MULTI-SCALE TIME SERIES OF BIOPHYSICAL PARAMETERS AND VEGETATION STRUCTURE IN HETEROGENEOUS LANDSCAPES OF WEST AFRICA

Frank Thonfeld, Jonas Meier, Ursula Gessner + CONCERT & WASCAL-DE-Coop teams

WASCAL Science Symposium 2022, Ouagadougou, Burkina Faso, 6-9 December 2022

DLR

Greenhouse Gas Emissions & Mitigation Options Under Climate- and Land Use Change in West Africa: A Concerted Regional Modelling & Observation Assessment

CONCERT

Photo: Frank Thonfeld

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Federal Ministry of Education and Research
FONA Forschung für Nachhaltigkeit
WASCAL West African Science Service Centre on Climate Change and Adapted Land Use
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JÜLICH Forschungszentrum
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UNU-INRA Institute for Natural Resources in Africa
CILSS
AGRHYMET

Objectives

- Quantify and estimate present **greenhouse gas emissions** (GHG) and **agricultural productivity** for the WASCAL region
- Set up, initialize and calibrate a **coupled regional climate-hydrology-dynamic vegetation Earth System Modeling (ESM) framework**
- to assess water availability, land use, crop production, biogeochemical cycling, and GHG emissions, specifically adapted to the West African conditions and defined IPCC emission scenarios

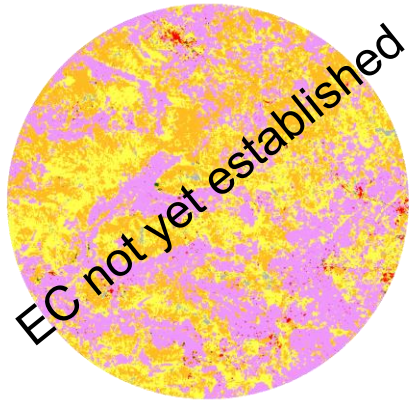
- Derive up-to-date and **high-resolution dynamic land cover and vegetation status information** for the WASCAL region

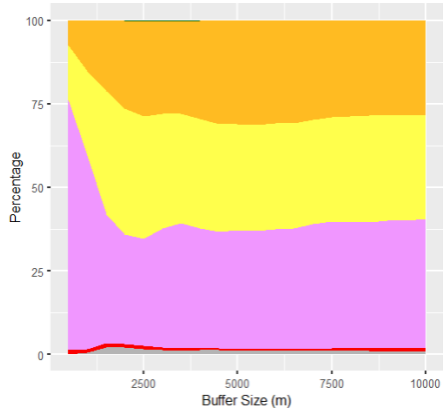
- Information about land cover (change) & vegetation dynamics is not yet adequately addressed in climate models → their impact on climate change & extremes unclear (Sy & Quesada 2020)

CONCERT Study Sites

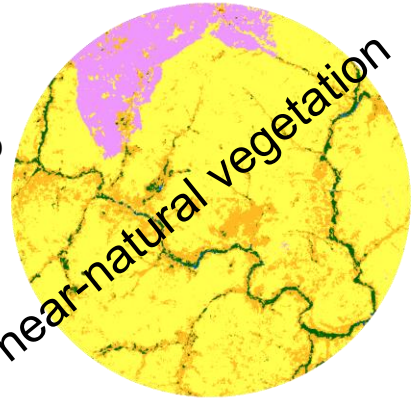
Land Cover
- Tree Cover
- Shrubland
- Grassland
- Cropland
- Built-up
- Bare / Sparse Vegetation
- Snow & Ice
- Permanent Water Bodies
- Herbaceous Wetland
- Mangroves
- Moss & Lichen

