



WELCOME TO THE TRA 6 LECTURE SERIES INNOVATION PATHWAYS TO SUSTAINABILITY

SENSING FOR SUSTAINABILITY: NOVEL EARTH OBSERVATION
APPROACHES SUPPORTING THE LAND USE SECTOR

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Add (human) self-awareness to Earth's self-regulation for sustainability

- We don't know the best solution in advance, but can improve sensors and learn and rectify (sensing for sustainability)
- Self-awareness: track the lag time between environmental changes, versus impacts and reactions by humans/societies
- Climate-smart and sustainable land use



SUSTAINABILITY

Gaia 2.0

Could humans add some level of self-awareness to Earth's self-regulation?

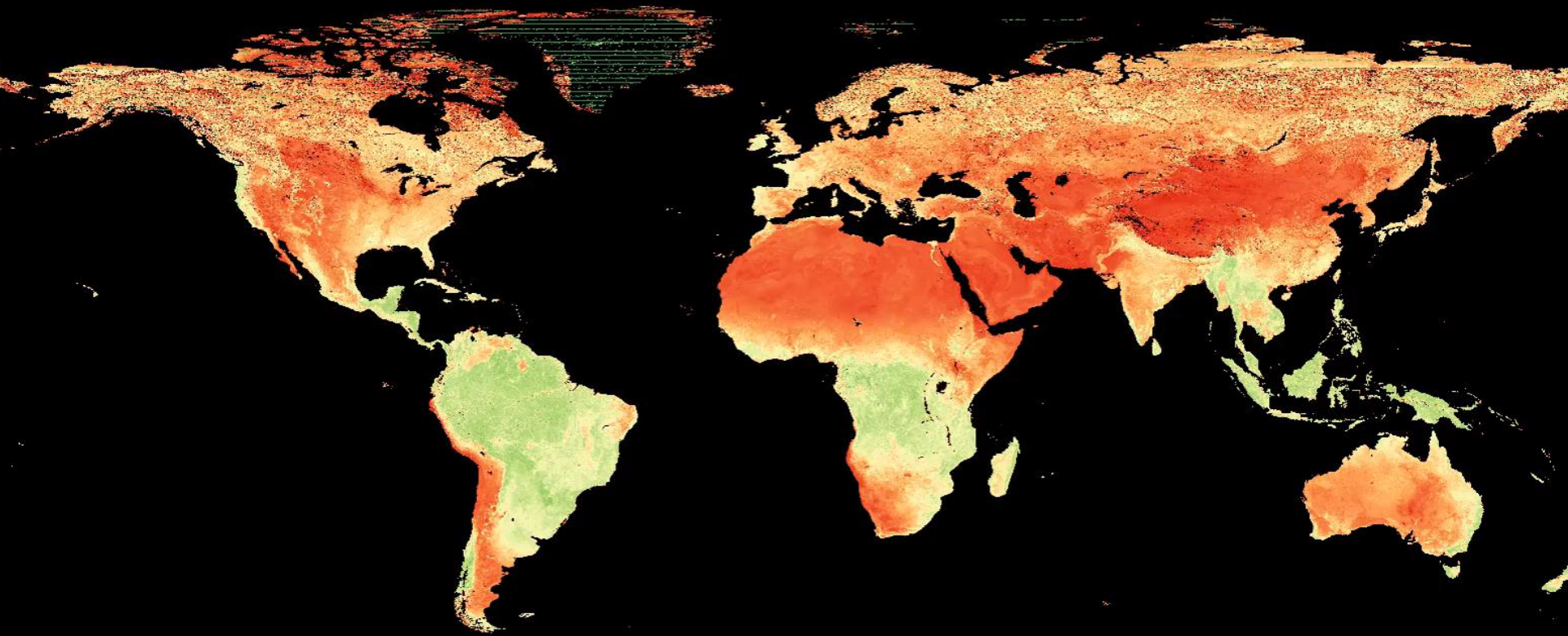
called the Anthropocene (3), and humans are beginning to become aware of the global consequences of their actions. As a result, deliberate self-regulation—from personal action to global geoengineering schemes—is either happening or imminently possible. Making such conscious choices to operate within Gaia constitutes a fundamental new state of Gaia, which we call Gaia 2.0. By emphasizing the agency

The commercial Earth observation satellite WorldView-4 has been providing high-resolution imagery since its launch in 2016 from Vandenberg Air Force Base in California.

what is now seen as the start of the Anthropocene (3). Furthermore, the examples of social Darwinism, sociobiology, and dialectical materialism suggest that drawing political lessons from nature is problematic.

