

RAM NA

Rangeland Monitoring for Africa Using Earth Observation - Continental Demonstrator

EO for Africa Symposium 2024

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Donvan Grobler³, Patrick Griffiths⁴, Michael Munk⁵, Mahendra Pal², Paul Senty⁵

Tasks

- 1) Map African rangelands
- 2) Quantify rangeland herbaceous biomass monthly
- 3) Quantify rangeland vegetation phenology
- 4) Define and map rangeland ecosystem types
- 5) Rangeland social-ecological trade-offs and performance

Extent: Africa

Resolution: 10 m

Data: Sentinel 1-3

Period: 2022 (± 3 months)



An African rangeland

Also a
rangeland





Still a rangeland...

A rangeland is any vegetated land that is not cropped and not closed-canopy forest

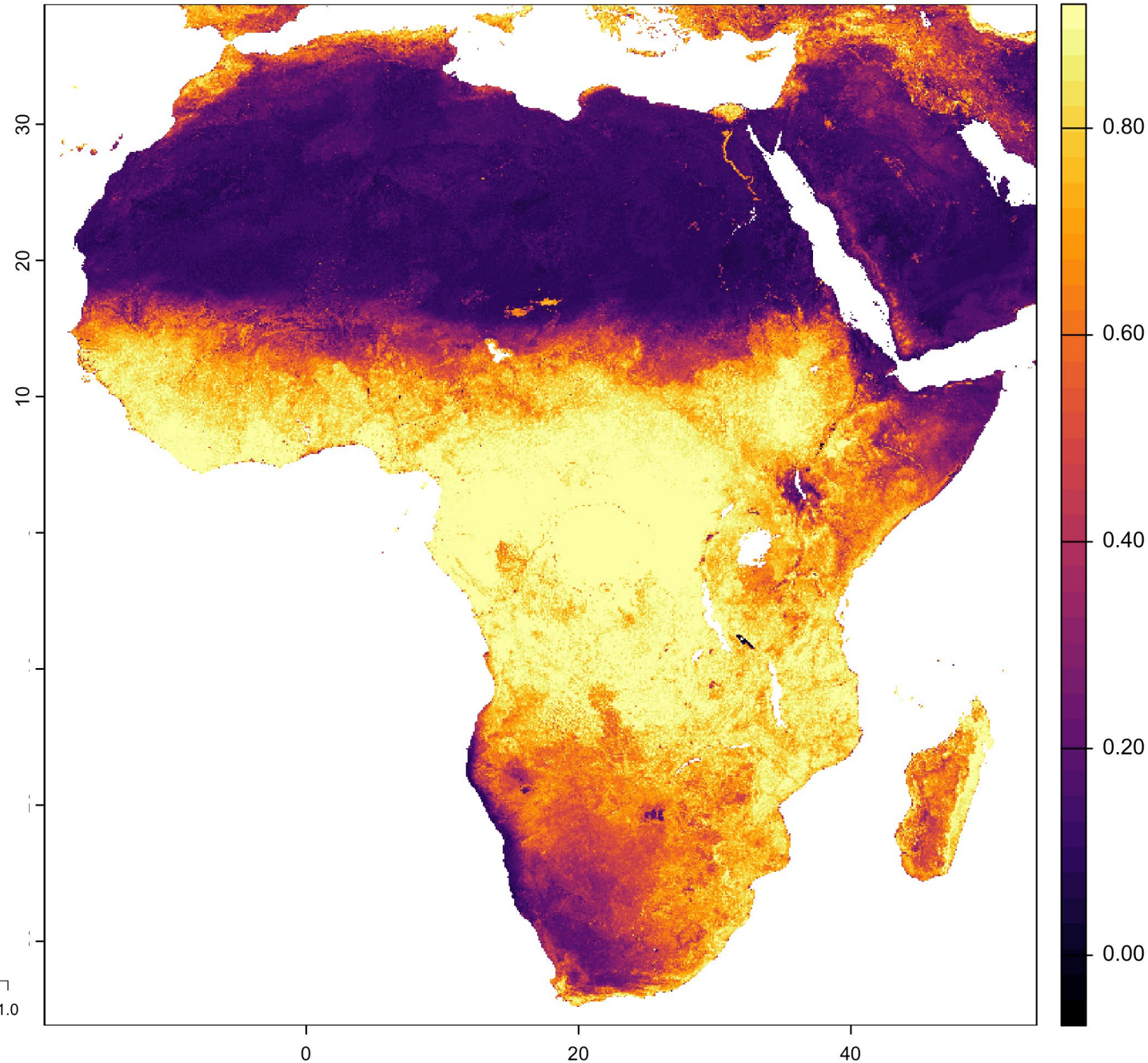
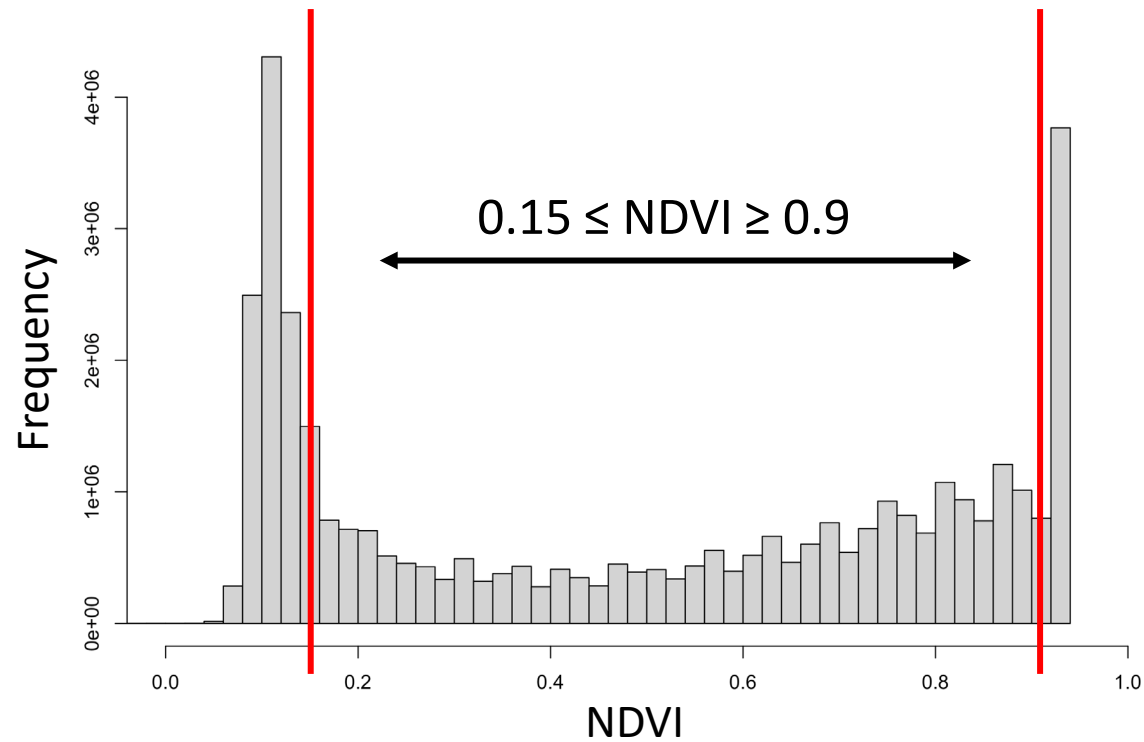
Nearly identical to FAO, IUCN, UNEP, ILRI, WWF, World Bank, etc. definitions but easier to operationalise with EO data



Mapping African rangelands – the long-term maximum envelope

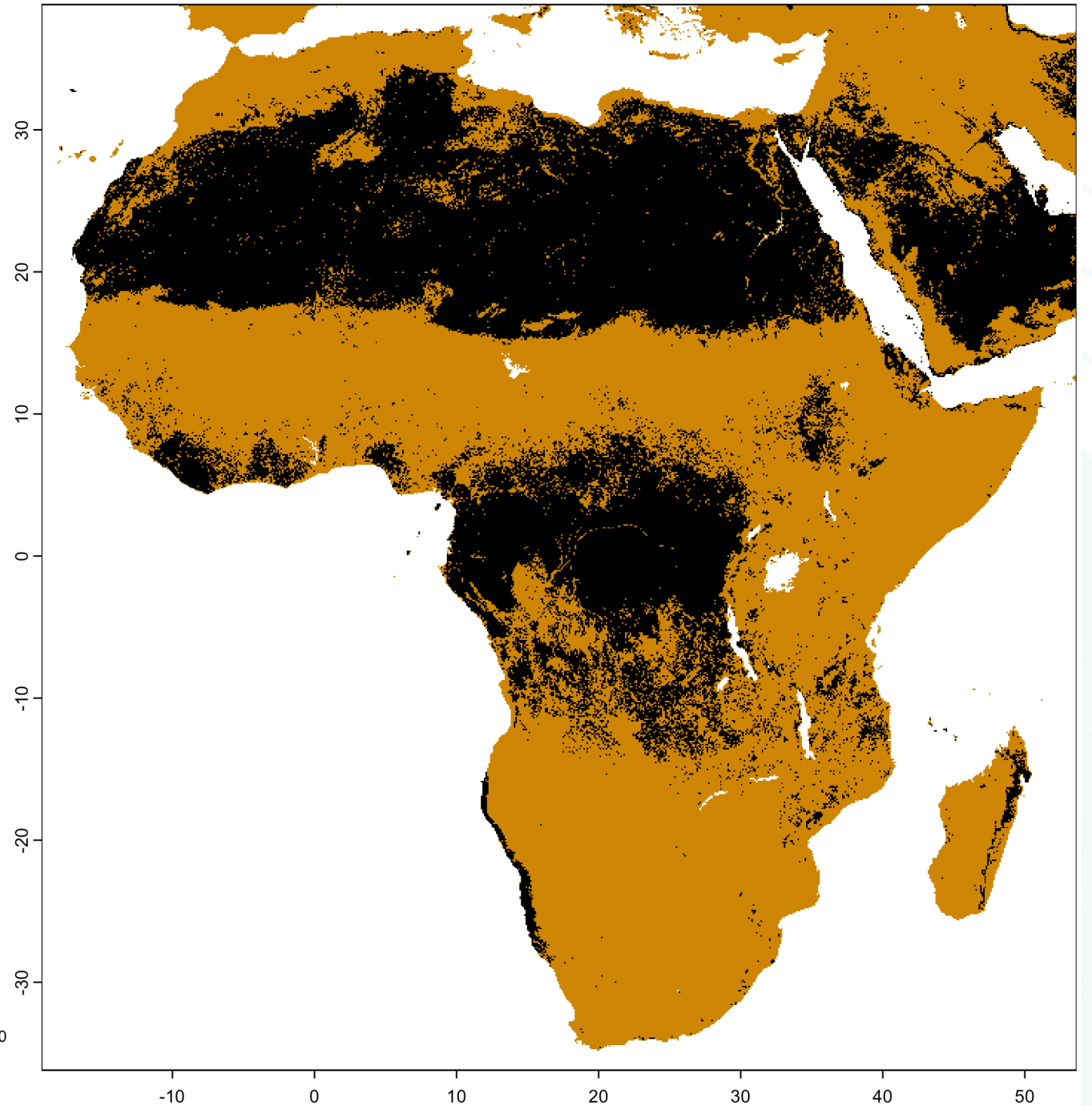
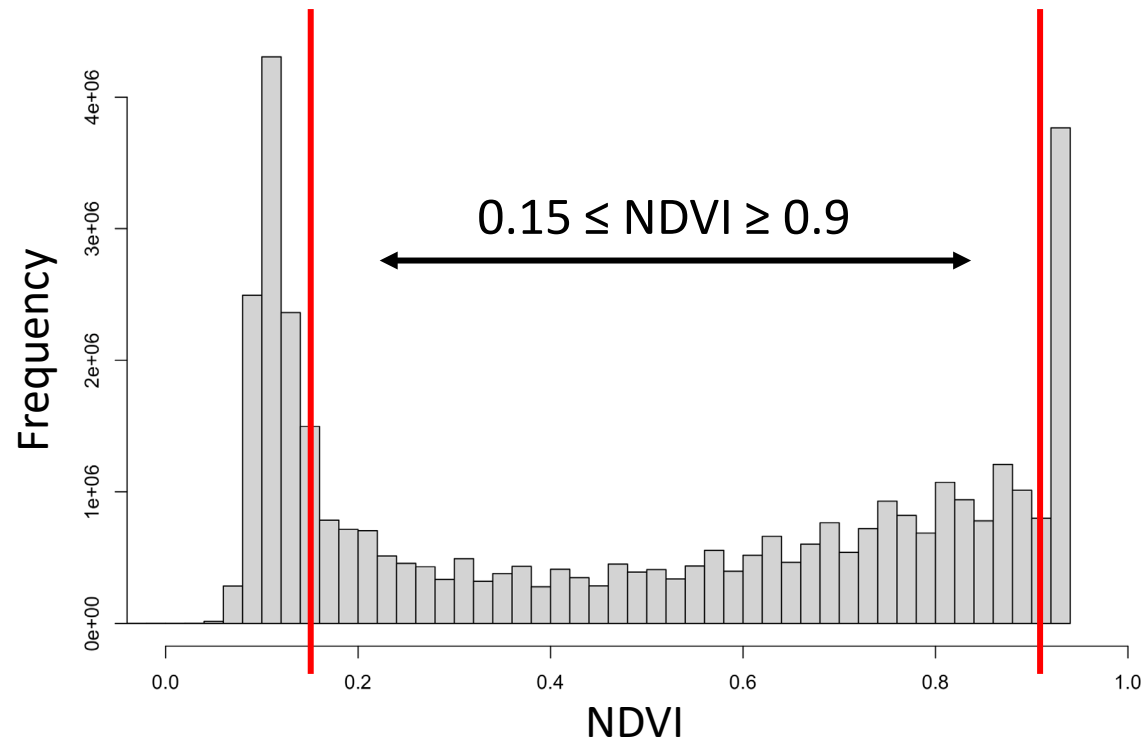
African rangeland envelope

Long-term maximum NDVI
1999- 2019 from MODIS



African rangeland envelope

Long-term maximum NDVI
1999- 2019 from MODIS

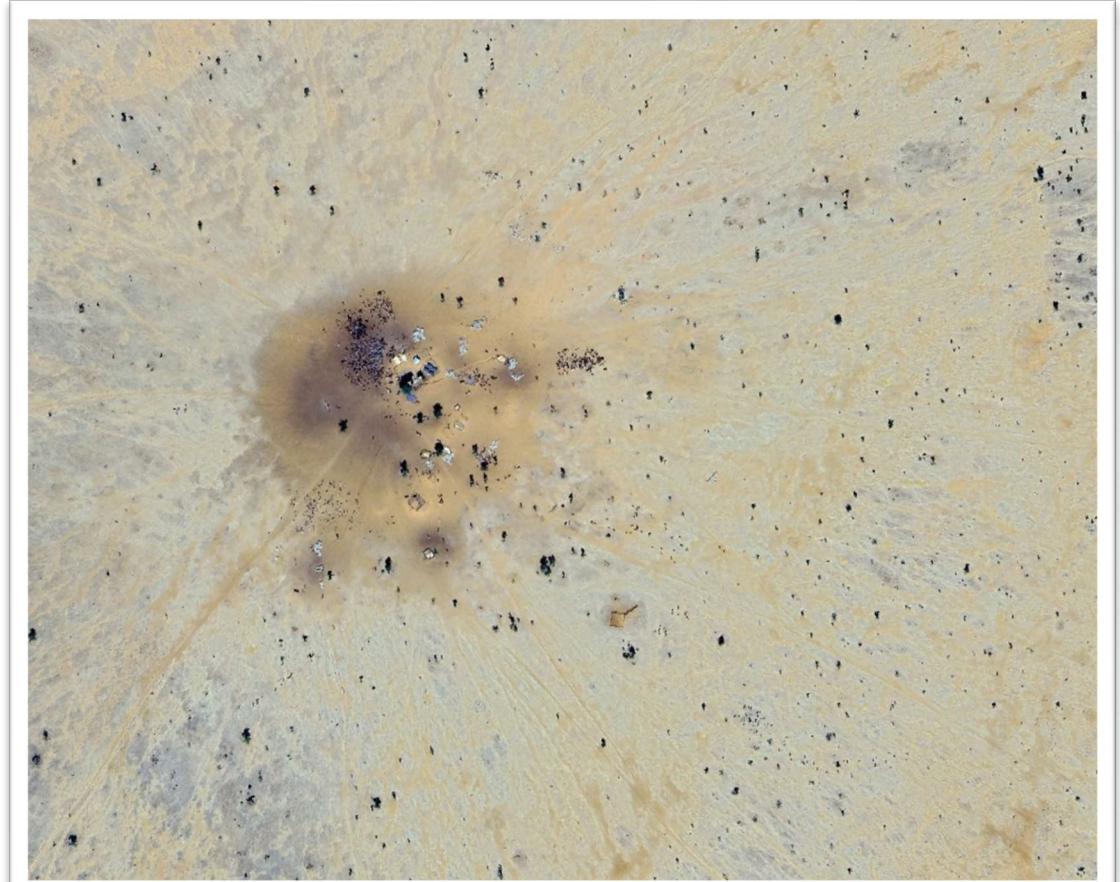


Mapping African rangelands – high-resolution 2022 rangeland extent

(i.e. within the long-term envelope)