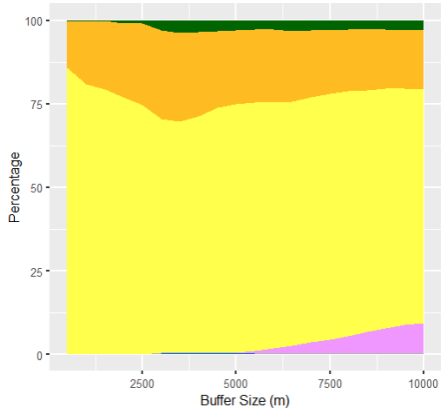
Sanon



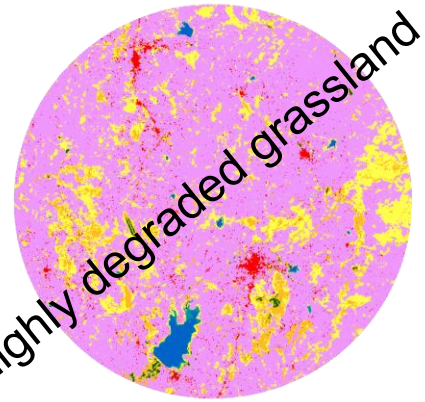


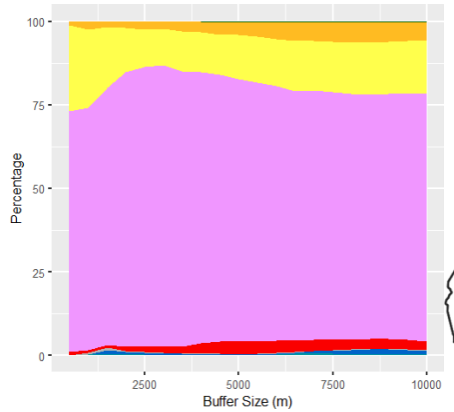
Nazinga



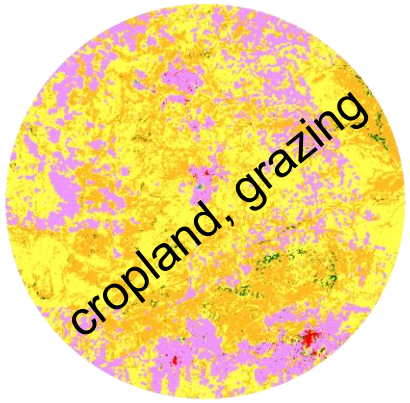


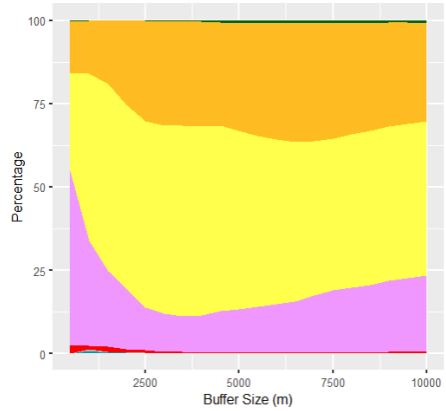
Gorigo



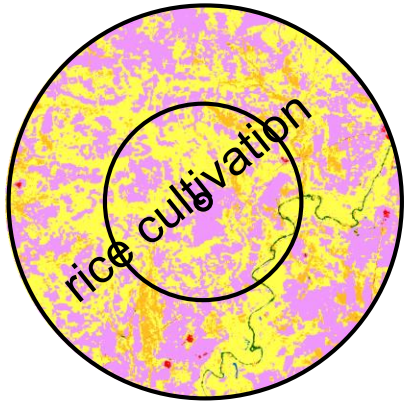


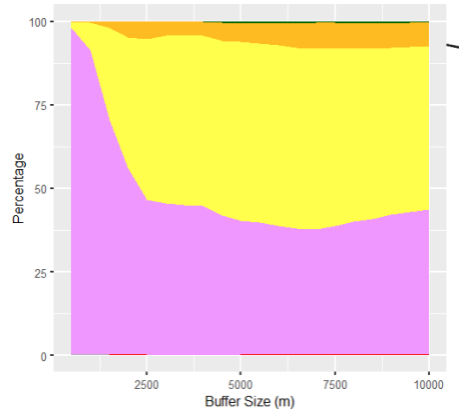
Kayoro





Janga

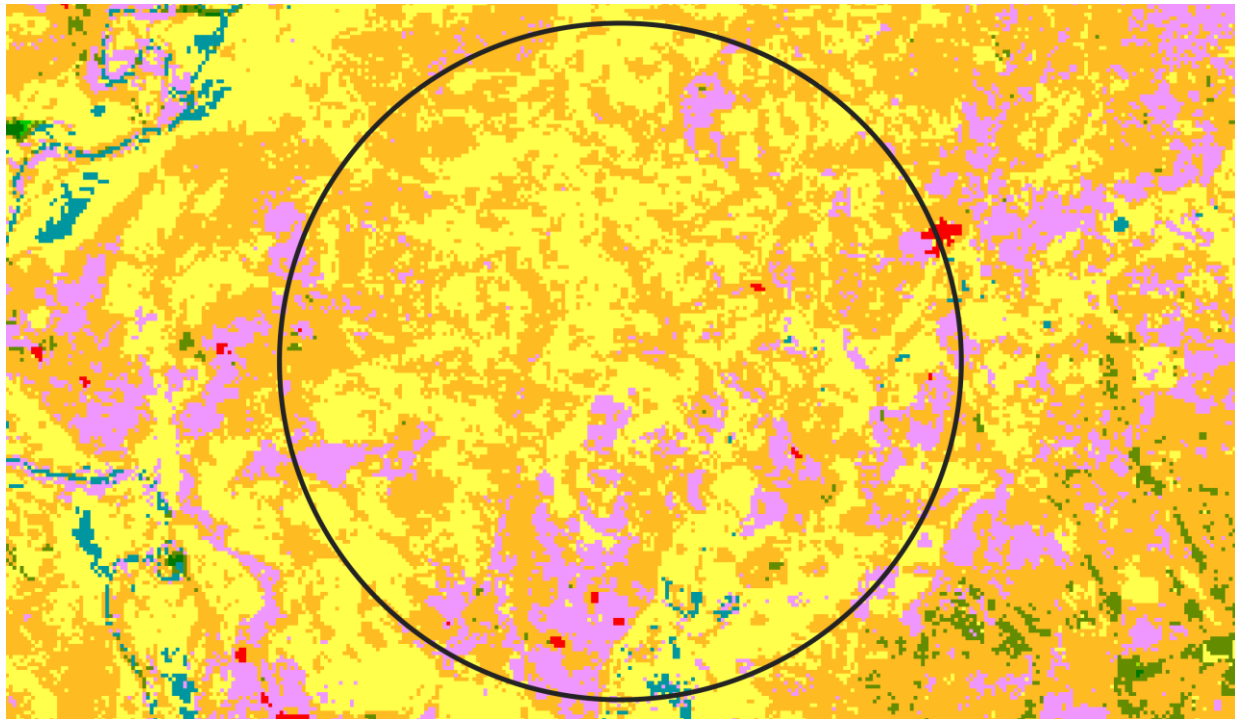




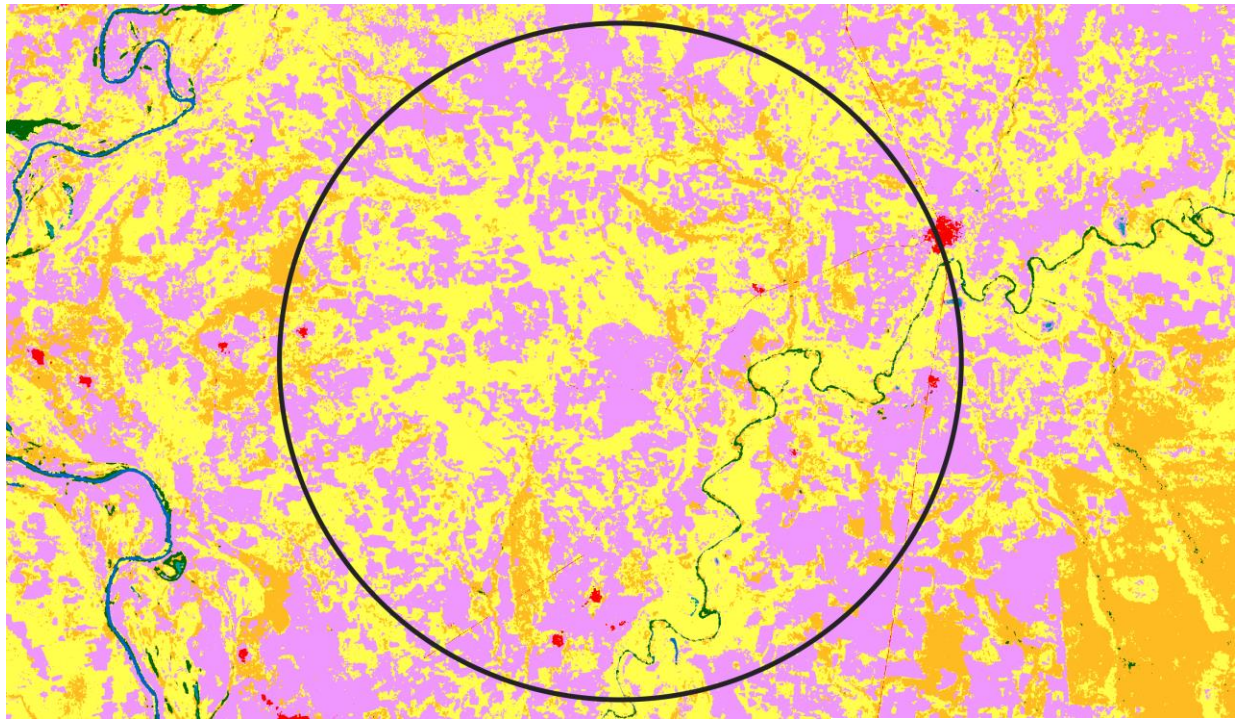
Zanaga et al. 2022

Land Cover (Janga Site) – Opportunities & Limitations

Copernicus Land Cover 2019 (Buchhorn et al. 2020)