Overview

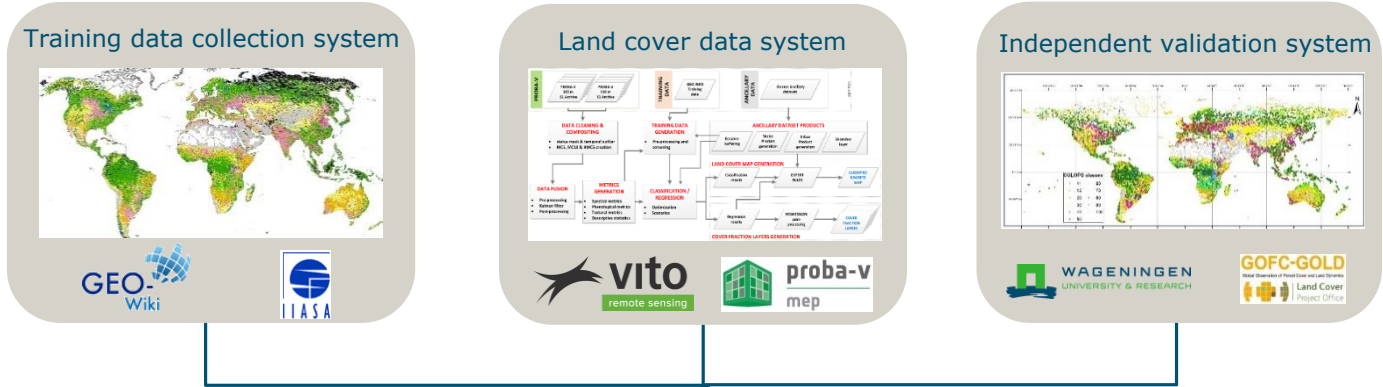
1. Recent progress in tracking global land dynamics
2. Evolving technologies and approaches:
 - Near-real time assessments
 - New sensing opportunities
 - Linking data science and (process) modelling
3. Towards sustainability: examples and demonstrations



OpenGeoHUB
Connect • Create • Share • Repeat

NDVI_1982_M01

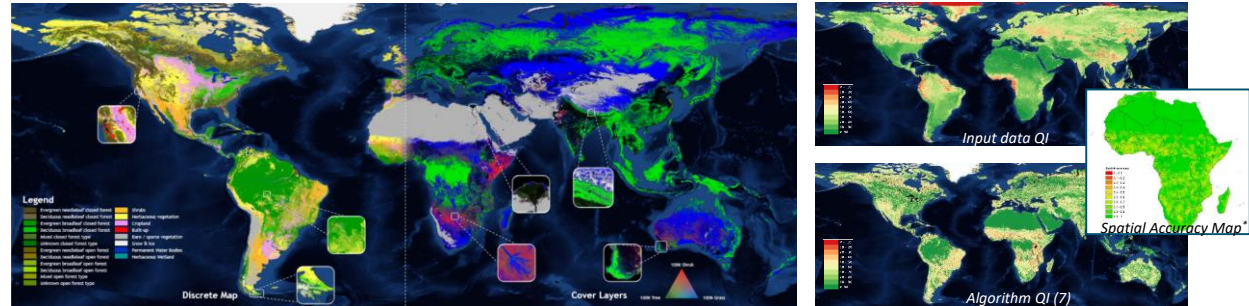
Copernicus Global Land Cover Monitoring Service



- Annual (since 2015)
- Global
- 100m
- Land cover classes and fractions

<https://land.copernicus.eu/global/products/lc>

A systematic **service** providing dynamic, **yearly**, **user-oriented** **global** land cover maps from 2015

