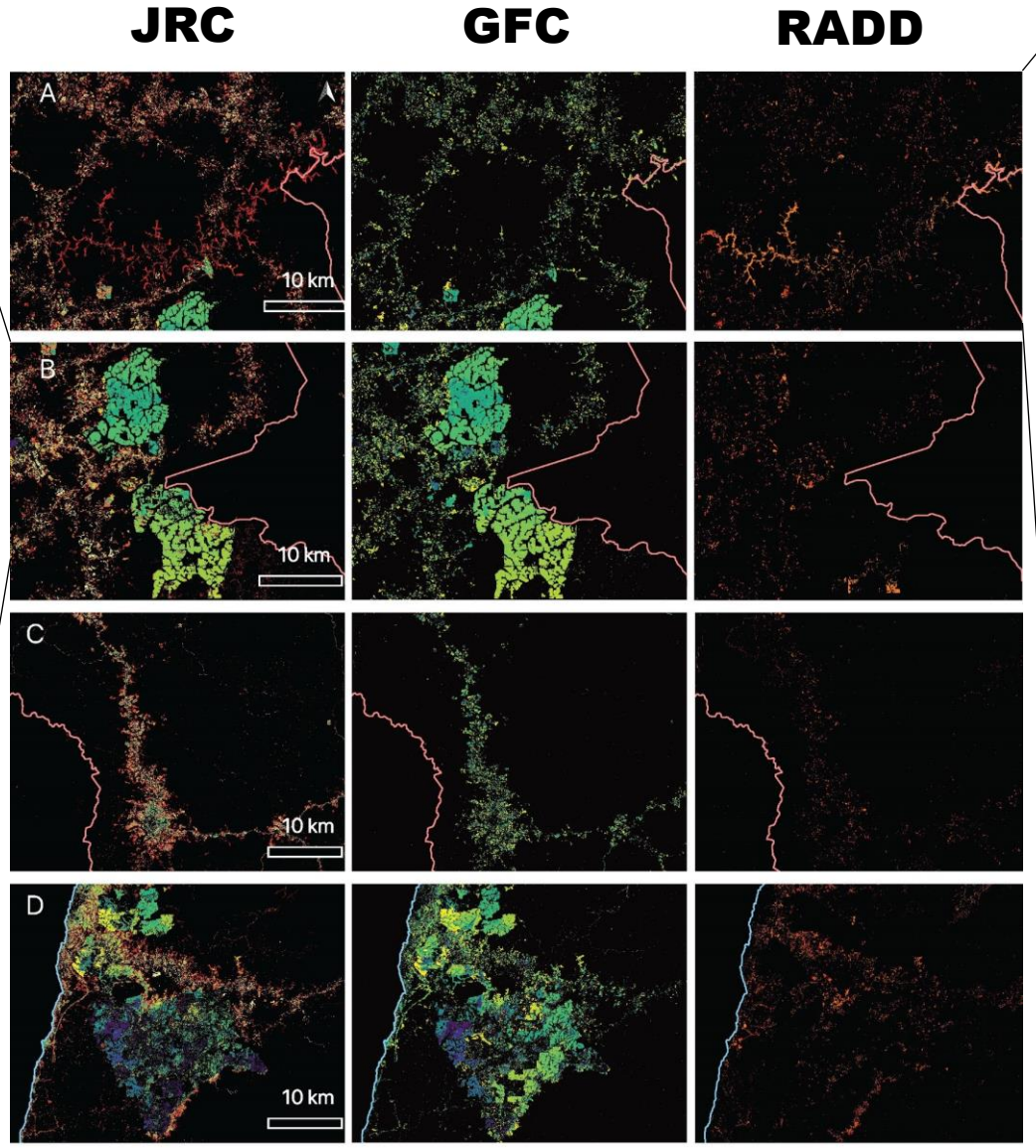
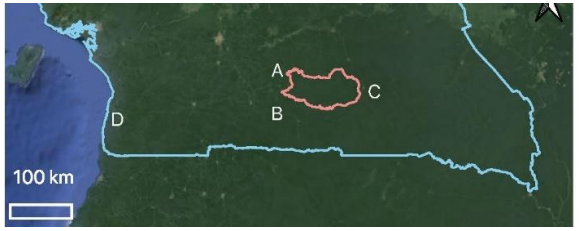
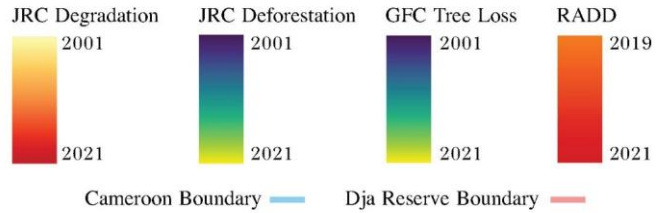
SkySat image collection over plantation near Dja Reserve







Forest disturbance due to flooding of Dja river.

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