WorldCover 2021 (Zanaga et al. 2022)



Land Cover

- Forests
- Shrubland
- Herbaceous Vegetation
- Cropland
- Built−up
- Bare / Sparse Vegetation
- Snow & Ice
- Permanent Water Bodies
- Herbaceous Wetland
- Moss & Lichen

Closed forest	Open forest
Evergreen needle-leaved	Evergreen needle-leaved
Deciduous needle-leaved	Deciduous needle-leaved
Evergreen broadleaved	Evergreen broadleaved
Deciduous broadleaved	Deciduous broadleaved
Mixed type	Mixed type
Unknown type	Unknown type

+ Fractional cover

- Global maps
- PROBA-V 100 m vs. S1/2 10 m
- 10+12 discrete classes vs. 11
- 2015-2019 & 2020-2021

Land Cover

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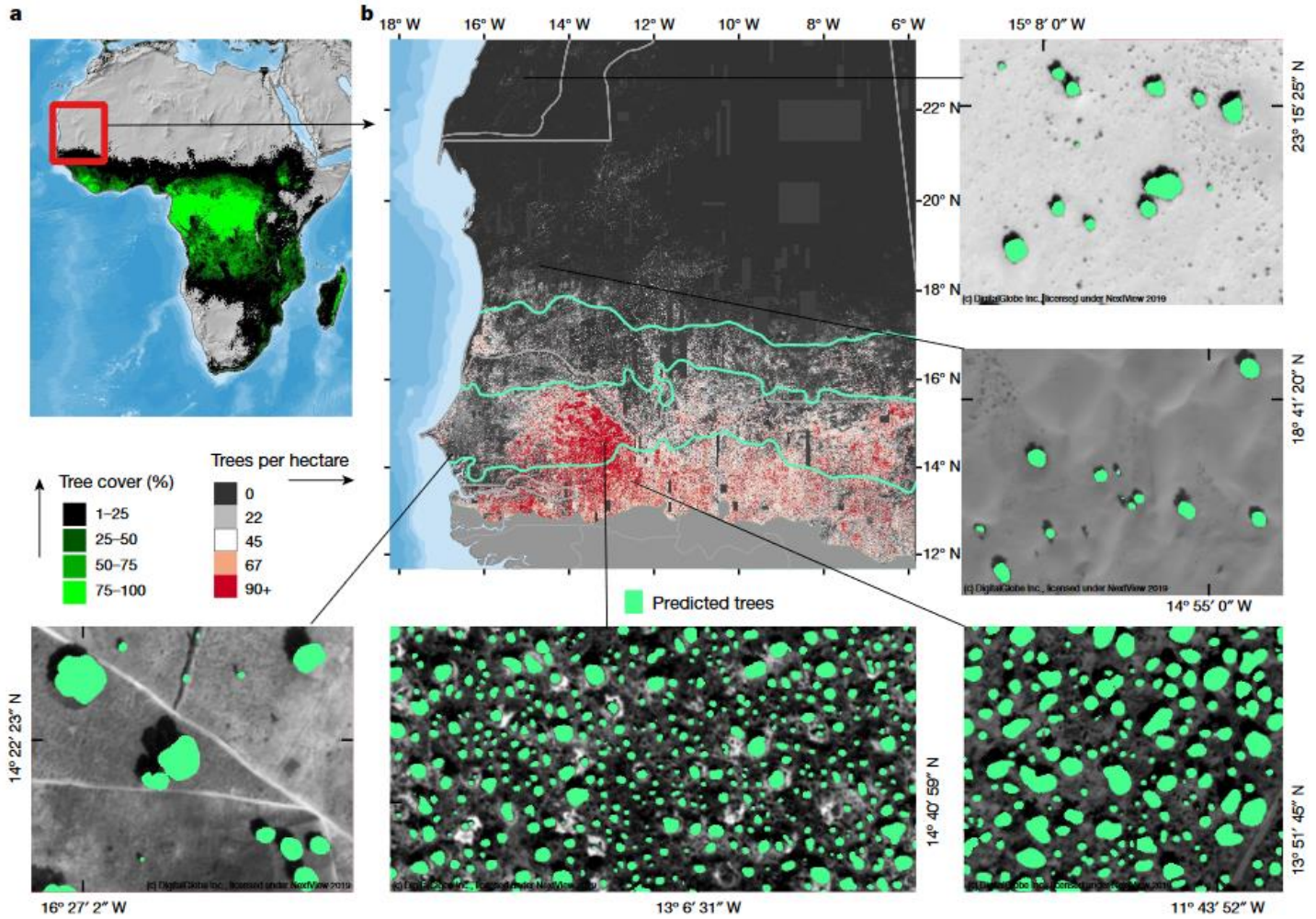
Land Cover

- Number of trees is underestimated



Article

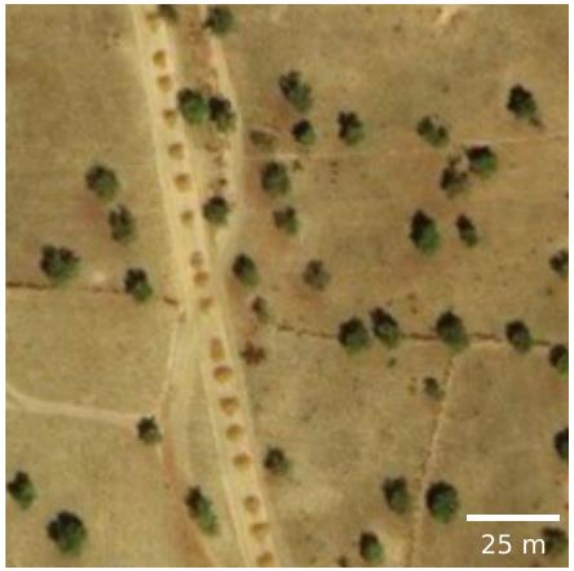
An unexpectedly large count of trees in the West African Sahara and Sahel