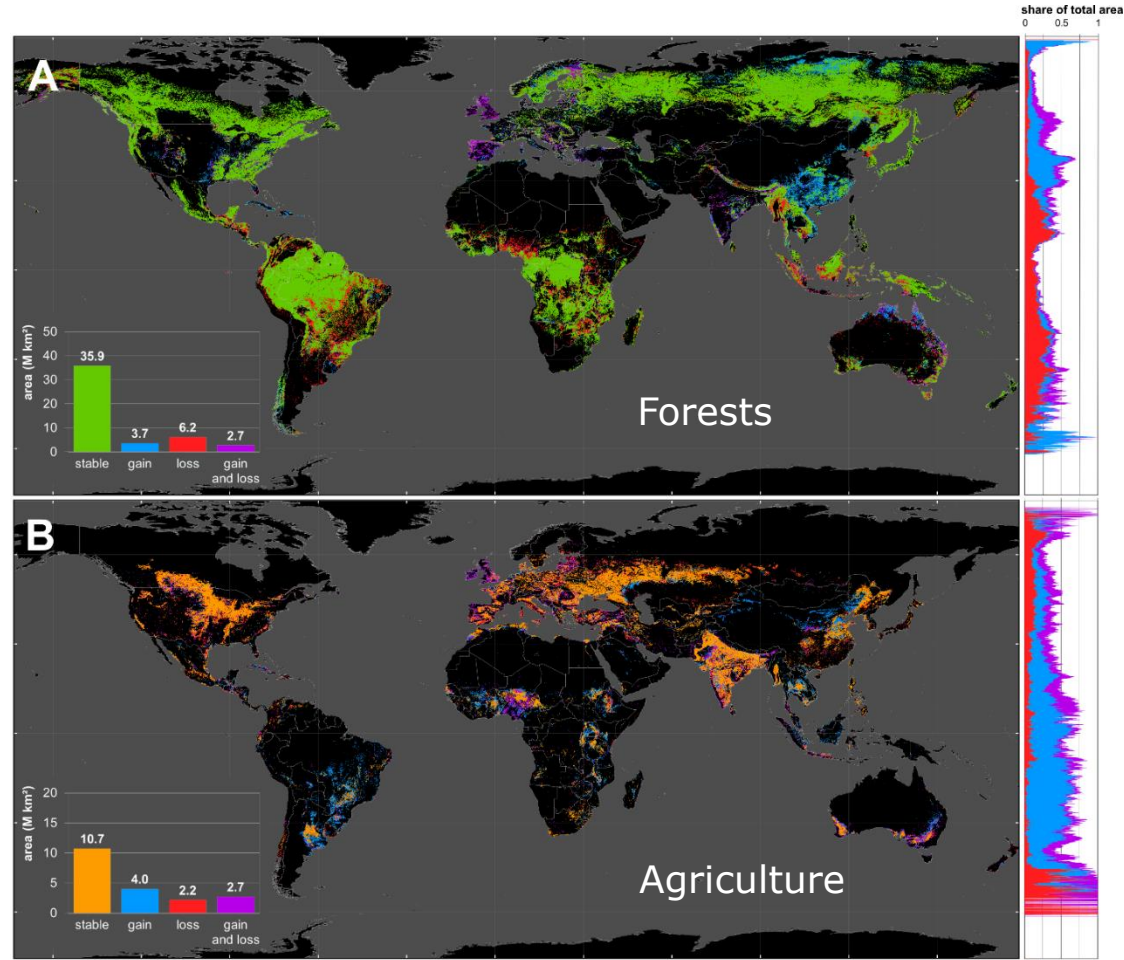
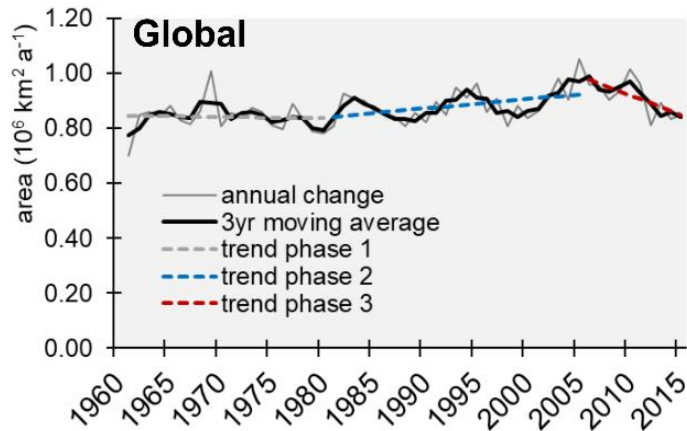