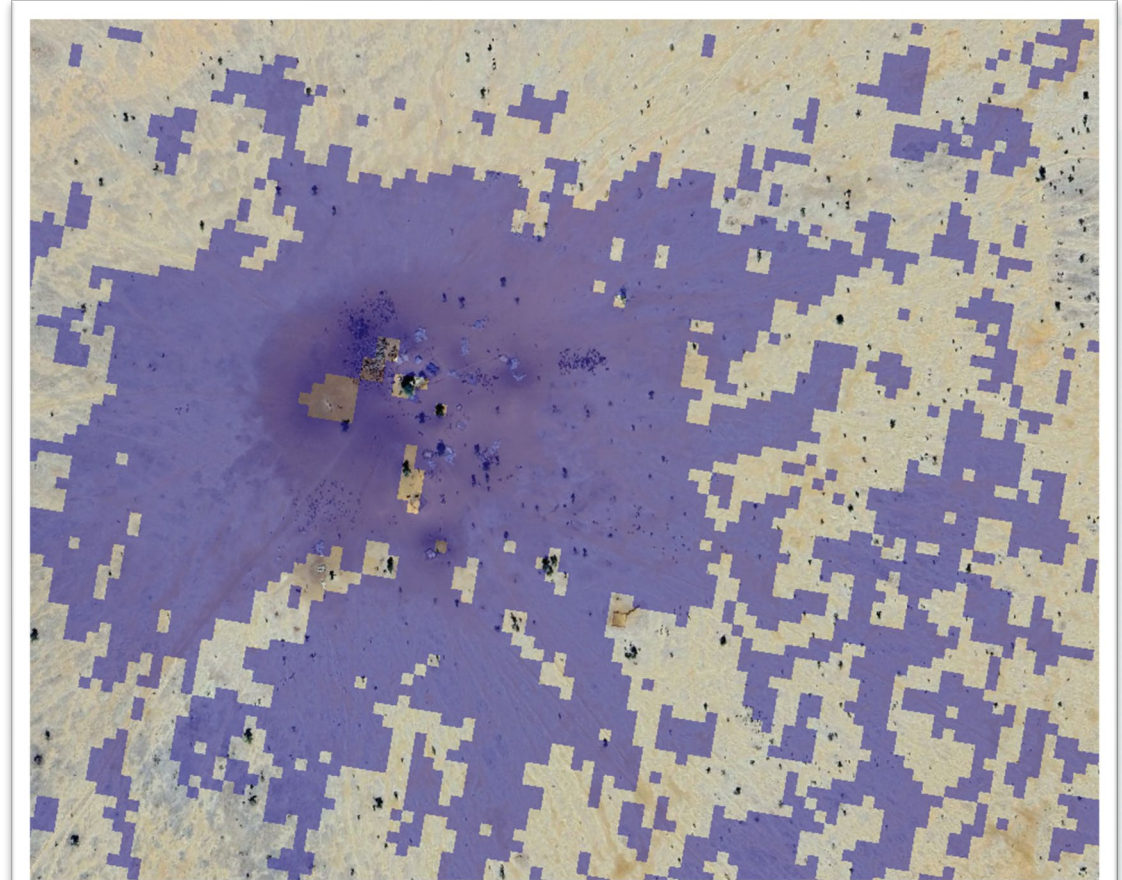
High-resolution rangeland extent for 2022

Remove unvegetated cells (max GPP = 0)

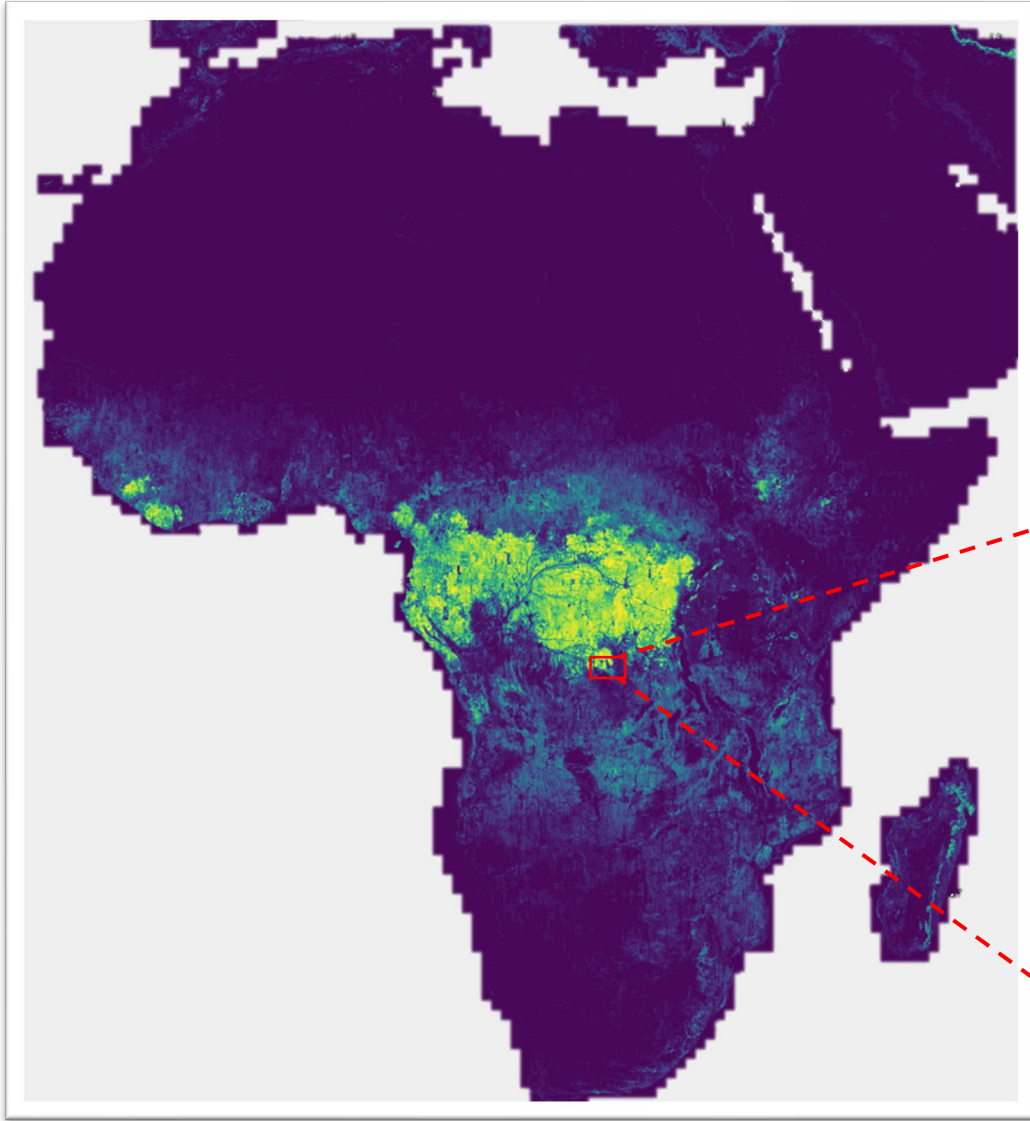


High-resolution rangeland extent for 2022

Step 1: Mask unvegetated cells (max GPP = 0)