Martin Brandt[1,2✉], Compton J. Tucker[3✉], Ankit Kariryaa[2,4], Kjeld Rasmussen[1], Pierre Hiernaux[2,6], Christin Abel[1], Jennifer Small[2,3], Jerome Chave[5], Laura Vang Rasmussen[1], Abdoul Aziz Diouf[7], Laurent Kergoat[8], Ole Mertz[1], Christian Igel[9], Fabian Gieseke[9,10], Johannes Schöning[4], Sizhuo Li[1], Katherine Melocik[2,3], Jesse Meyer[2,3], Scott Sinno[2,3], Eric Romero[2,3], Erin Glennie[2,3], Amandine Montagu[11], Morgane Dendoncker[12] & Rasmus Fensholt[1]

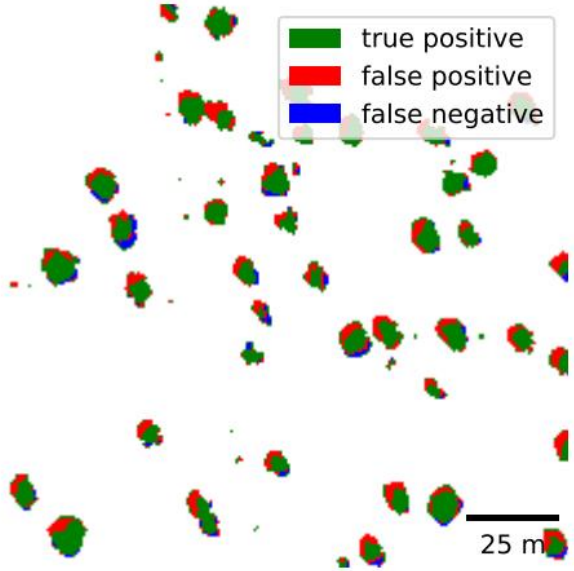
Brandt et al. 2020

Land Cover

- Tree classification based on Bing maps & U-Net convolutional neural networks (CNN)
- Limited transferability of training data to other environments
- Huge demand for training data & processing power

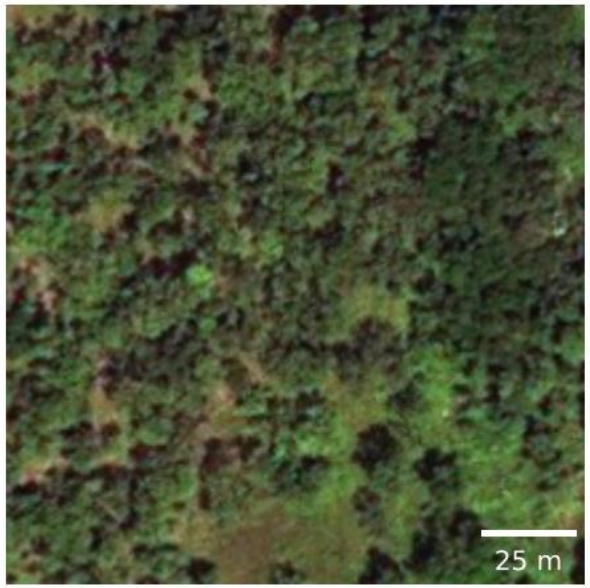


(a) RGB image.

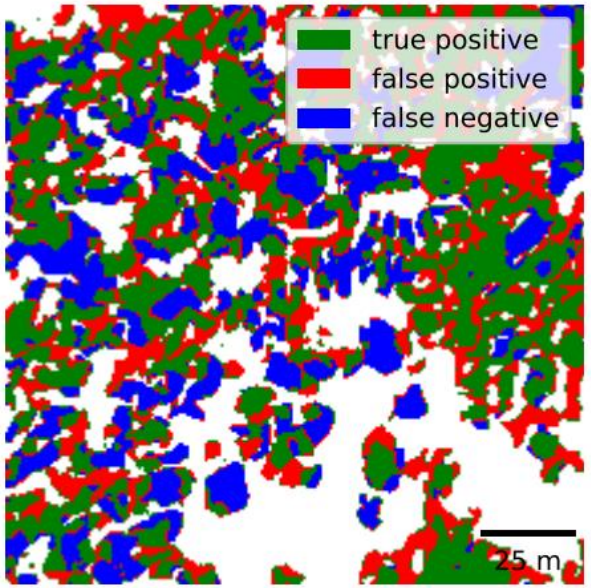


(b) Prediction.

Good performance



(a) RGB image.



(b) Prediction.