Buchhorn et al., 2020, Rem.Sens.
Szantoi et al., 2020, ESP, 112

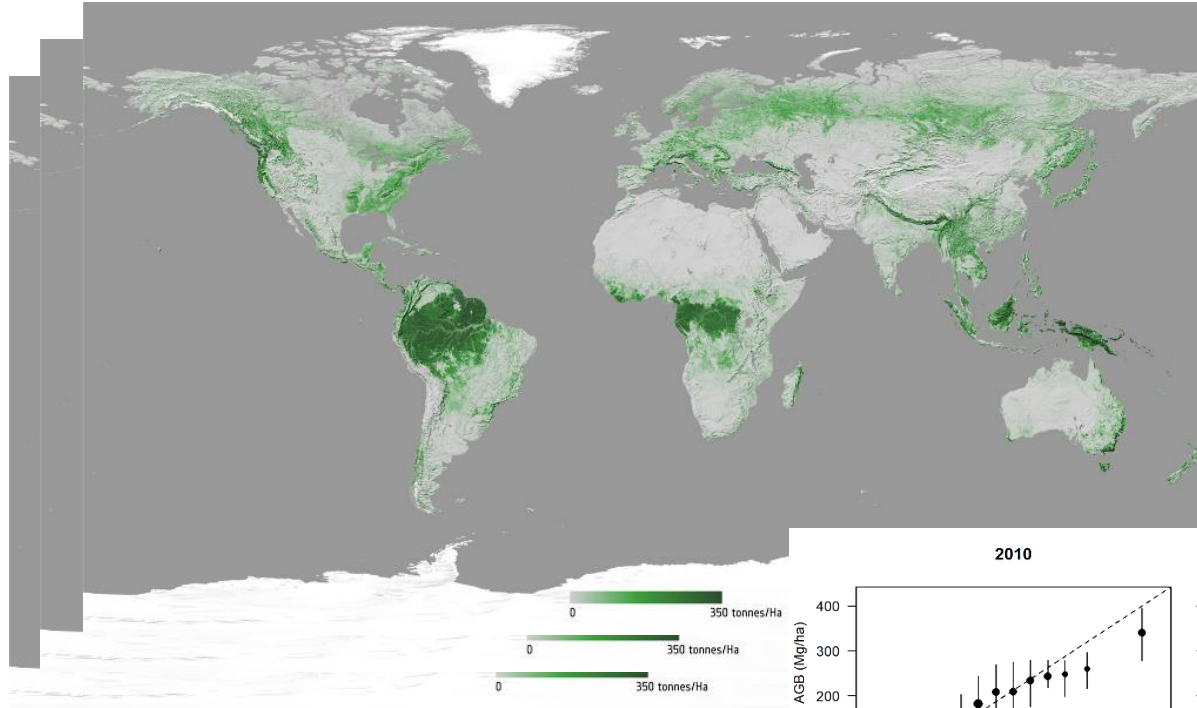
Global land cover/use change 1960-2015

- 4-times more change
- Phases of acceleration and deceleration

Winkler et al., (subm.)