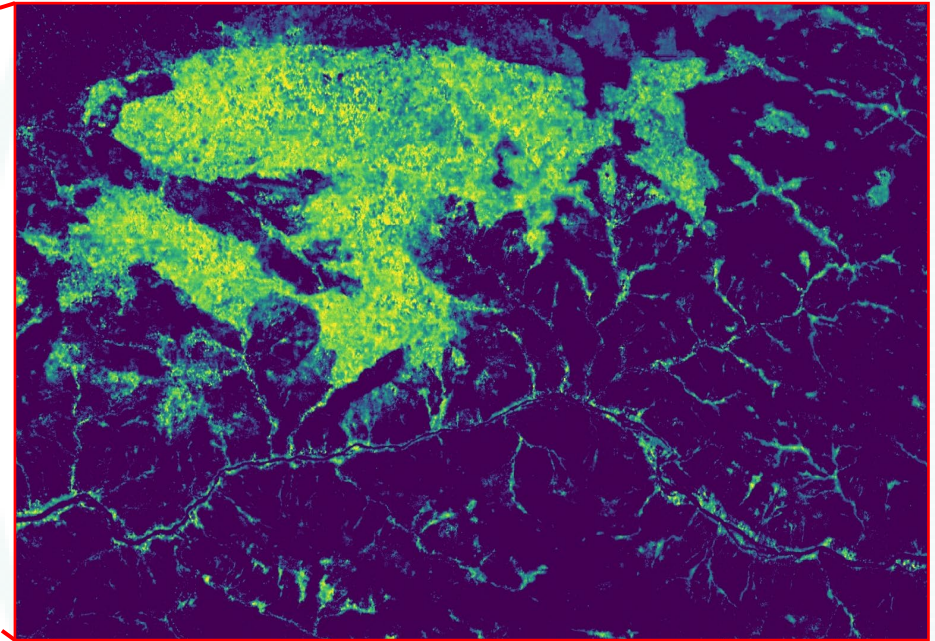


High-resolution rangeland extent for 2022



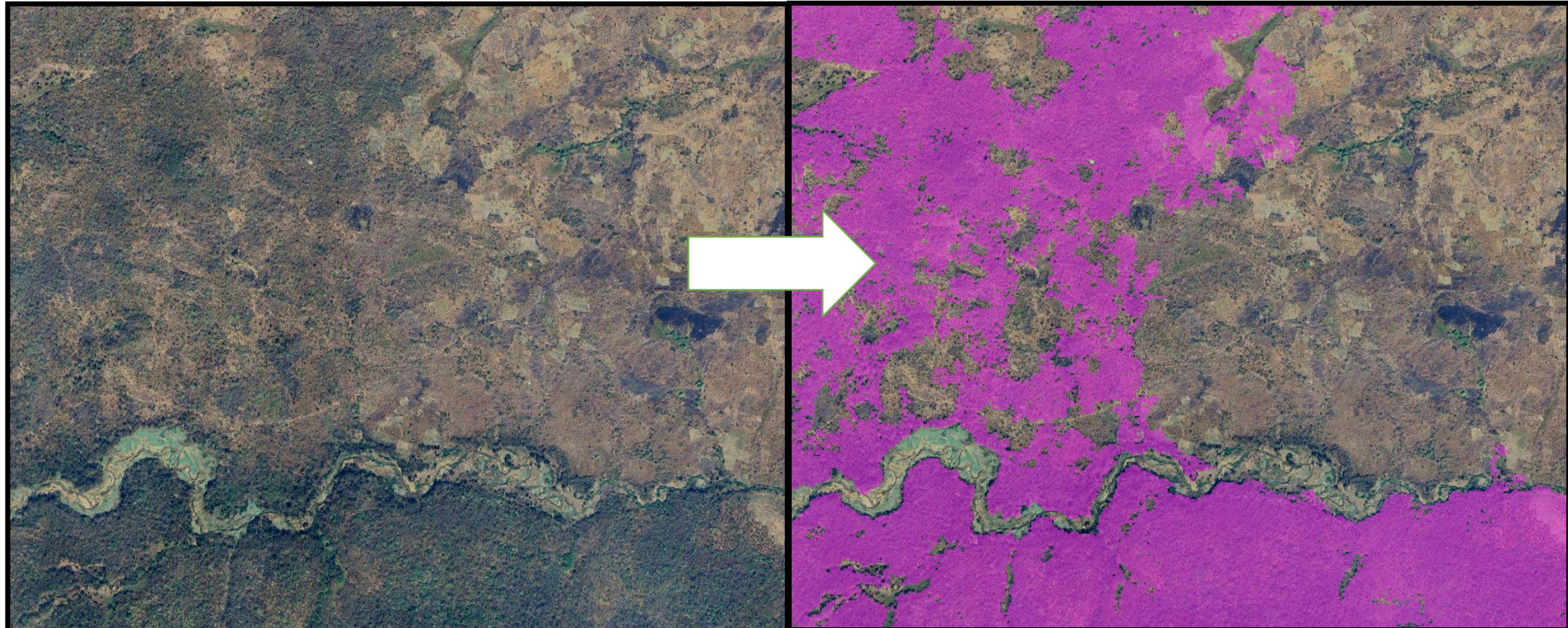
Step 2: Mask closed-canopy forest when

- woody cover $\geq 90\%$
- area ≥ 5 ha
- median canopy height ≥ 5 m



High-resolution rangeland extent for 2022

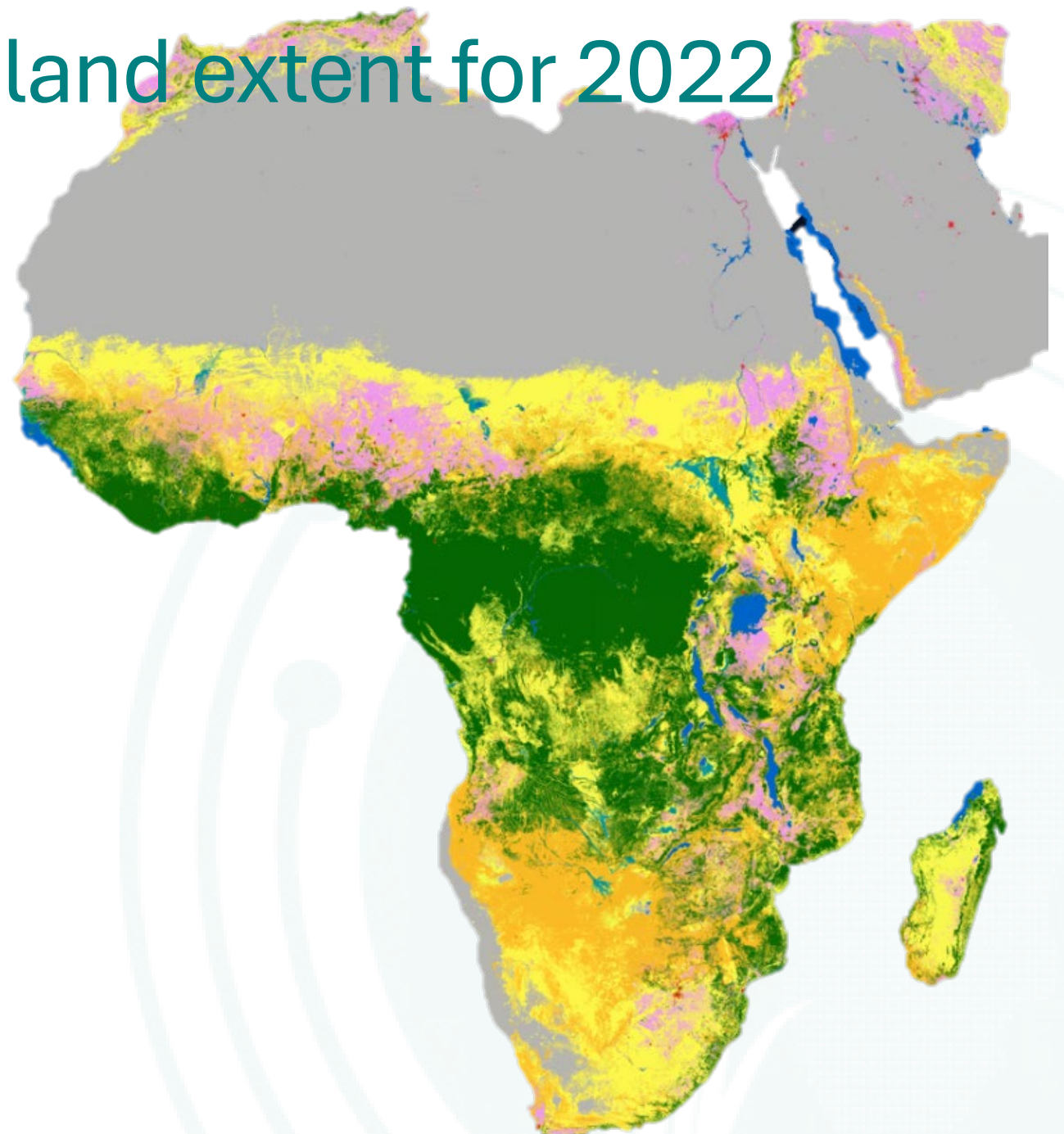
Example of masking closed-canopy forest

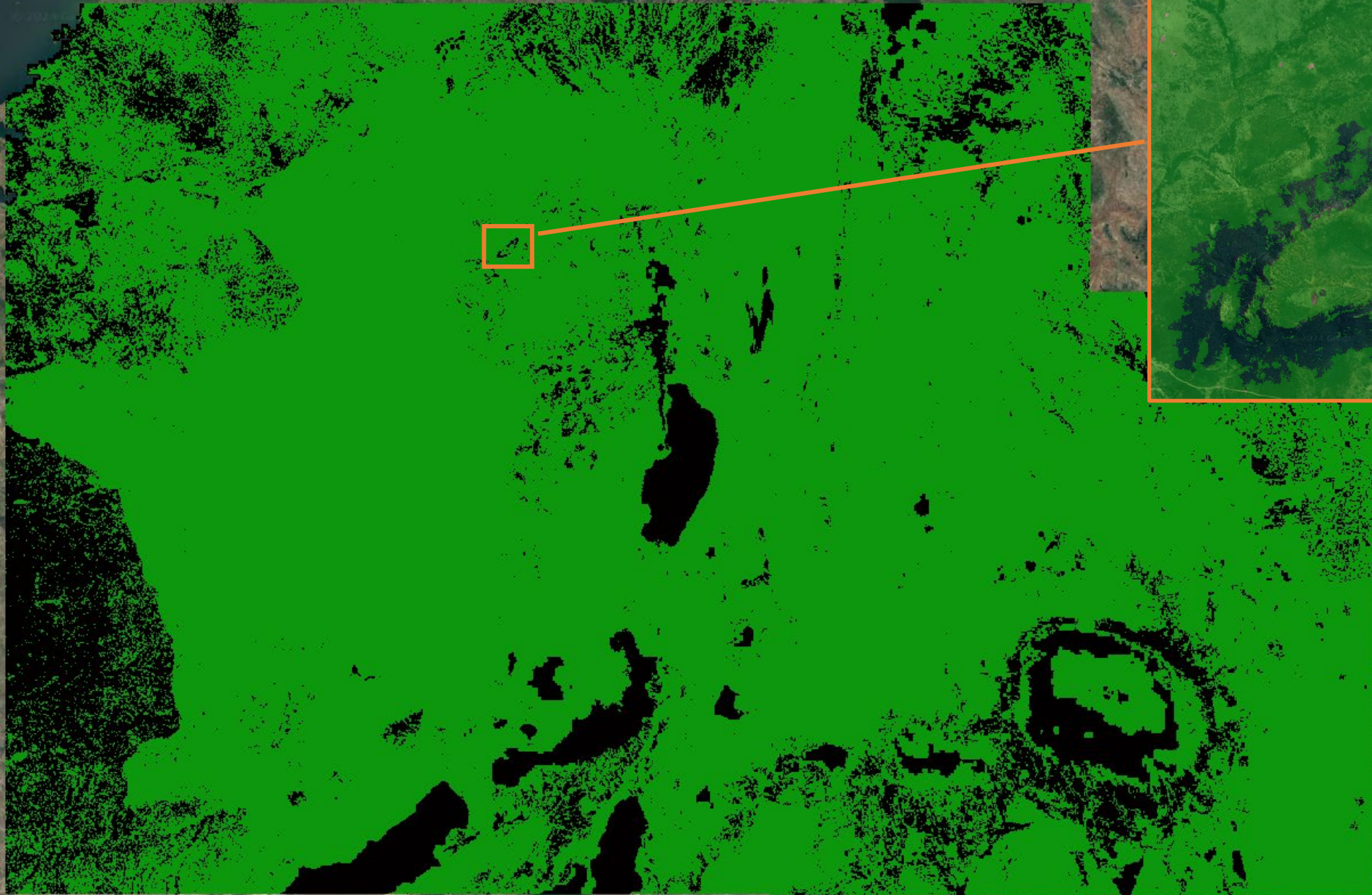


High-resolution rangeland extent for 2022

Step 3: Mask cropland and built-up area with WorldCover

WorldCover V2 2021

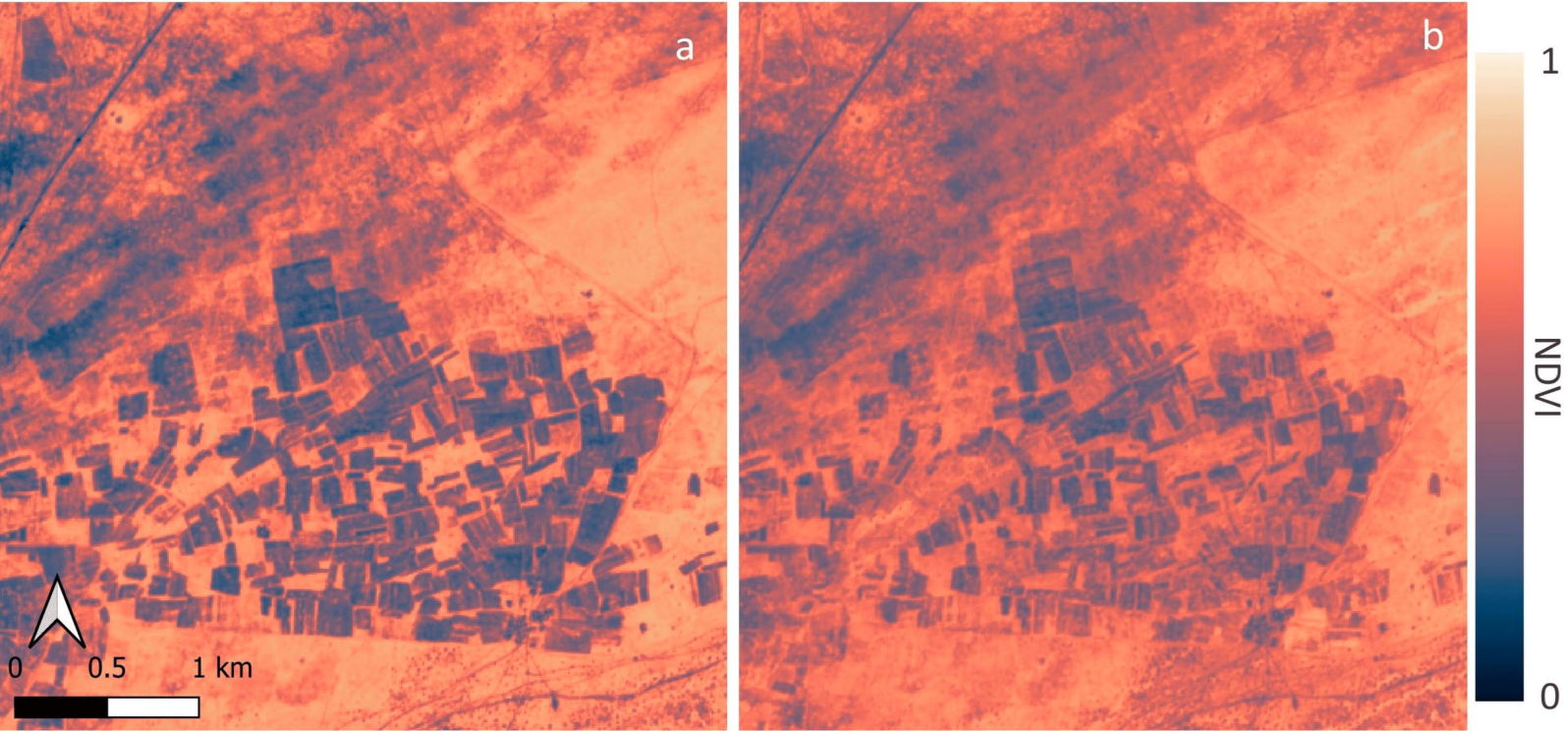
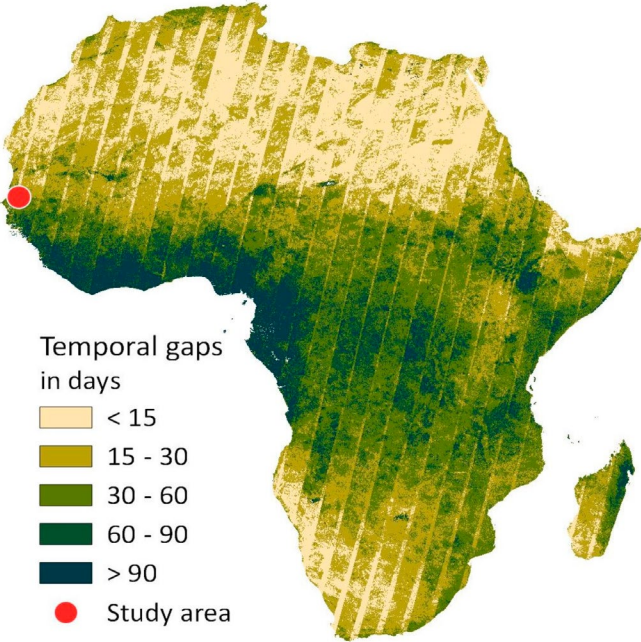
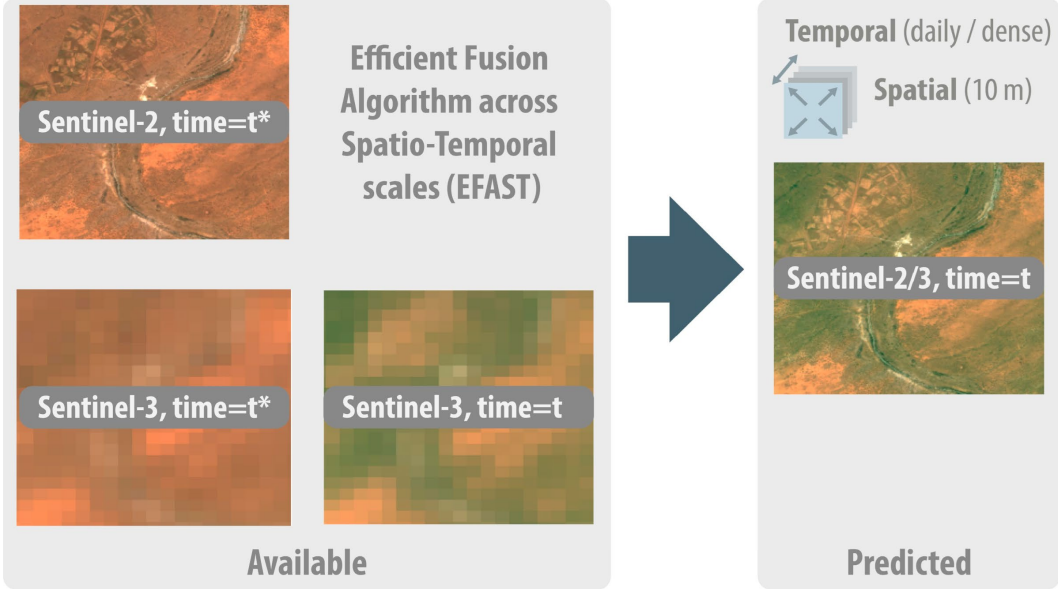




Generating high-density Sentinel-2 time series

The background of the slide features a light teal color. On the right side, there is a faint, stylized graphic. It includes a satellite in orbit with two solar panels, positioned above a large circular shape that represents the Earth. Below the Earth, there are several vertical, blade-like shapes that resemble grass or reeds, suggesting a focus on agriculture or land use monitoring.

Gap-filled Sentinel-2 time series by fusing with data from Sentinel-3 and Sentinel-1



Sentinel-2

EFAST

Senty, P., Guzinski, R., Grogan, K., Buitenwerf, R., Ardö, J., Eklundh, L., Koukos, A., Tagesson, T., & Munk, M. (2024). Fast Fusion of Sentinel-2 and Sentinel-3 Time Series over Rangelands. Remote Sensing, 16(11), 1833. <https://doi.org/10.3390/rs16111833>

Rangeland herbaceous biomass productivity



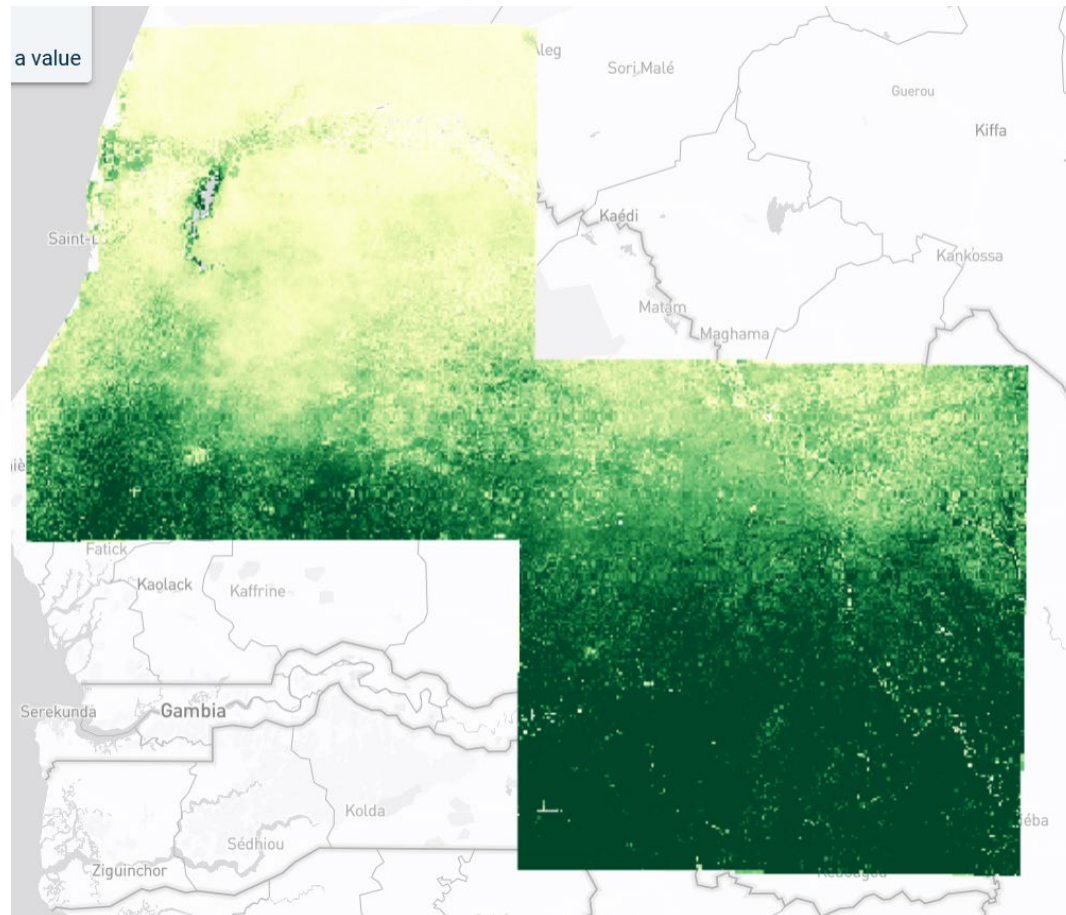
Herbaceous Biomass productivity

Workflow

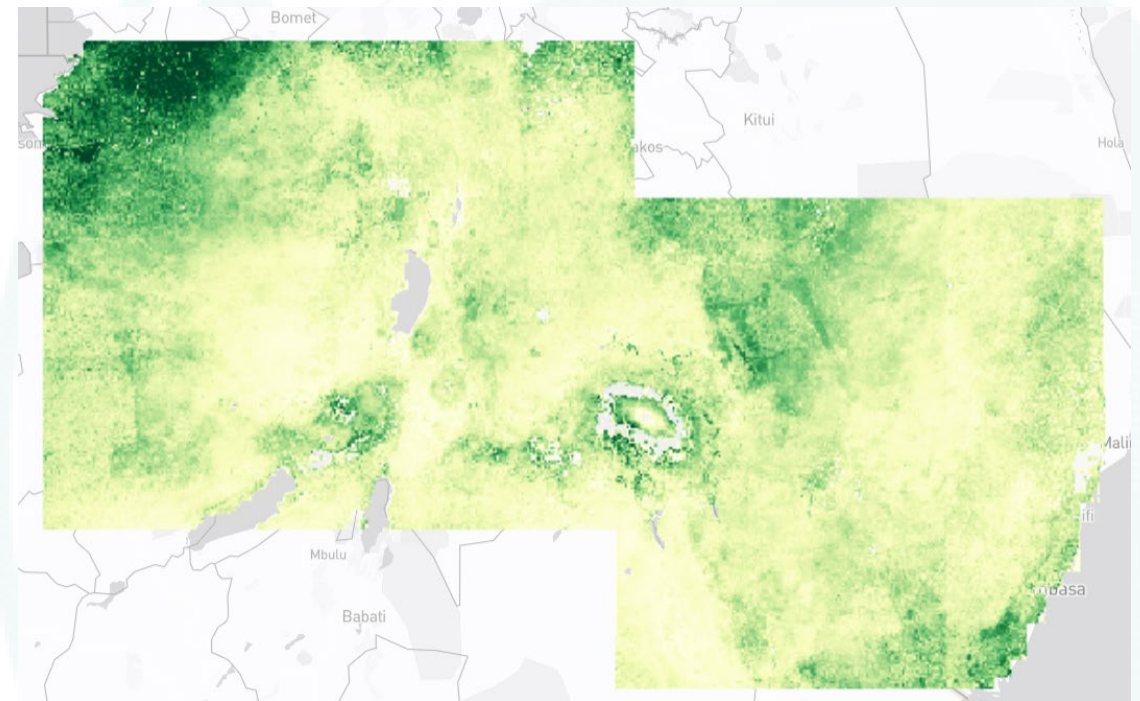
- 1) Intake gap-filled NDVI time series
- 2) Estimate 5-day GPP from a light-use efficiency model (calibrated using available eddy covariance data)
- 3) Separate GPP into woody and herbaceous fraction using woody cover
- 4) Sum GPP to monthly accrued biomass