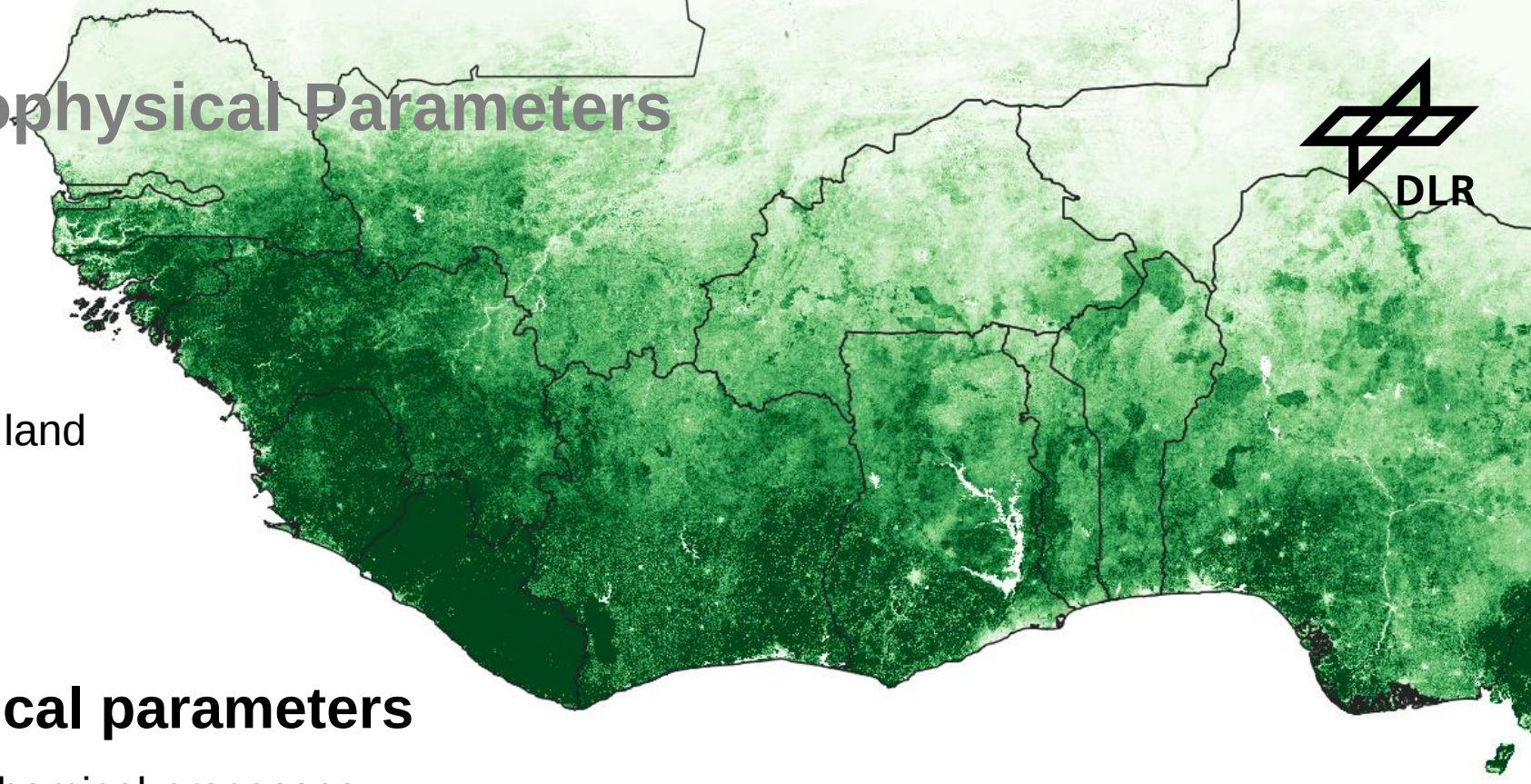
Bad performance

MA thesis, Hoefer 2022

BIOPHYSICAL PARAMETERS

Photo: Frank Thonfeld

Discrete Maps & Biophysical Parameters



Discrete maps

- Land cover
- Strong changes (conversion of land cover types, e.g. deforestation)
- Status

Time series of biophysical parameters

- Related to biological/physical/chemical processes
- Allow to reveal vegetation dynamics at various temporal scales
- Indicator of abrupt changes, long-term changes, changes in dynamics, changes in seasonality, phenology etc.

→ Sensitive to

- (climate/climate change related) events (e.g. droughts, floods, insects) & processes
- human impact (e.g.land use, land management, land degradation)

Biophysical Parameters (Leaf Area Index)

- MODIS MCD15A2H Leaf Area Index/FPAR (MODIS-LPDAAC, Myneni et al. 2015)
  - 8-day composites
  - 500 m resolution
  - Radiative transfer modeling & look-up tables
  - Since 2002

- MODIS GLASS LAI (MODIS-UMD, Ma & Liang 2022)
  - 8 day
  - 250 m resolution
  - Deep learning based on surface reflectance data
  - Since 2002

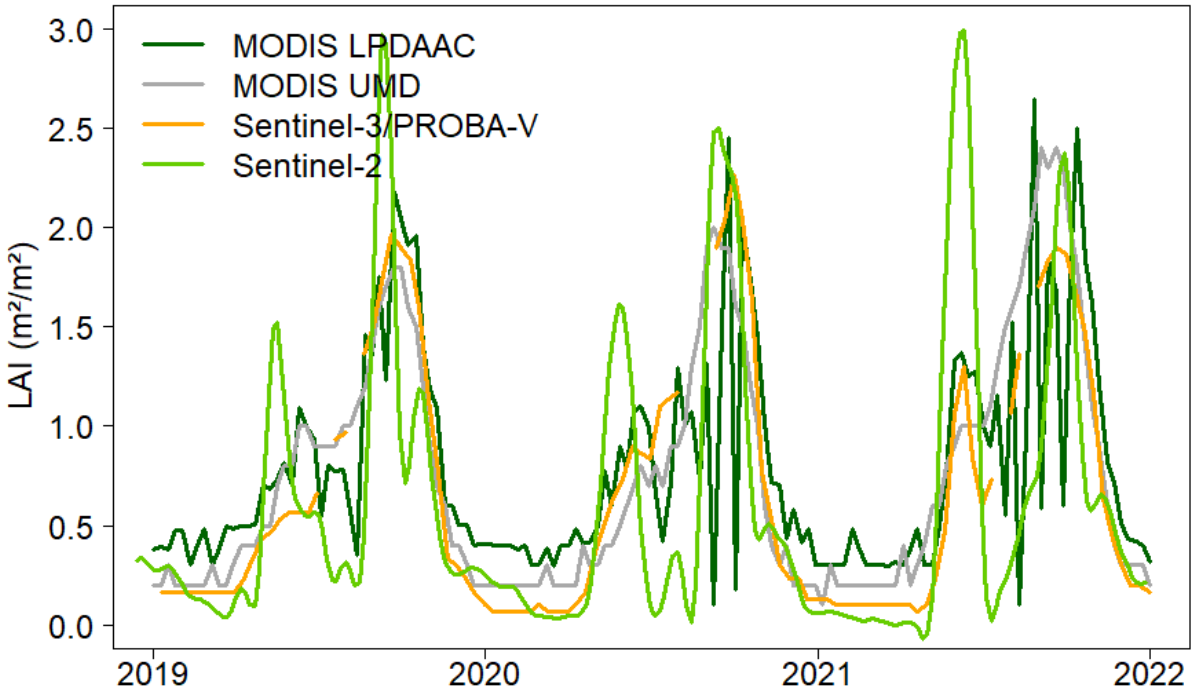
- Copernicus Sentinel-3/PROBA-V LAI (Fuster et al. 2020)
  - 10 day
  - 300 m resolution
  - Neural network based on surface reflectance data (OLCI) or TOA (PROBA-V), smoothing, gap-filling, compositing
  - Since 2014