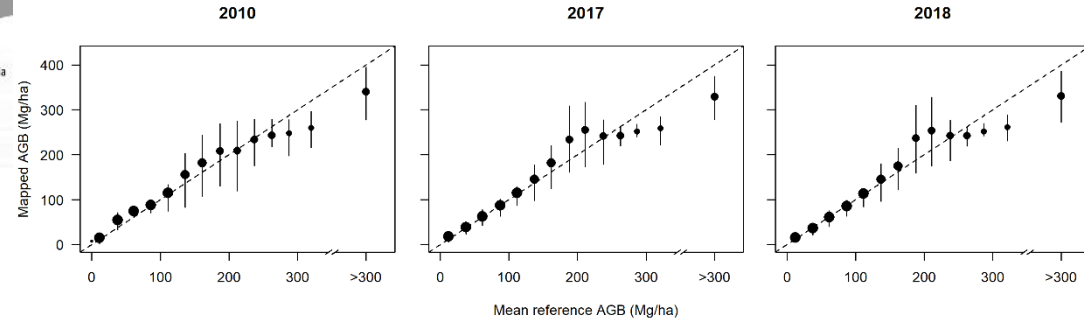
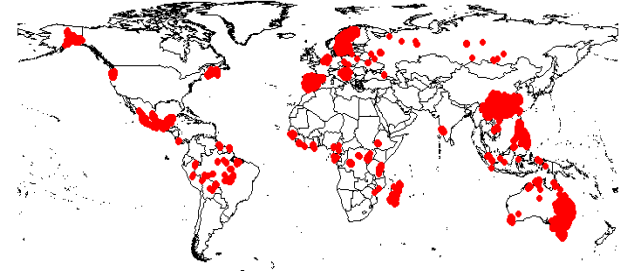


Space-based global biomass monitoring

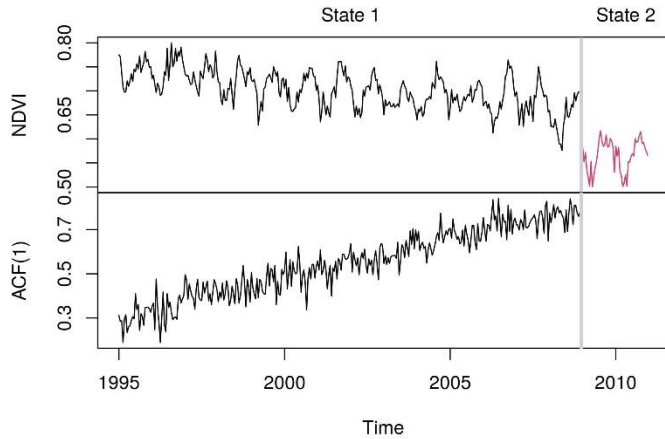


Global aboveground biomass for 2010, 2017, 2018
<http://cci.esa.int/biomass>

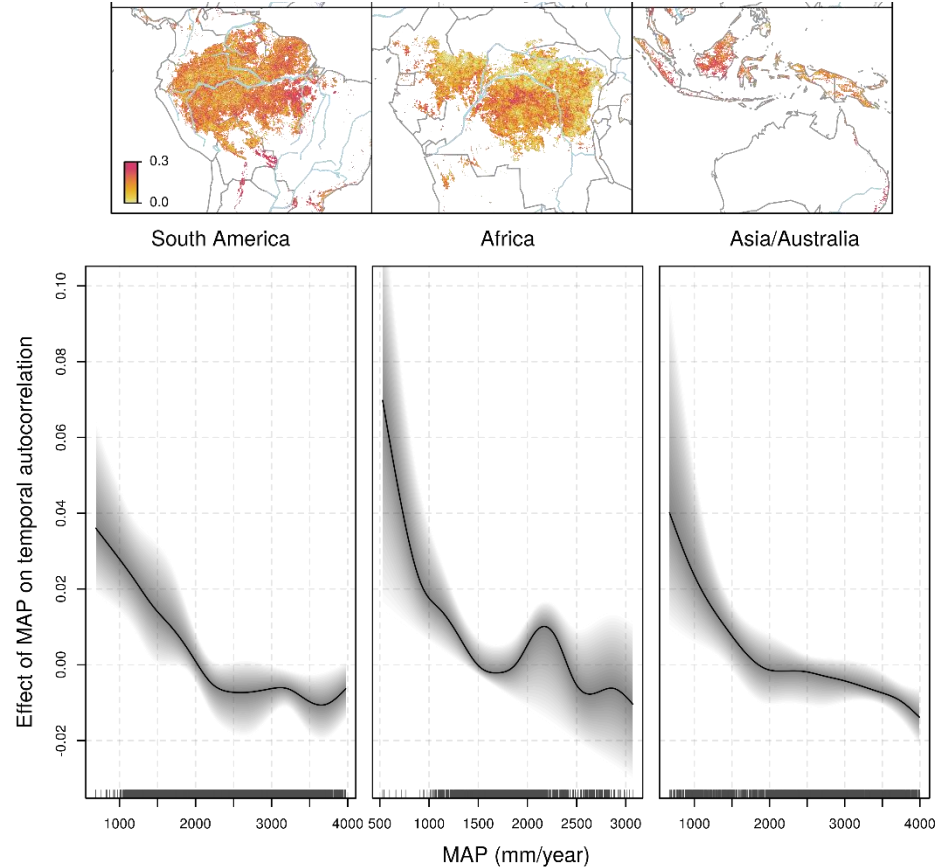
Global plot reference database (~109.000)