Large-scale patterns

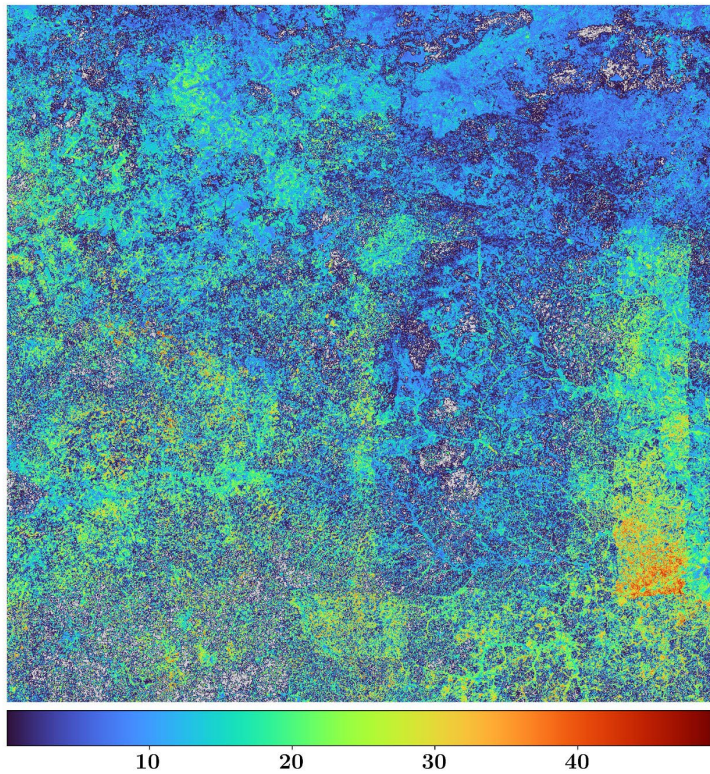
West Africa (Oct)



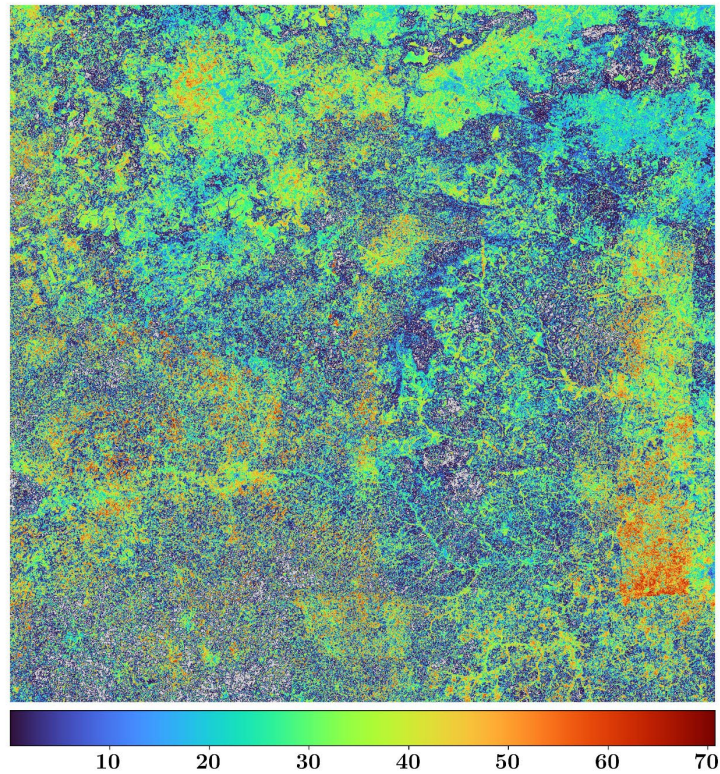
East Africa (Nov)



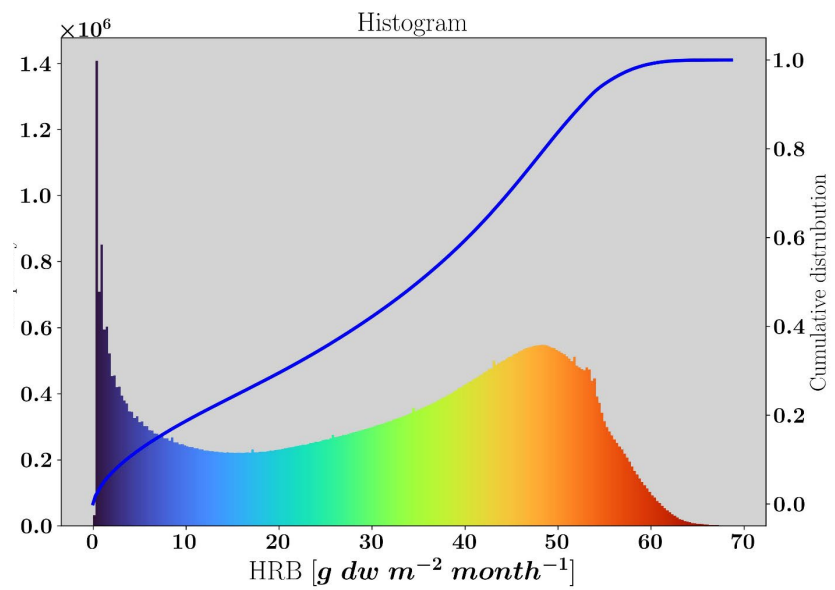
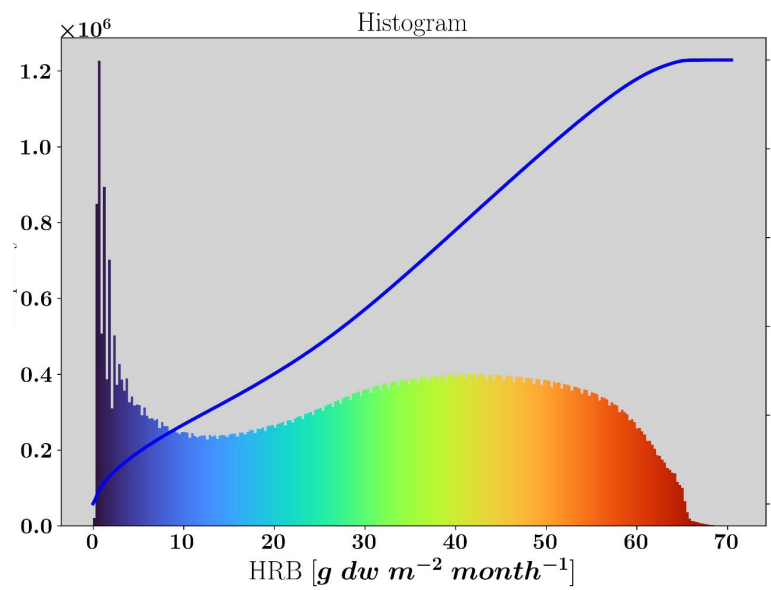
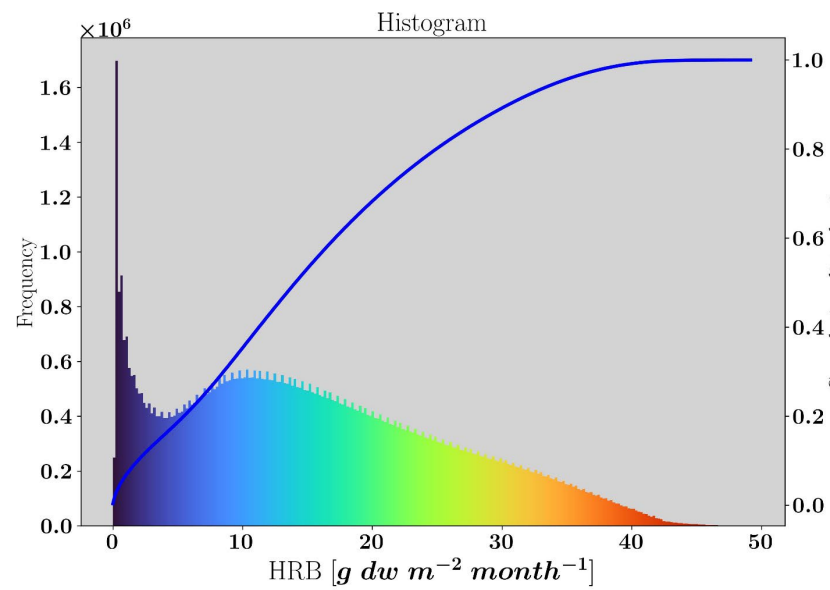
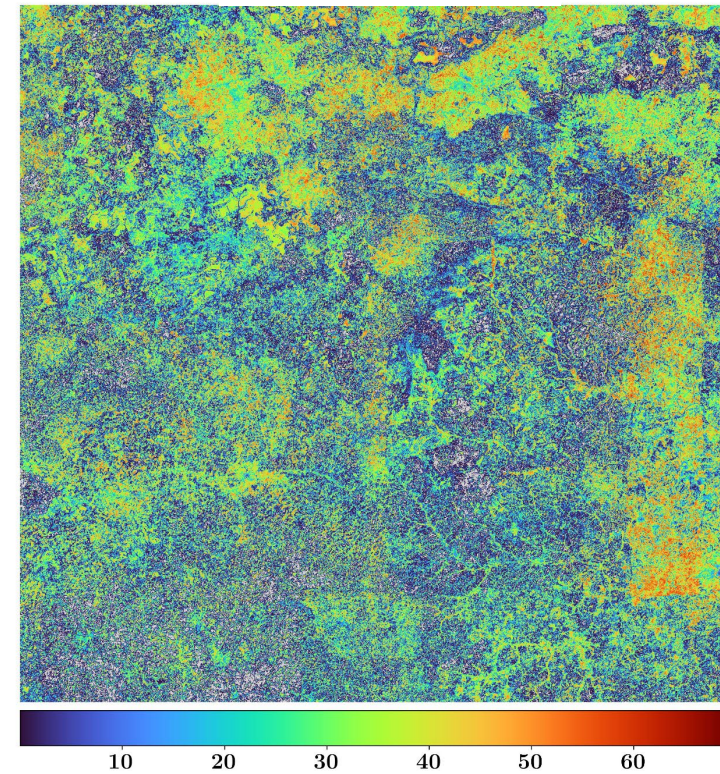
May



June



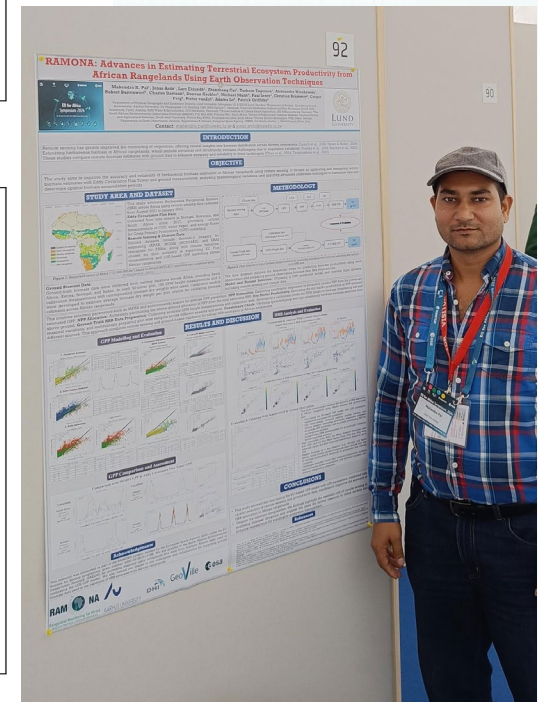
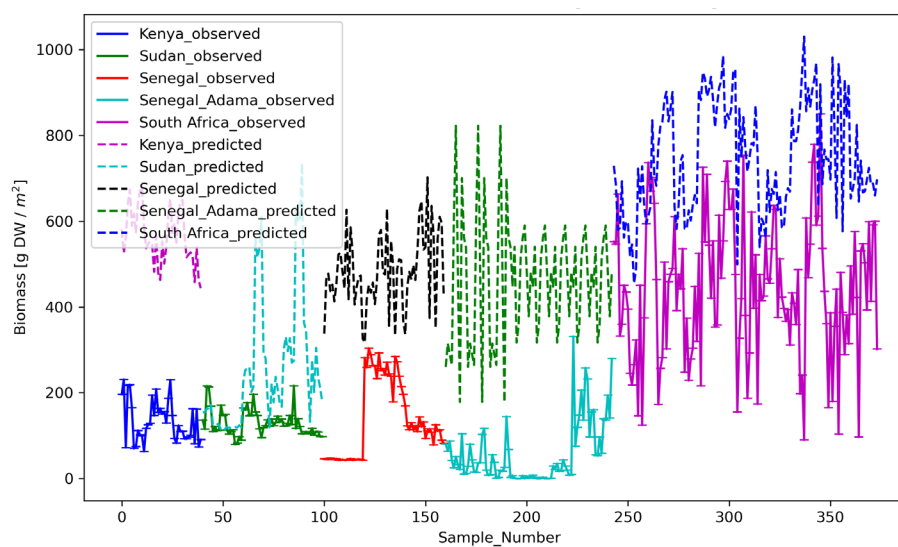
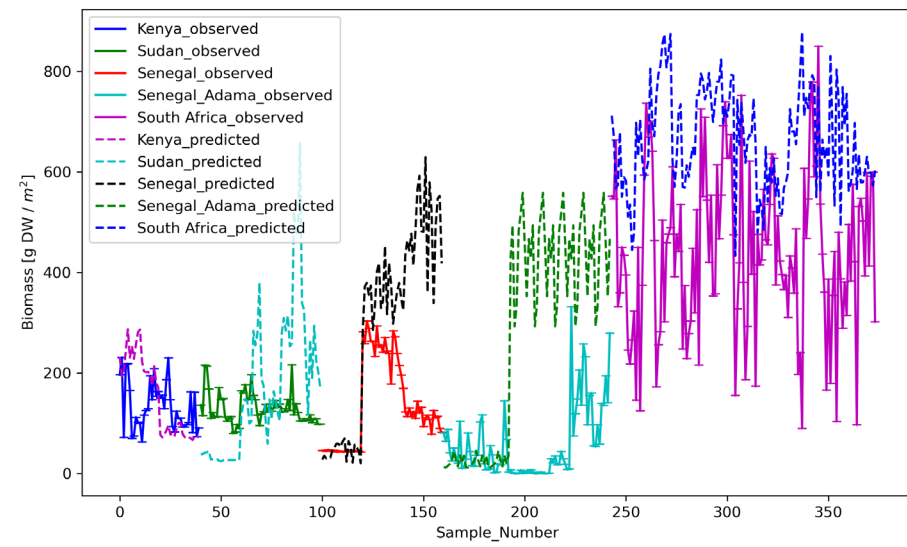
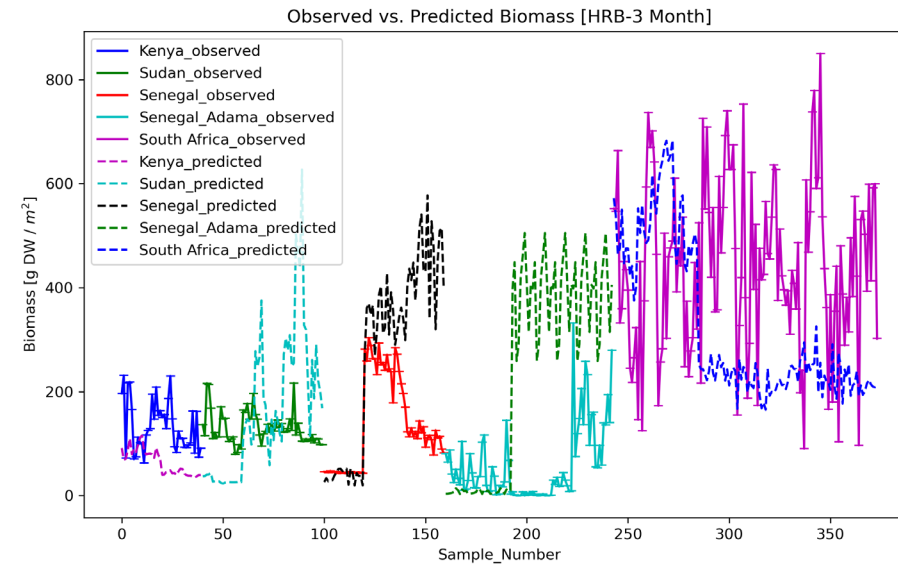
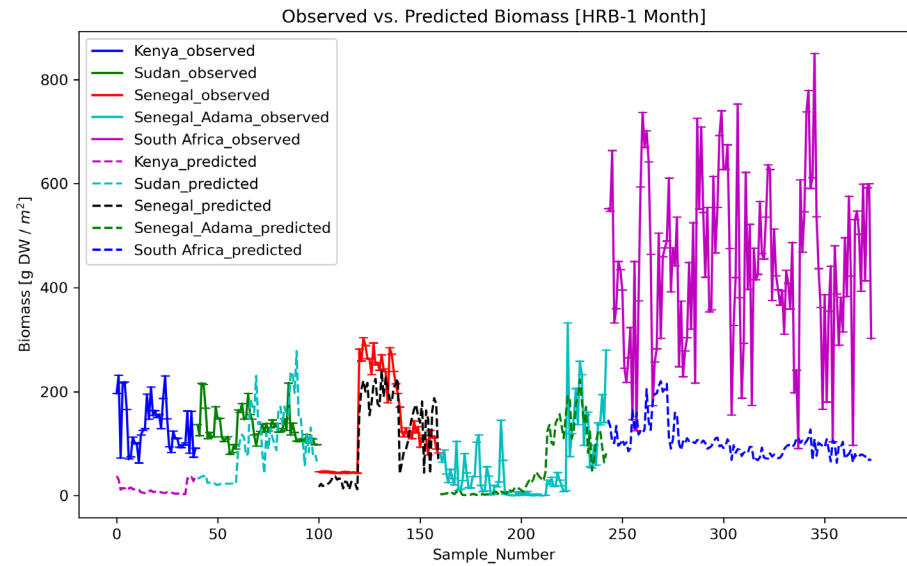
July