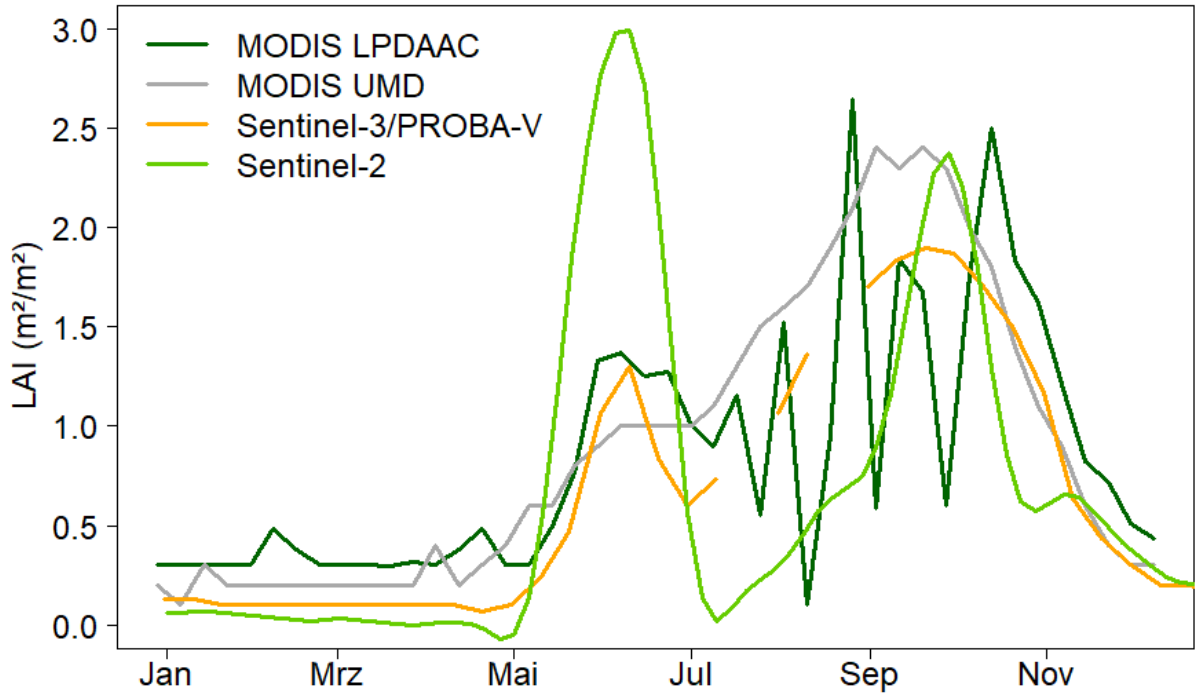
Biophysical Parameters (Leaf Area Index)

- Sentinel-2 LAI (Pipia et al. 2021)
  - daily
  - 20 m resolution
  - Gaussian process regression to model LAI & to fill gaps
  - Since 2015

Biophysical Parameters (Leaf Area Index)