Temporal autocorrelation \sim resilience



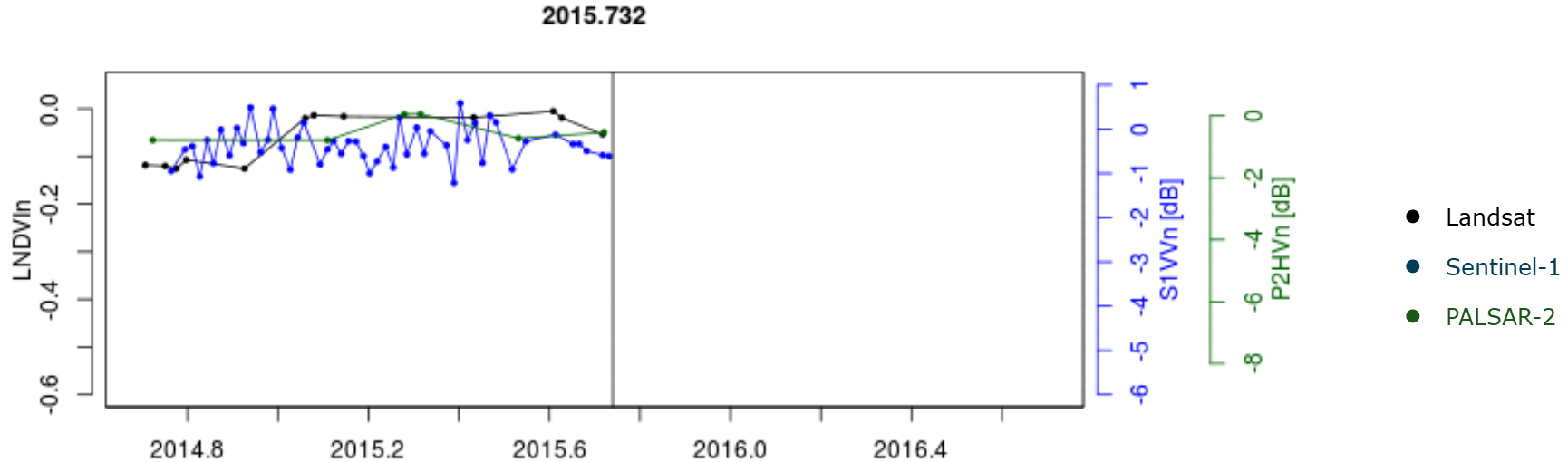
Verbesselt, J. *et al.* Remotely sensed resilience of tropical forests. *Nat. Clim. Chang.* (2016).

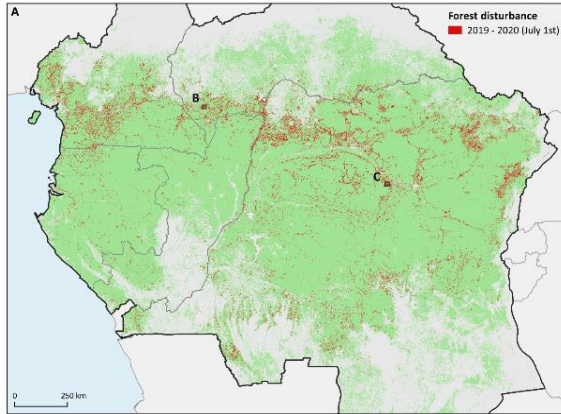


Overview

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Dense time-series for near-real time detection