Evaluation using field measured biomass in Senegal, Sudan, Kenya and South Africa



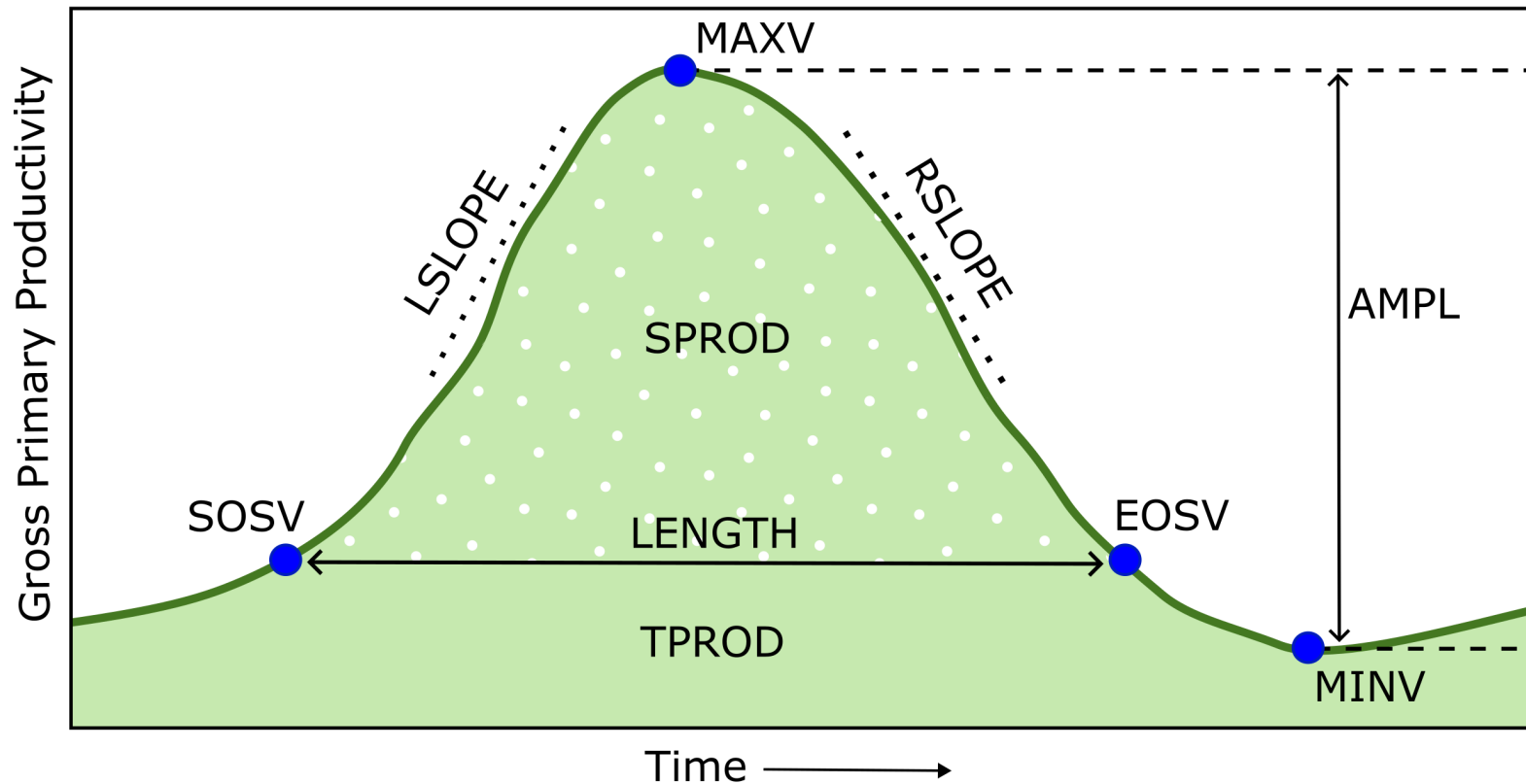
Poster 92



Phenology of herbaceous rangeland vegetation

The background features faint, light-colored graphics. On the right side, there is a large, semi-transparent circular graphic containing a stylized plant with long, thin leaves. To the left of this circle, there is a diagram consisting of several curved lines and small circular nodes, resembling a network or a simplified molecular structure.

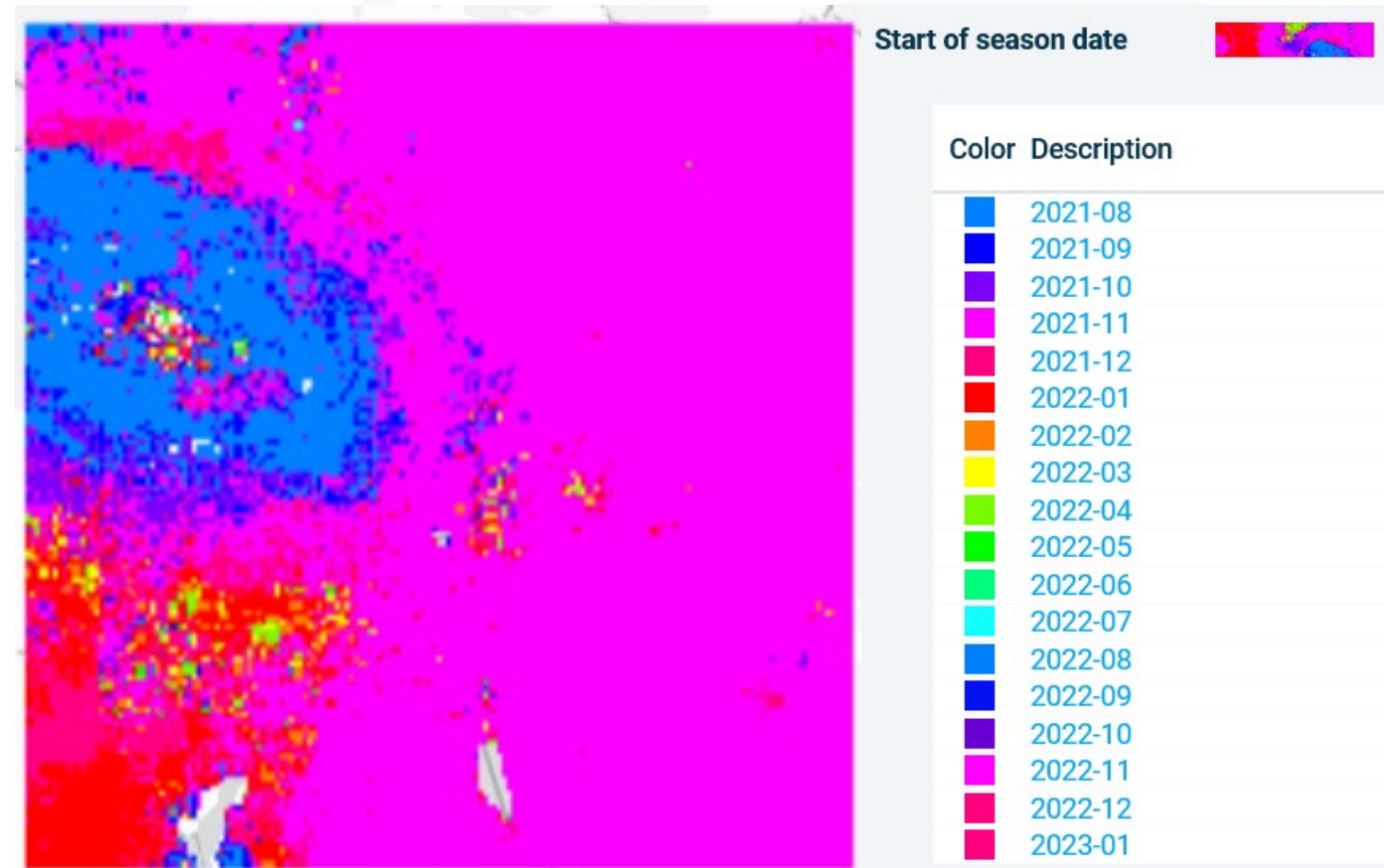
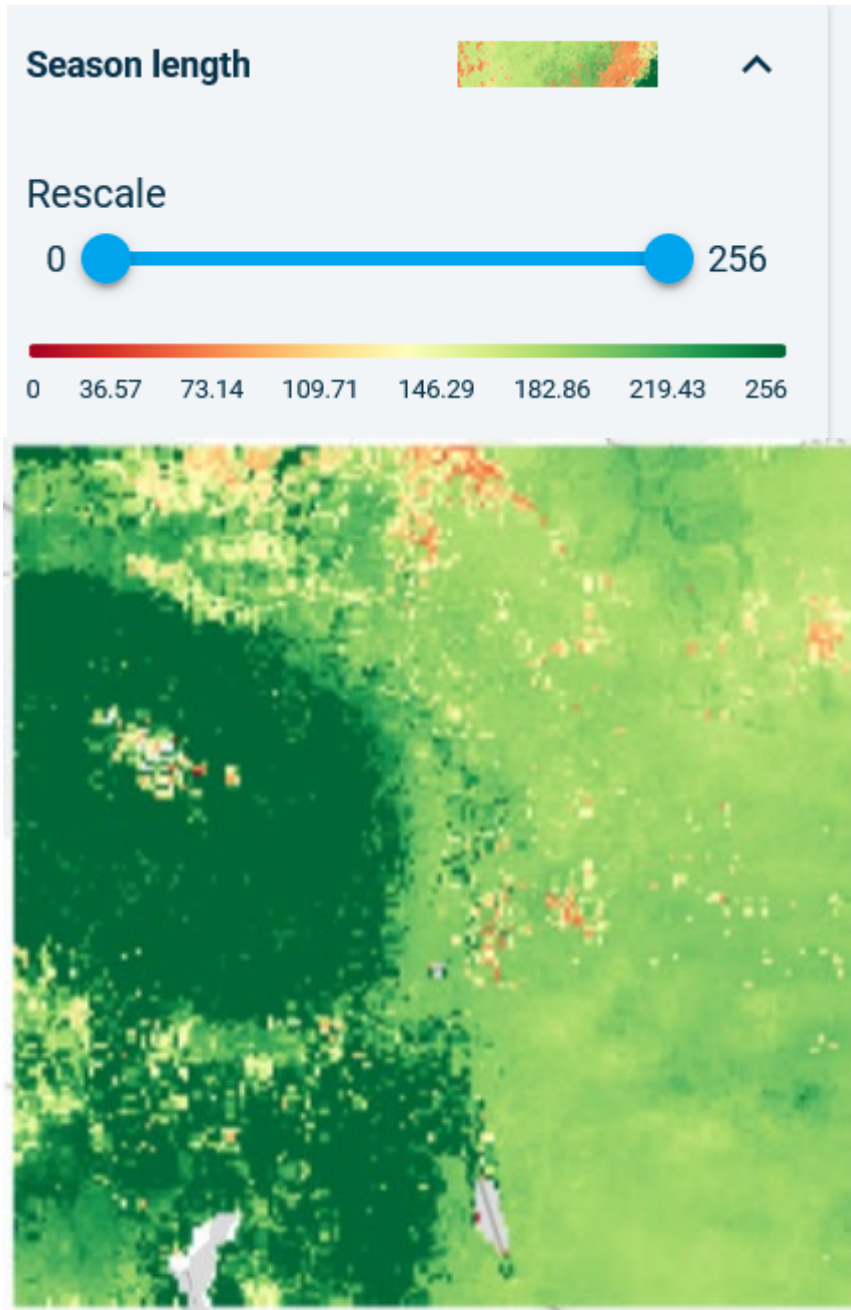
Herbaceous biomass phenology



Relevant for

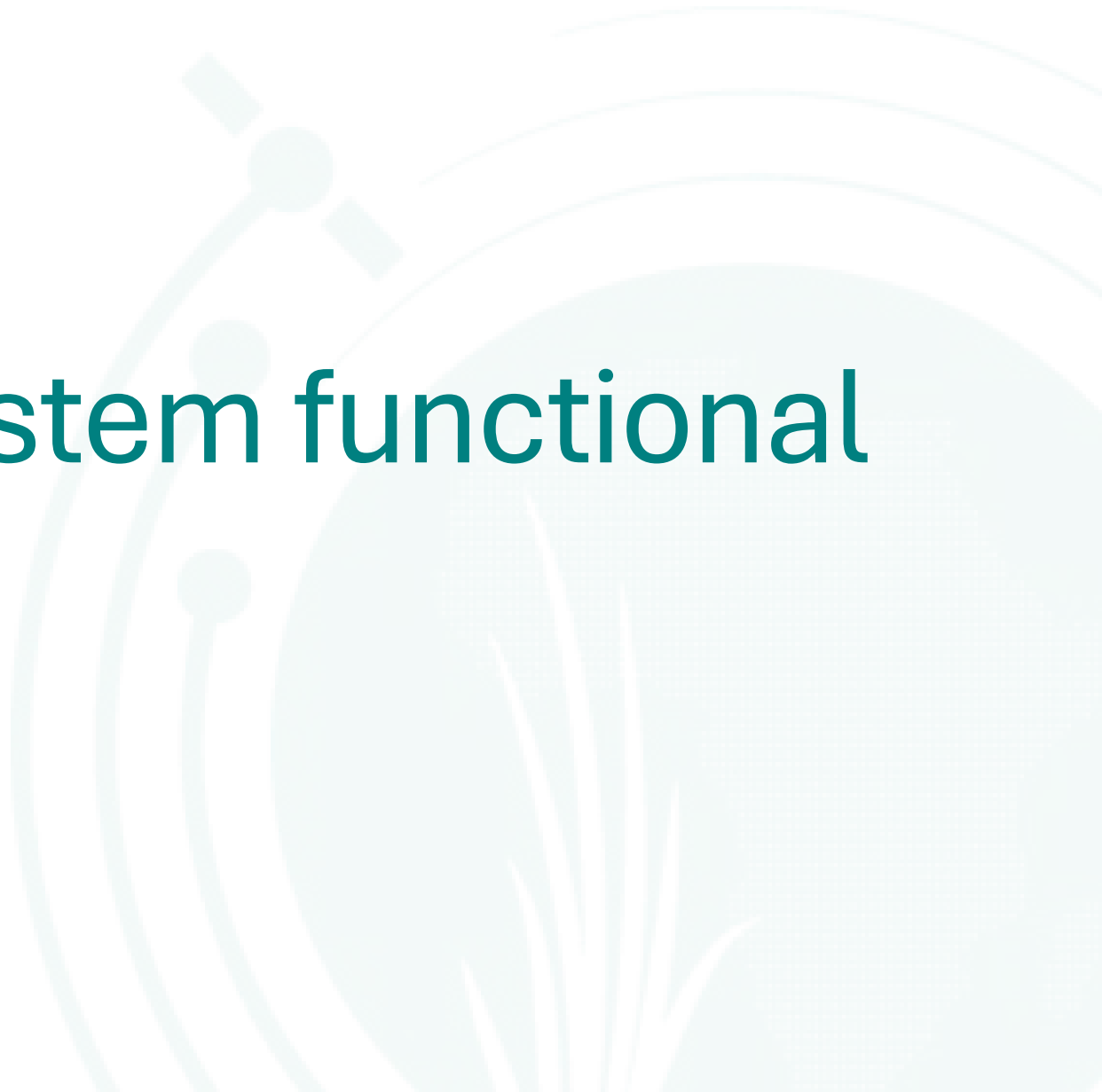
- Livestock grazing
- Fire management
- Wildlife movements
- Ecosystem functioning, e.g. C sequestration

Herbaceous biomass phenology



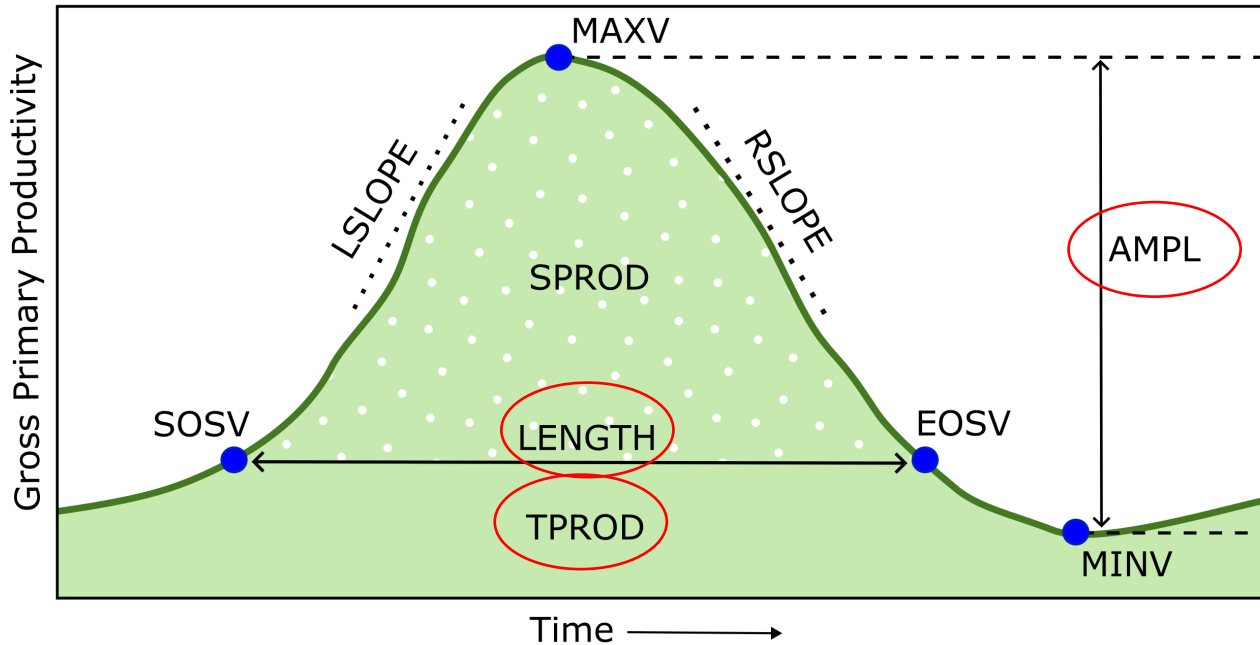
Rangeland ecosystem functional types

(not a thematic map)