LAI @ Janga site

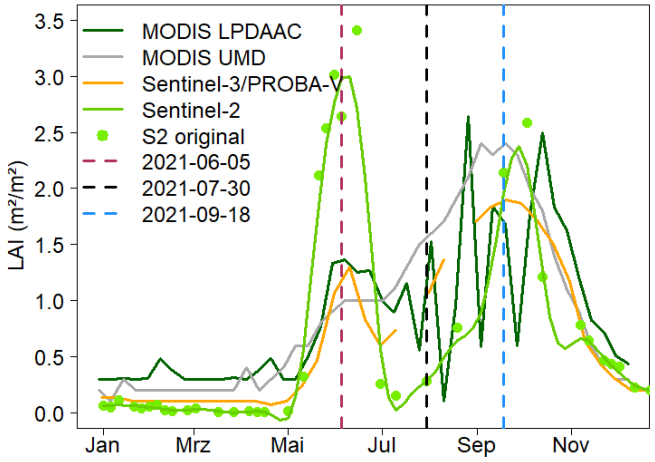


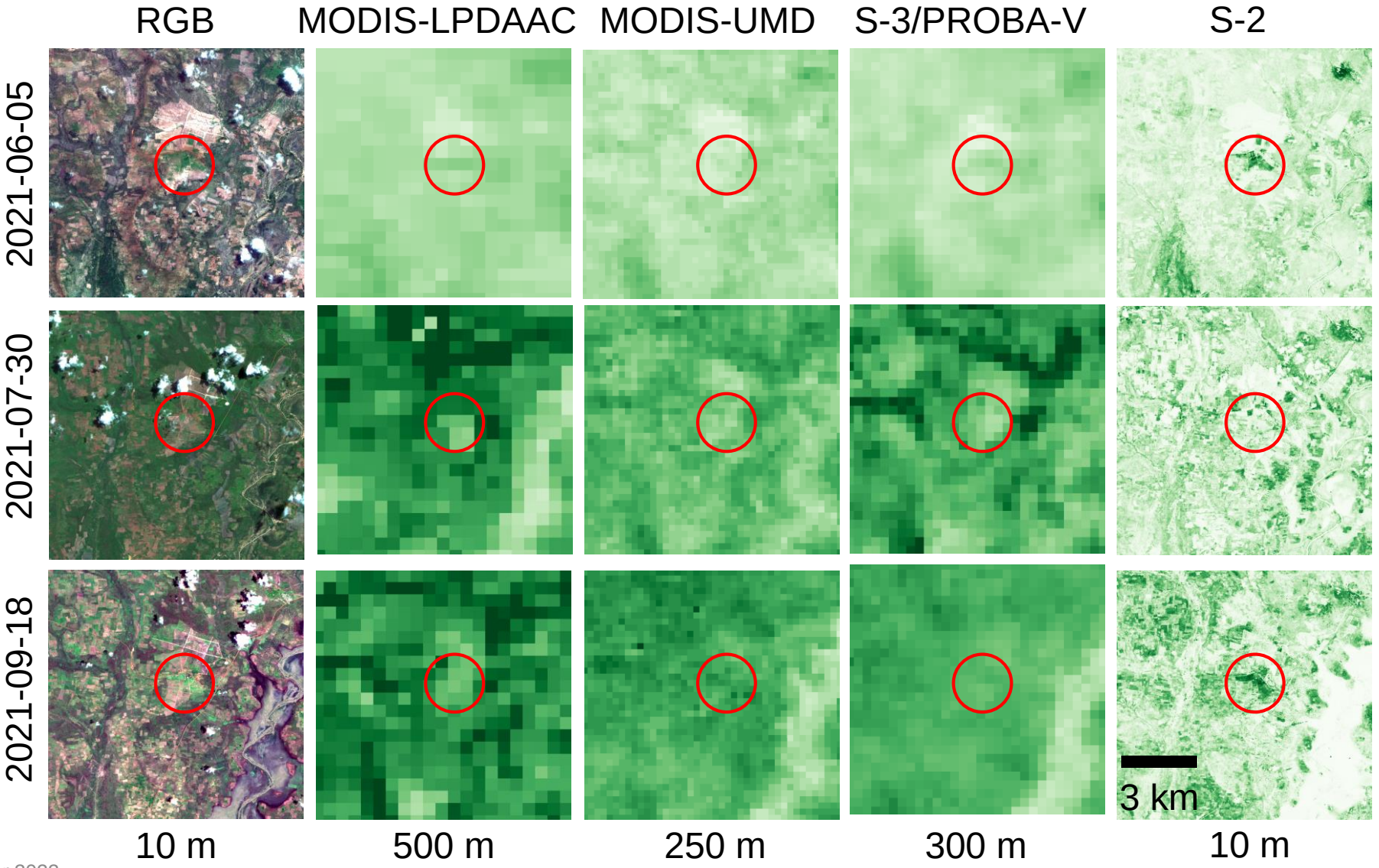


- MODIS LPDAAC: noisy, overestimation in off-season(?)
- MODIS UMD: outleveling seasonality (secondary growth cycles lost)
- Sentinel-3/Proba-V: harmonic, with gaps
- Sentinel-2: overestimating secondary peak

Biophysical Parameters (Leaf Area Index)

LAI @ Janga site

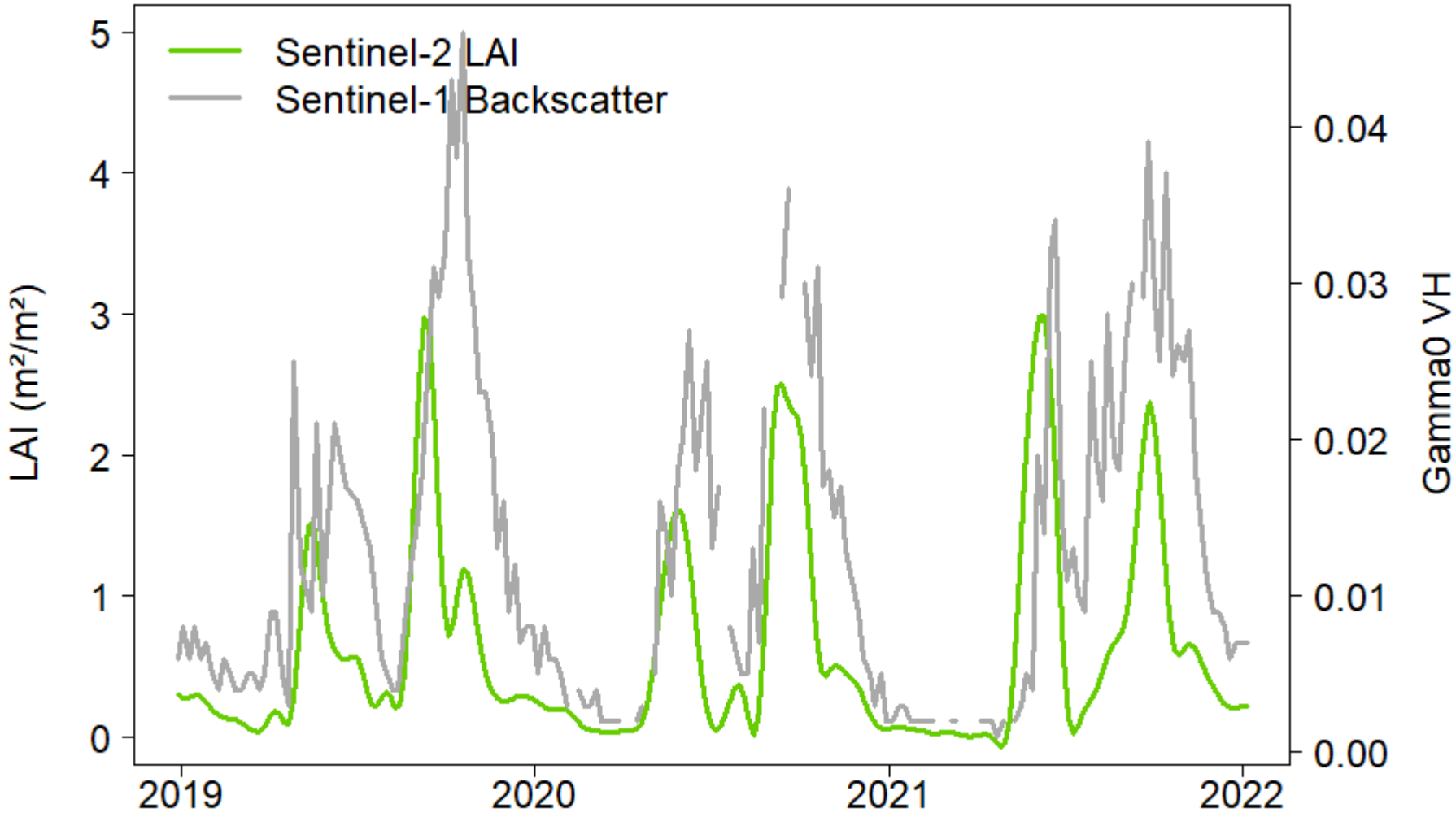




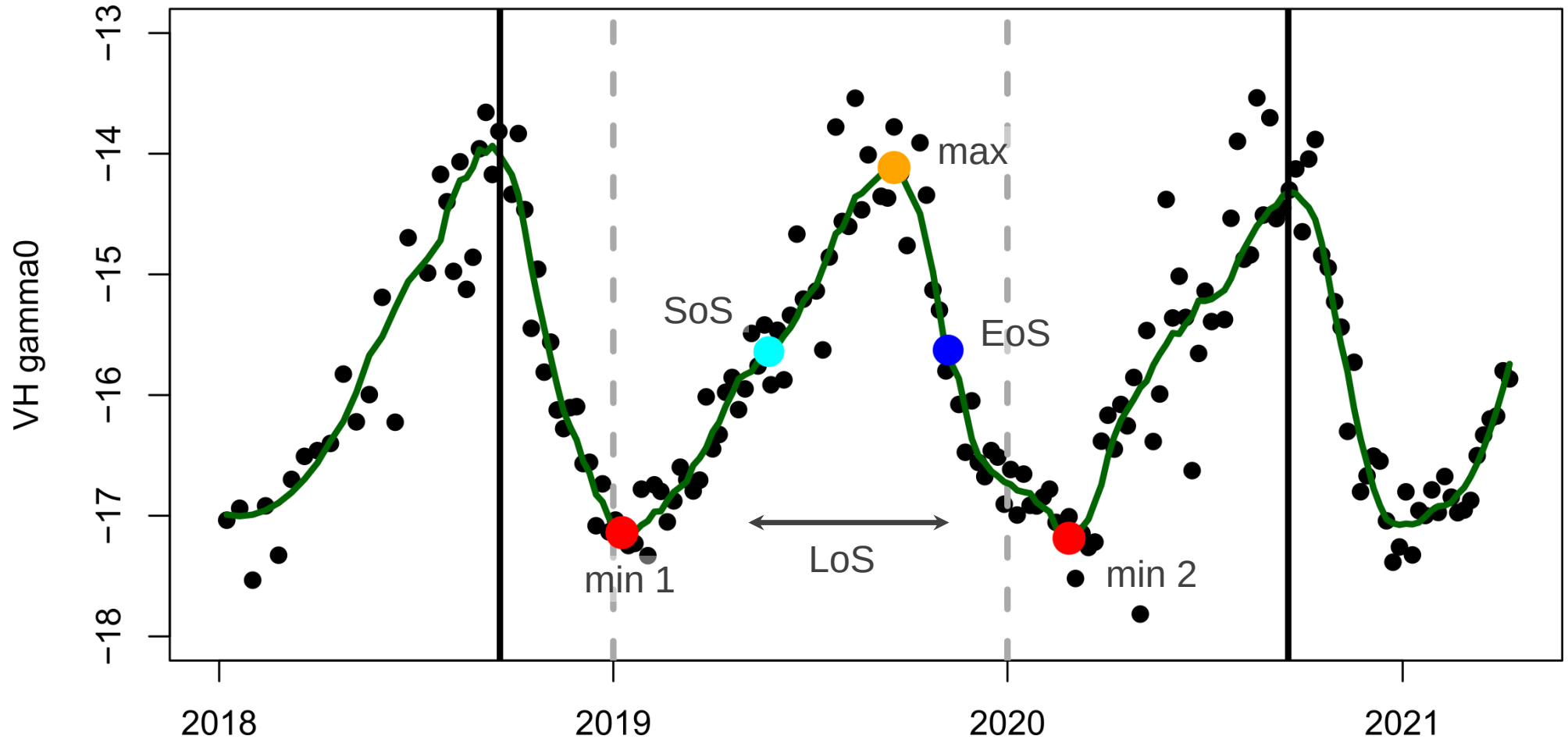
PHENOLOGY

Photo: Frank Thonfeld

Phenology of Optical vs. SAR data



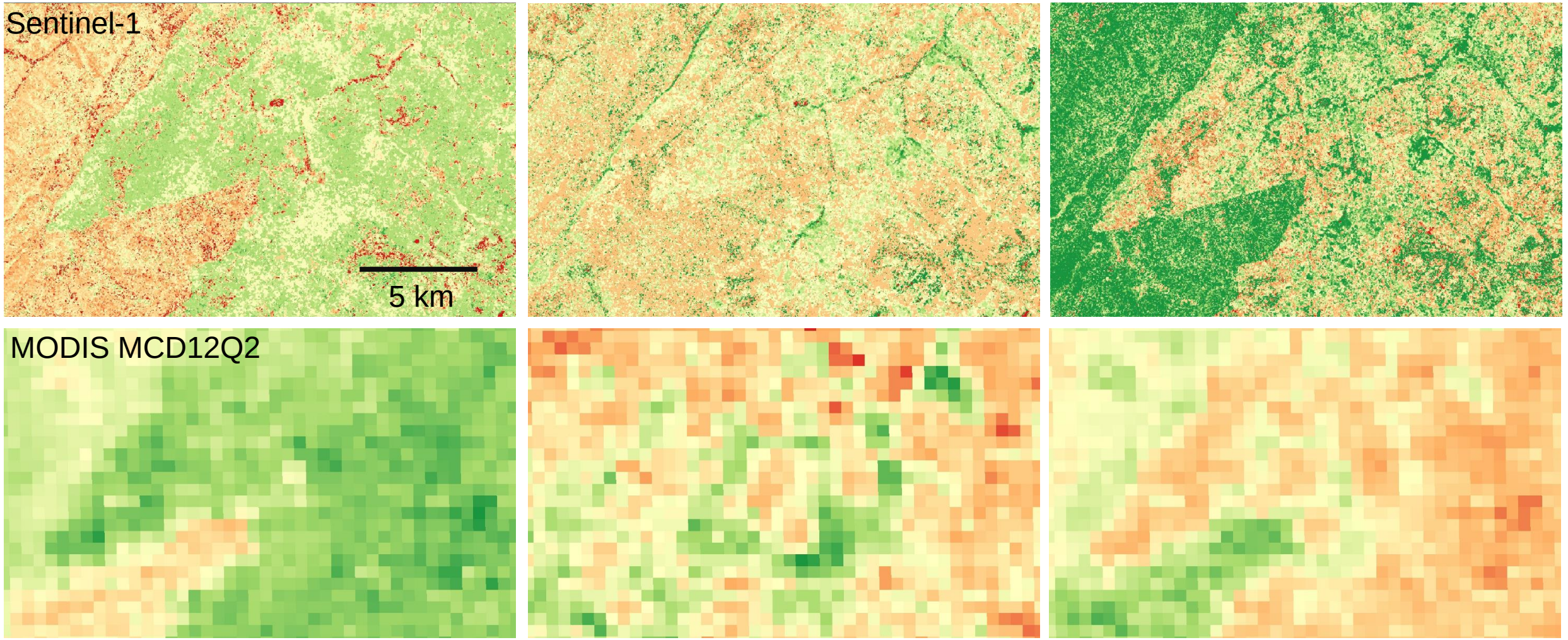
Phenology Based on Sentinel-1 Time Series



SoS (start of season), EoS (end of season), LoS (length of season)

Descals et al. 2020

Phenology Based on Sentinel-1 Time Series



Conclusion

- (Global) discrete classification schemes do not adequately reflect the heterogeneity of West African landscapes
- Tree cover still uncertain, not adequately resolved in coarse-scale products
- LAI is a good proxy of phenology but is inconsistent among products
- Challenges in creating dense time series of high-resolution satellite data due to presence of clouds & cloud shadows
- SAR data as option

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THANK YOU FOR YOUR ATTENTION

Photo: Frank Thonfeld