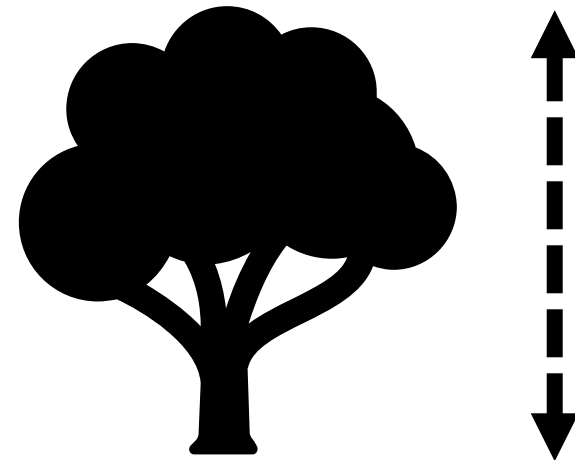
Phenology

Total productivity
Amplitude
Season Length



Structure

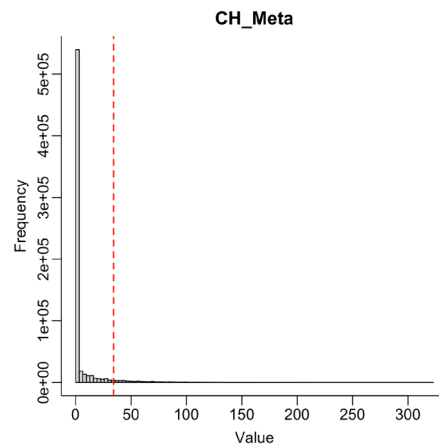
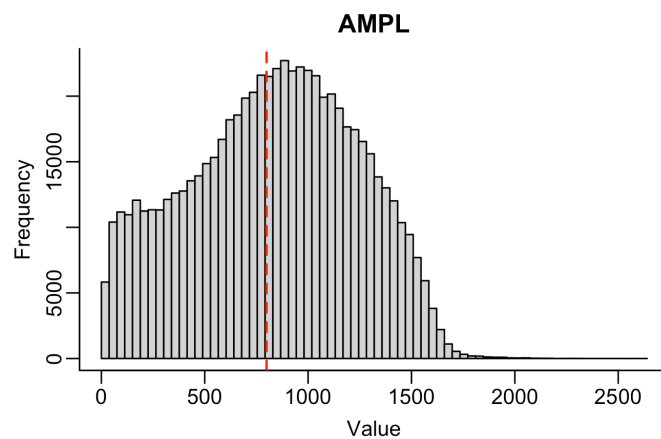
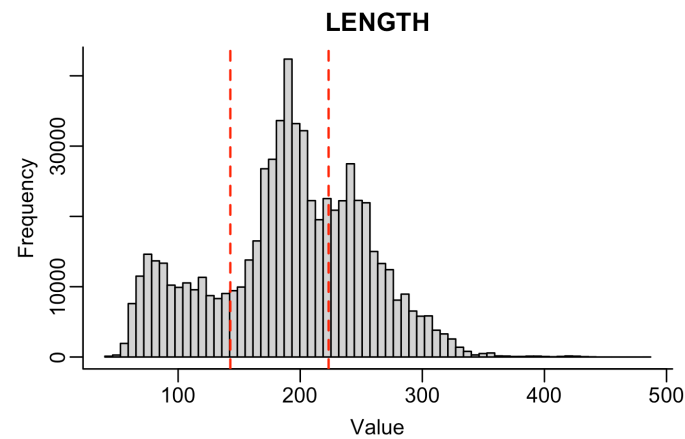
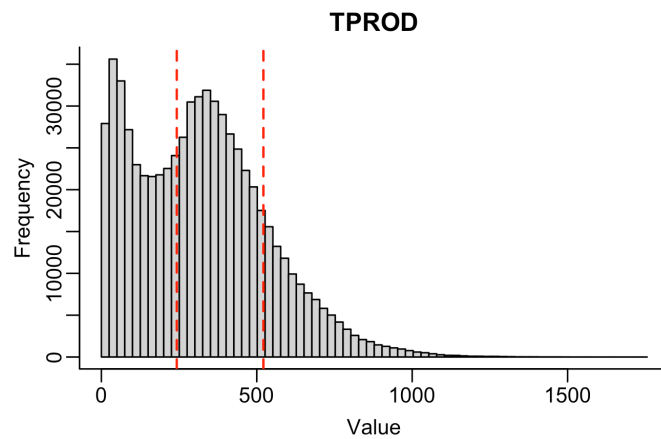
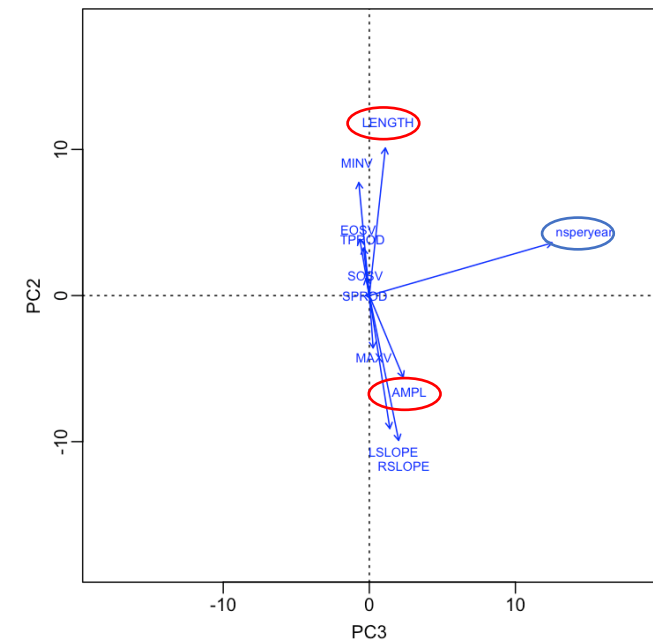
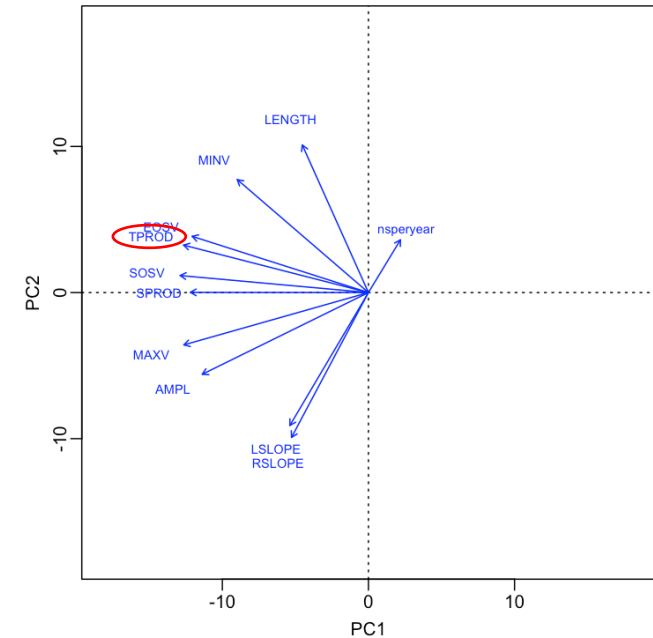
Canopy height





Objective thresholding to create classes



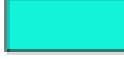



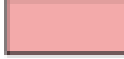

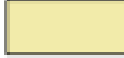









1) **PCA** to identify key variables

2) **K-means** clustering to identify optimal split points

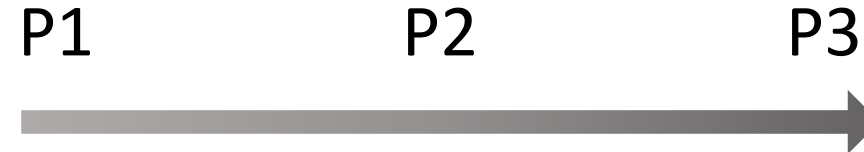


Classification scheme

Class 1 (P1, A1, H1, L1)	
Class 2 (P1, A1, H1, L2)	
Class 3 (P1, A1, H1, L3)	
Class 4 (P1, A1, H2, L1)	
Class 5 (P1, A1, H2, L2)	
Class 6 (P1, A1, H2, L3)	
Class 7 (P1, A2, H1, L1)	
Class 8 (P1, A2, H1, L2)	
Class 9 (P1, A2, H1, L3)	
Class 10 (P1, A2, H2, L1)	
Class 11 (P1, A2, H2, L2)	
Class 12 (P1, A2, H2, L3)	
Class 13 (P2, A1, H1, L1)	
Class 14 (P2, A1, H1, L2)	
Class 15 (P2, A1, H1, L3)	
Class 16 (P2, A1, H2, L1)	
Class 17 (P2, A1, H2, L2)	
Class 18 (P2, A1, H2, L3)	

Class 19 (P2, A2, H1, L1)	
Class 20 (P2, A2, H1, L2)	
Class 21 (P2, A2, H1, L3)	
Class 22 (P2, A2, H2, L1)	
Class 23 (P2, A2, H2, L2)	
Class 24 (P2, A2, H2, L3)	
Class 25 (P3, A1, H1, L1)	
Class 26 (P3, A1, H1, L2)	
Class 27 (P3, A1, H1, L3)	
Class 28 (P3, A1, H2, L1)	
Class 29 (P3, A1, H2, L2)	
Class 30 (P3, A1, H2, L3)	
Class 31 (P3, A2, H1, L1)	
Class 32 (P3, A2, H1, L2)	
Class 33 (P3, A2, H1, L3)	
Class 34 (P3, A2, H2, L1)	
Class 35 (P3, A2, H2, L2)	
Class 36 (P3, A2, H2, L3)	

Total productivity:



Amplitude:

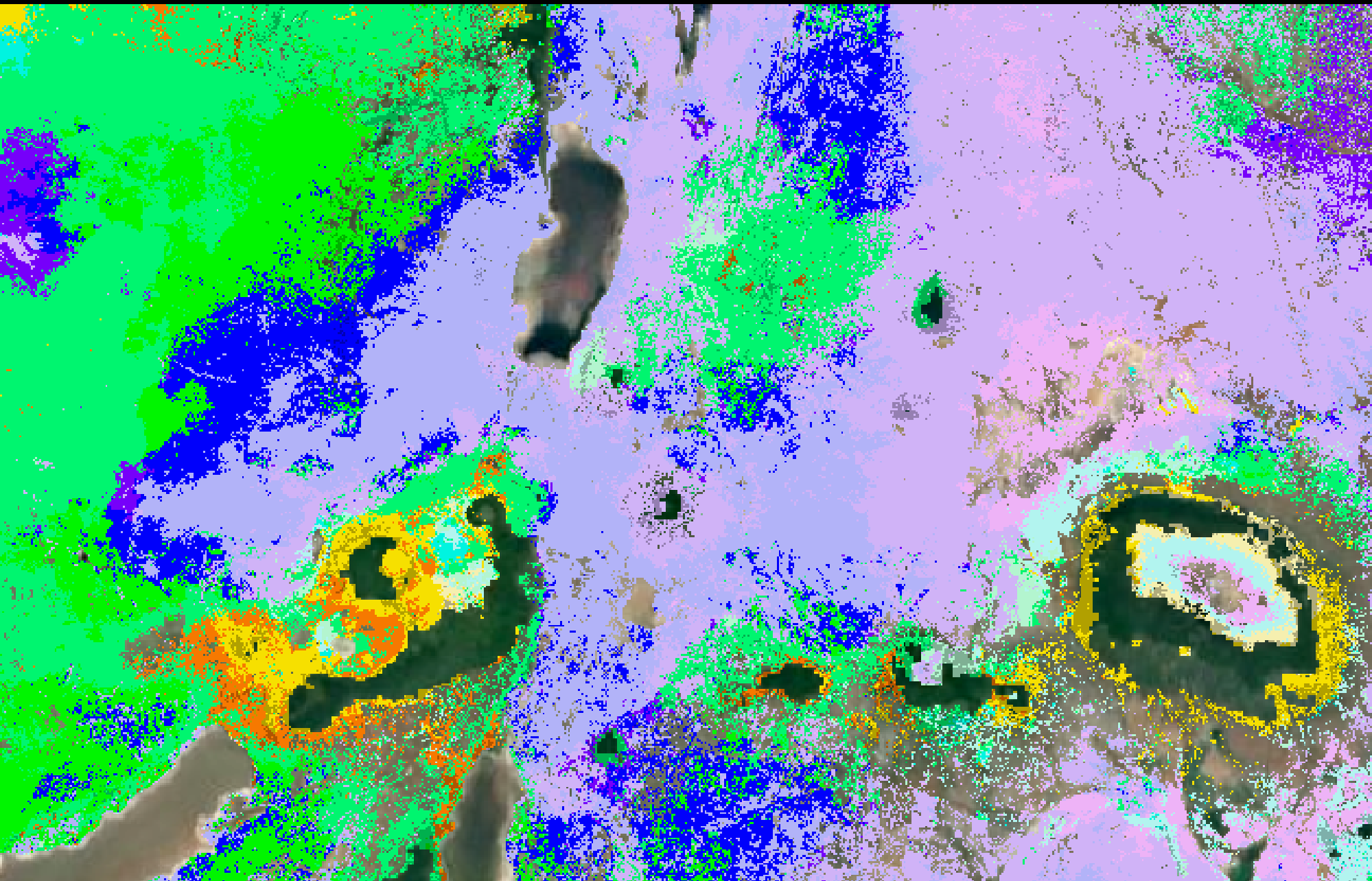


Canopy height:

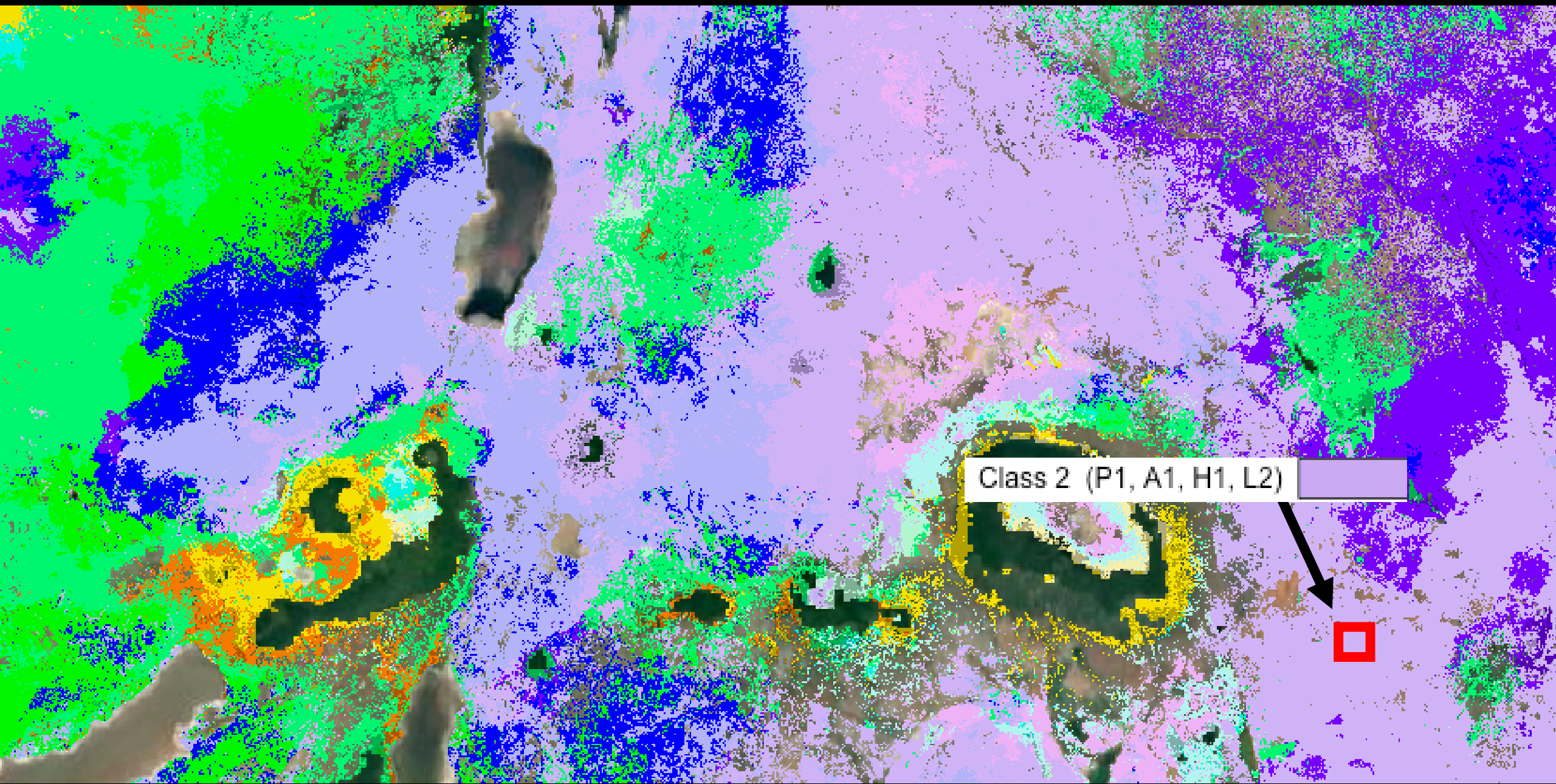


Season length:





Class 1 (P1, A1, H1, L1)	
Class 2 (P1, A1, H1, L2)	
Class 3 (P1, A1, H1, L3)	
Class 4 (P1, A1, H2, L1)	
Class 5 (P1, A1, H2, L2)	
Class 6 (P1, A1, H2, L3)	
Class 7 (P1, A2, H1, L1)	
Class 8 (P1, A2, H1, L2)	
Class 9 (P1, A2, H1, L3)	
Class 10 (P1, A2, H2, L1)	
Class 11 (P1, A2, H2, L2)	
Class 12 (P1, A2, H2, L3)	
Class 13 (P2, A1, H1, L1)	
Class 14 (P2, A1, H1, L2)	
Class 15 (P2, A1, H1, L3)	
Class 16 (P2, A1, H2, L1)	
Class 17 (P2, A1, H2, L2)	
Class 18 (P2, A1, H2, L3)	
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Class 30 (P3, A1, H2, L3)	
Class 31 (P3, A2, H1, L1)	
Class 32 (P3, A2, H1, L2)	
Class 33 (P3, A2, H1, L3)	
Class 34 (P3, A2, H2, L1)	
Class 35 (P3, A2, H2, L2)	
Class 36 (P3, A2, H2, L3)	

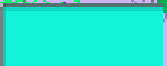



Class 2 (P1, A1, H1, L2)



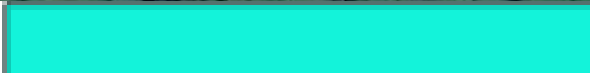
Class 2 (P1, A1, H1, L2)



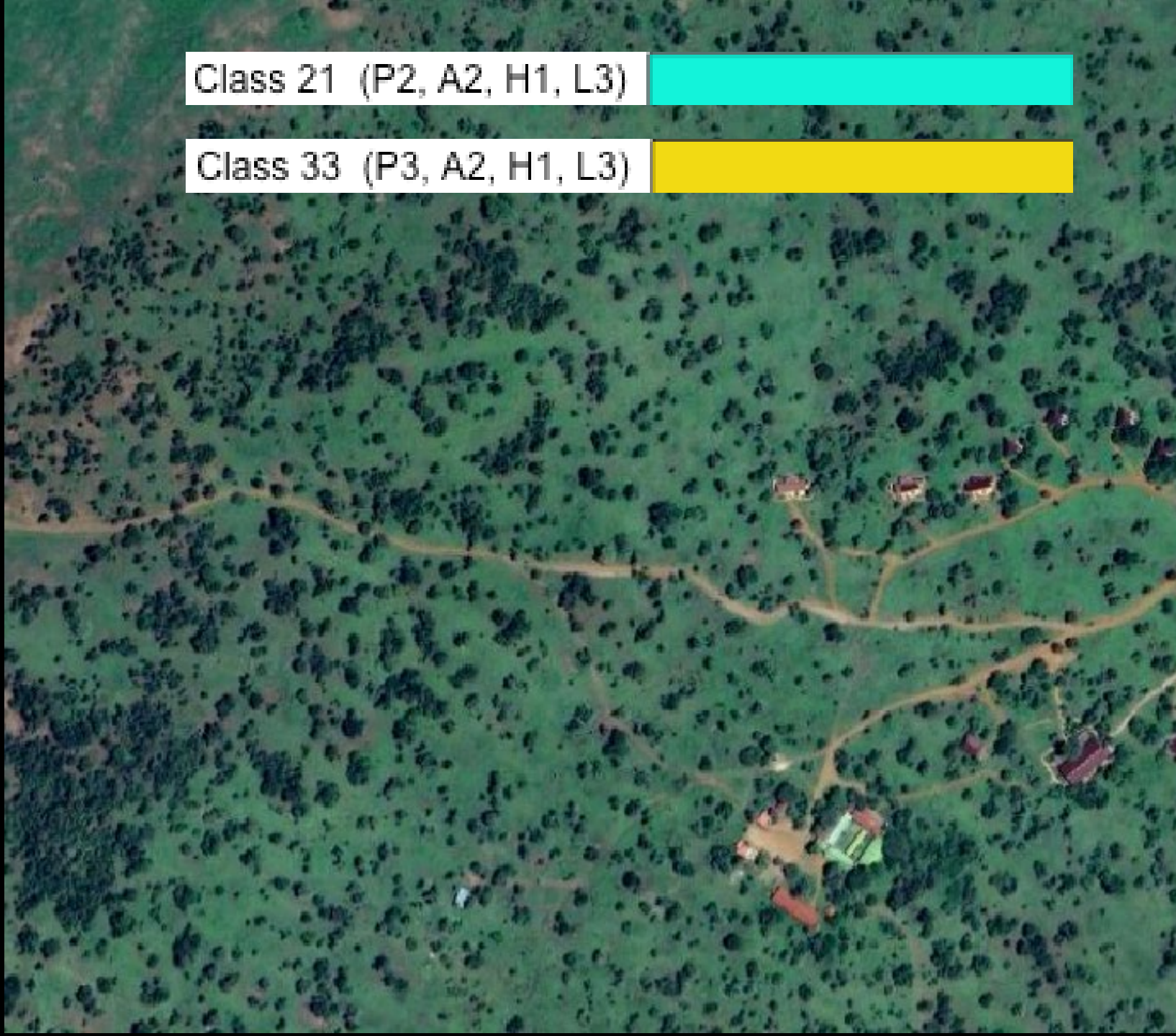
Class 21 (P2, A2, H1, L3) 
Class 33 (P3, A2, H1, L3) 



Class 21 (P2, A2, H1, L3)



Class 33 (P3, A2, H1, L3)

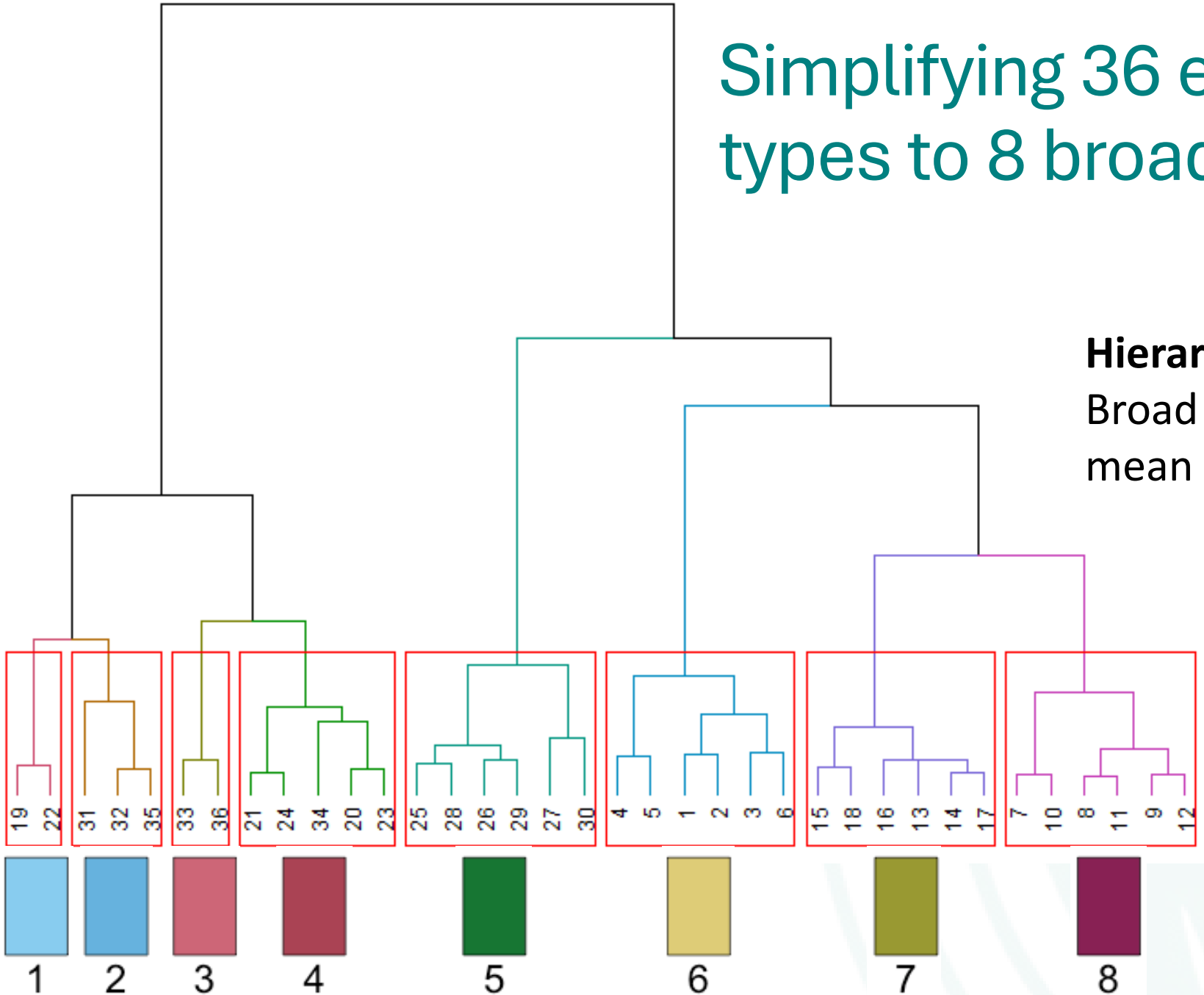


Simplifying 36 ecosystem types to 8 broad classes

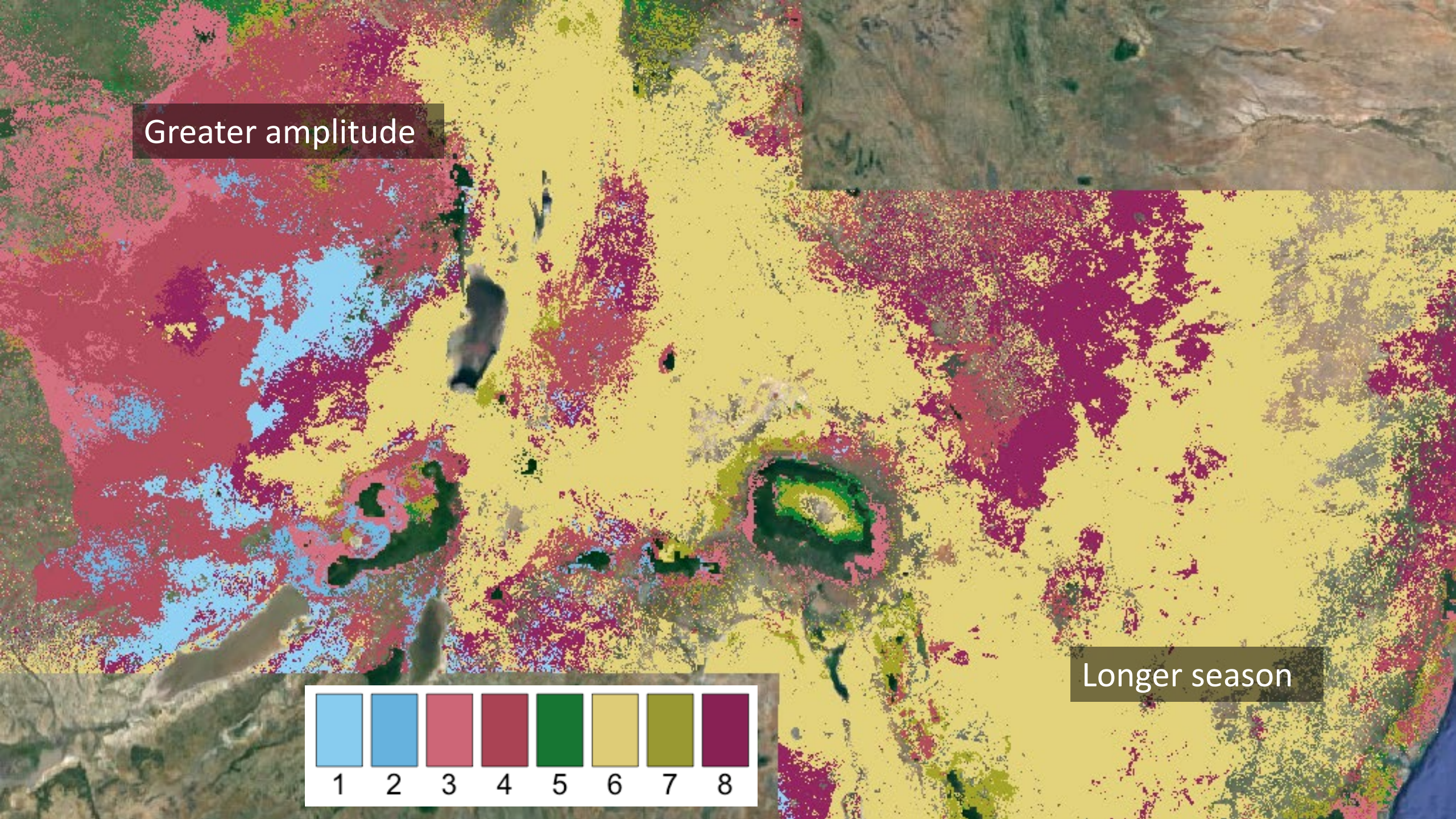
Hierarchical clustering
Broad classes based on mean values

Height

2000
1500
1000
500
0



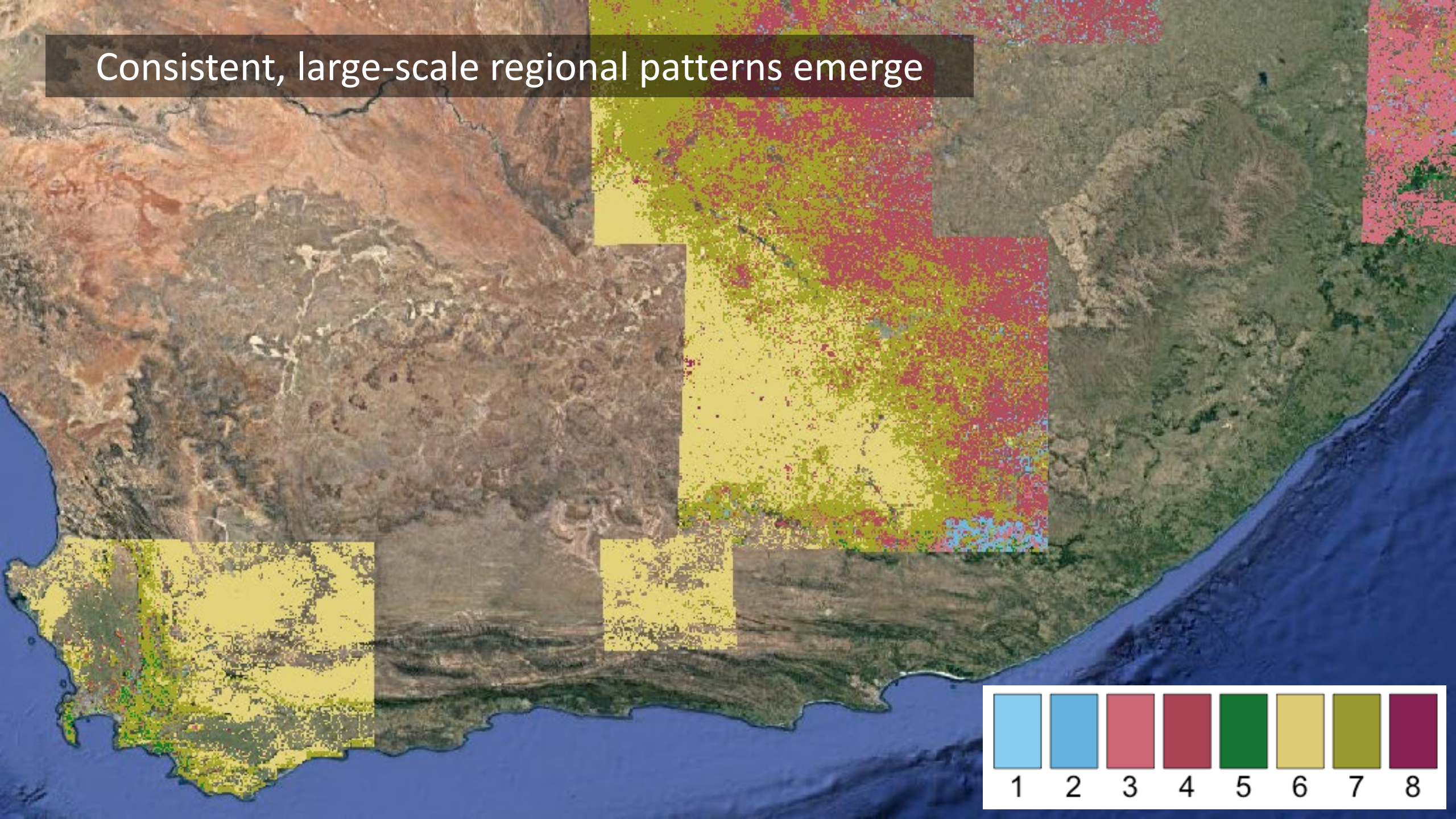
Greater amplitude



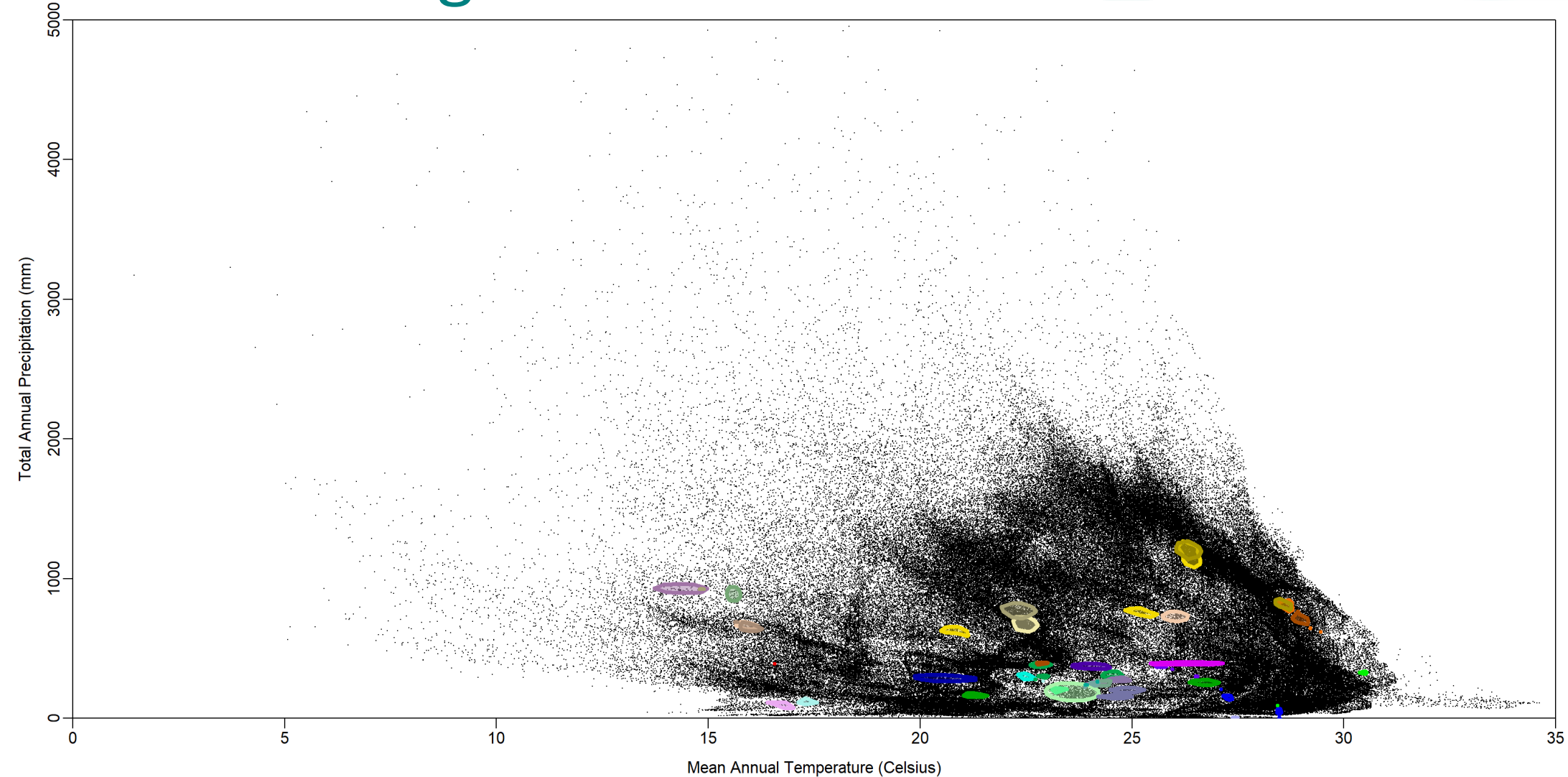
Longer season



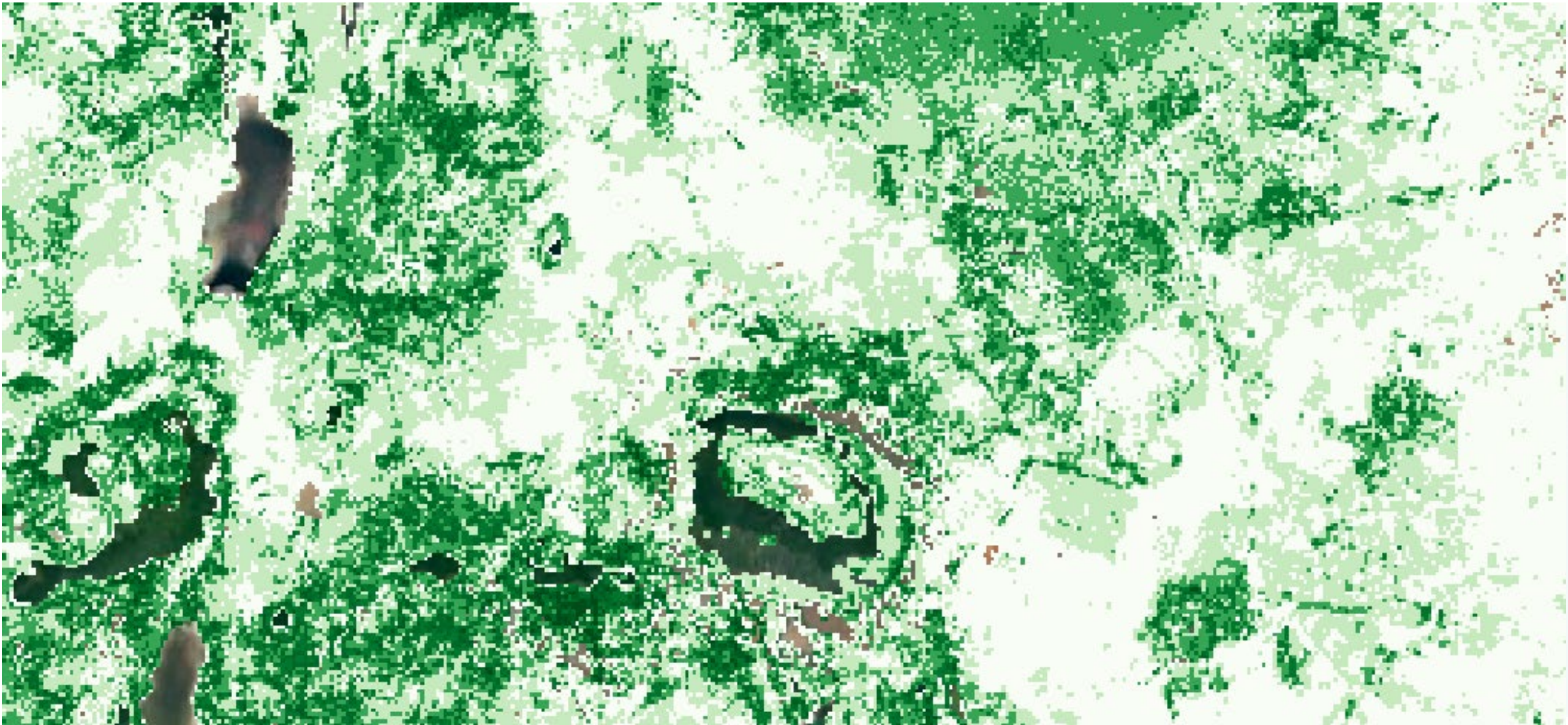
Consistent, large-scale regional patterns emerge



Rangeland types separate in climate space – RAMONA vegetation parameters capture major bioclimatic gradients



Rangeland type heterogeneity as a biodiversity metric



RAMONA posters

Michael Munk – Poster 79

RAMONA
Rangeland Monitoring for Africa
Using Earth Observation - Continental Demonstrator

The Rangeland Monitoring Using Earth Observation (RAMONA) one of the Continental Demonstrators under ESA initiative EO4Africa, aims to demonstrate how high-resolution Earth Observation data from Copernicus Sentinel can be used to assess rangeland indicators systematically and in unprecedented temporal and spatial resolution.

The RAMONA core and experimental product portfolio have been developed and implemented for 2020+ Sentinel-2 files at 10m resolution. The full product suite is freely available and accessible for visualization and download from an online viewer. These include products describing rangeland extent and typology, estimating herbaceous biomass and quantifying key vegetation phenology parameters of rangelands across the African continent.

Michael Munk¹, Robert Buitenwerf², Donovan Grobler³, Lars Eklundh⁴, Jonas Ardö⁵, Paul Senty⁶, Cai Zhanzhang⁷, Charles Davidson⁸, Mahendra Pal⁹, Radoslav Guzman¹⁰, Tordern Tagesson¹¹, Patrick Griffiths¹²
m.munk@dhlgroup.com / app.ramona.earth

Full product suite

Core rangeland information products

- Extent (10 m, yearly)
- Type (10 m, yearly)
- Herbaceous Biomass (10 m, monthly)

Experimental rangeland information products

- Biomass anomalies (300 m, quarterly)
- Phenology parameters (10 m, yearly)

Look at some data

Type (10 m, yearly)

CONTINENTAL PRODUCTION OF RANGELAND INFORMATION PRODUCTS

Explore the products

Herbaceous Biomass (monthly HBB 2021-08 to 2023-01 for file 29PKM)

Select product

Zoom to area

Download data

Compare dataset

Methods

- 1) We mapped the long-term maximum extent of African rangelands as areas with maximum NDVI 0.15 > 0.9 (1999-2019), Copernicus V2 2021).
- 2) Masked out cropland, built-up areas, and water bodies (WorldCover V2 2021).
- 3) Removed closed canopy forests: patches ≥ 5 ha with woody cover ≥ 90% and median canopy height ≥ 5 m (data from WWF & MSA).
- 4) Excluded areas with no vegetation signal during the 18-month target period using RAMONA phenology data.

Next steps

We are interested in exploring the environmental space that African rangelands occupy, African rangelands, both in terms of climate and disturbance indicators such as fire and herbivory.

ESA Copernicus Sentinel offers an unprecedented rangeland monitoring approach.

Project lead: r.buitenwerf@bio.au.dk
PosterID: c.davidson@bio.au.dk

Charlie Davison – Poster 79

Mapping rangeland functional types across Africa

Charles Davidson¹, Jonas Ardö², Oliver Baines³, Zhangchang Cai⁴, Lars Eklundh⁵, Donovan Grobler⁶, Patrick Griffiths⁷, Michael Munk⁸, Pal Mahendra⁹, Paul Senty¹⁰, Robert Buitenwerf¹¹

AARHUS UNIVERSITY (1) LUND (2) GeoVille (3) ESA (4) DHI (5)

RAMONA
Rangeland Monitoring for Africa

Online viewer: [QR Code]

African rangelands support millions via livestock production, sequester carbon, and preserve unique bio- and cultural diversity. Yet, their sustainability is increasingly threatened by anthropogenic pressures.

RAMONA aims to develop a high-resolution monitoring system for African rangelands using Sentinel 1-3. Core products include rangeland extent, rangeland functional types, and herbaceous biomass.

Rangeland extent

Effectively monitoring changes in rangeland ecosystems requires accurate information on their extent and distribution; however, there is a great diversity of land uses and ecological gradients in rangelands. We therefore take a broad view of rangelands as: **All vegetated land which is not closed canopy or cropland.**

Rangeland functional types

Rangeland functional types provide a framework for comparing ecological processes across diverse regions and facilitates the monitoring of changes due to anthropogenic and environmental pressures.

Phenology

Structure

Using fused Sentinel 1-3 data, we estimated Gross Primary Productivity (GPP) and 14 phenological parameters at 10m resolution. This was integrated with high-resolution canopy height data, thus combining productivity, phenology, and vegetation structure.

Classification system

We identified 4 key variables using PCA and applied k-means clustering to split them into ordinal (low to high) values.

Method

- 1) We mapped the long-term maximum extent of African rangelands as areas with maximum NDVI 0.15 > 0.9 (1999-2019), Copernicus V2 2021).
- 2) Masked out cropland, built-up areas, and water bodies (WorldCover V2 2021).
- 3) Removed closed canopy forests: patches ≥ 5 ha with woody cover ≥ 90% and median canopy height ≥ 5 m (data from WWF & MSA).
- 4) Excluded areas with no vegetation signal during the 18-month target period using RAMONA phenology data.

Next steps

We are interested in exploring the environmental space that African rangelands occupy, African rangelands, both in terms of climate and disturbance indicators such as fire and herbivory.

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Mahendra Pal – Poster 92

RAMONA: Advances in Estimating Terrestrial Ecosystem Productivity from African Rangelands Using Earth Observation Techniques

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INTRODUCTION

Remote sensing has greatly improved the monitoring of vegetation, offering crucial insights into biomass distribution across diverse ecosystems (Lassini et al., 2014; Mann & Huber, 2014). Estimating herbaceous biomass in African rangelands, which include savannas and shrublands, remains challenging due to vegetation variability (Yvova et al., 2012; Kozay et al., 2012). These studies compare remote biomass estimates with ground data to enhance accuracy and reliability in these landscapes (Chen et al., 2014; Turpin et al., 2012).

OBJECTIVE

The study aims to improve the accuracy and stability of herbaceous biomass estimation in African rangelands using remote sensing. It focuses on calibrating and comparing remote biomass estimates with Eddy Covariance Flux Tower and ground measurements, analyzing spatiotemporal variations, and applying advanced calibration techniques to harmonize data and determine optimal biomass accumulation periods.

STUDY AREA AND DATASET

The study examines herbaceous Rangelands Biomass (RBL) across Africa using remote sensing data collected from August 2021 to January 2023. Eddy Covariance Flux Tower (ECFT) data, providing direct measurements of CO₂ water vapor, and energy flux measurements of Gross Primary Productivity (GPP) from the Fluxnet Africa and Climate Data (FACD) network, were used for validation. The study area includes South Africa since 2017, providing direct measurements of CO₂ water vapor, and energy flux measurements of Gross Primary Productivity (GPP) from the Fluxnet Africa and Climate Data (FACD) network, were used for validation. The study area includes South Africa since 2017, providing direct measurements of CO₂ water vapor, and energy flux measurements of Gross Primary Productivity (GPP) from the Fluxnet Africa and Climate Data (FACD) network, were used for validation. The study area includes South Africa since 2017, providing direct measurements of CO₂ water vapor, and energy flux measurements of Gross Primary Productivity (GPP) from the Fluxnet Africa and Climate Data (FACD) network, were used for validation.

METHODOLOGY

The flow diagram outlines the workflow for predicting biomass productivity using Earth Observation (EO) data. It involves data collection, preprocessing, and validation against ground truth data. The process includes: EO Data (Sentinel-1, Sentinel-2) → Preprocessing (Cloud Masking, Radiometric Calibration) → Feature Extraction (Vegetation Indices, Canopy Height) → Model Development (Machine Learning, Statistical Models) → Validation (Comparison with Ground Truth Data) → Biomass Estimation (GPP, HBB) → Uncertainty Assessment (Sensitivity Analysis, Error Propagation).

RESULTS AND DISCUSSION

GPP Modelling and Assessment

Validation with Sentinel-1 and Sentinel-2

CONCLUSIONS

This study showed that Earth-based EO-based GPP estimates, combined with ground truth data, significantly improved the accuracy of GPP estimates in African rangelands. Despite the challenges associated with remote sensing, the results indicate that EO-based biomass estimates can provide valuable insights into rangeland health and productivity. Further research is needed to refine the models and expand the application of these techniques to other ecosystems.

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Rangeland Monitoring for Africa
Using Earth Observation - Continental Demonstrator

Description

Monitoring rangeland social-ecological state, productivity and biodiversity at 10 m resolution using Copernicus Sentinel satellites.

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Core Products

Rangeland extent

Maximum extent (1km) [v](#)

Annual extent (10m) [v](#)

Rangeland type [v](#)

Herbaceous biomass [^](#)

The Herbaceous Rangeland Biomass (HRB) productivity describe the amount of biomass produced in and 10x10 meter pixel for each

Latitude:
Longitude:
Click on the map to select a value