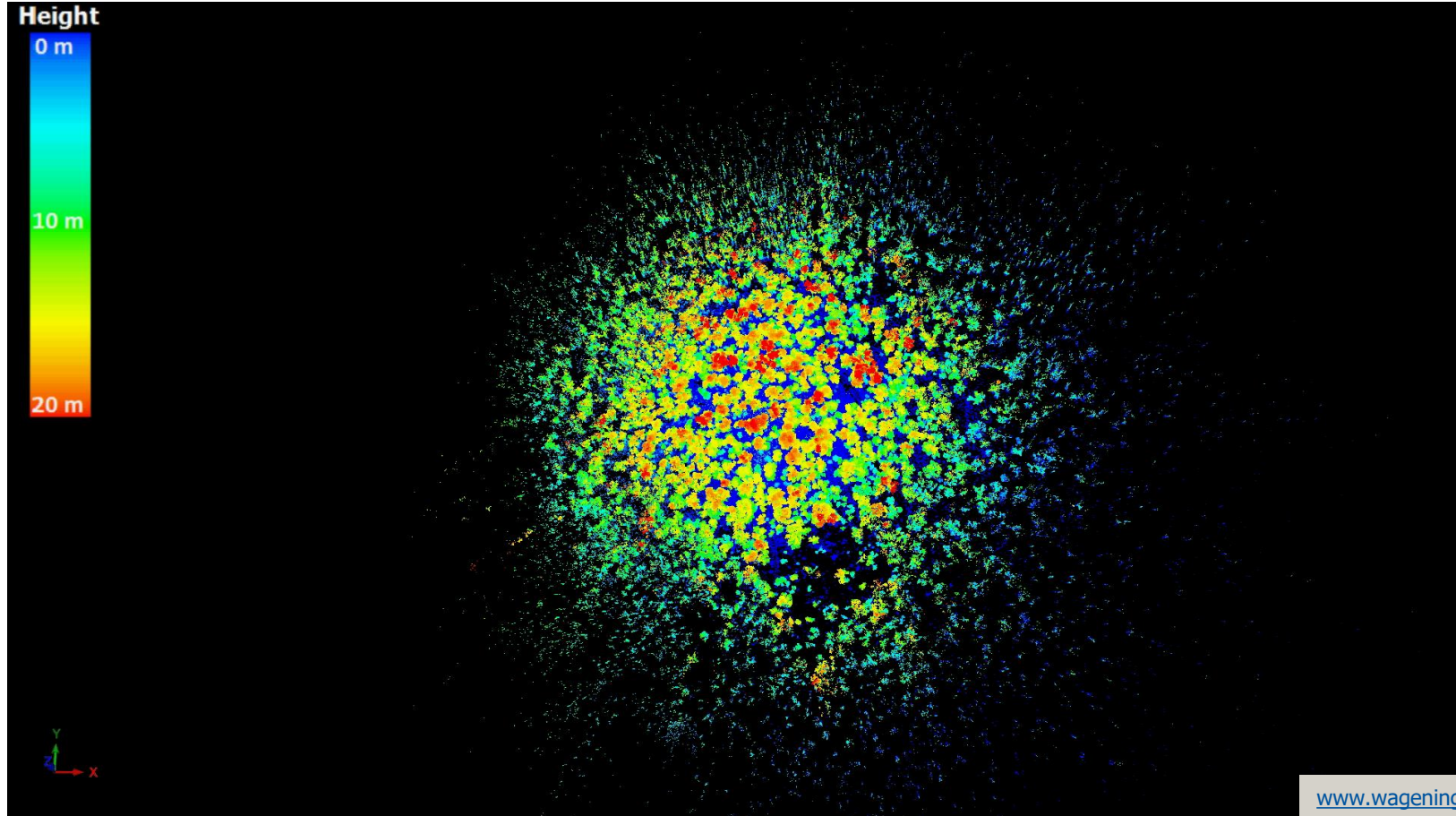


Selective logging pattern in DRC based on weekly forest disturbance alerts

Reiche et al. (in rev.), ERL

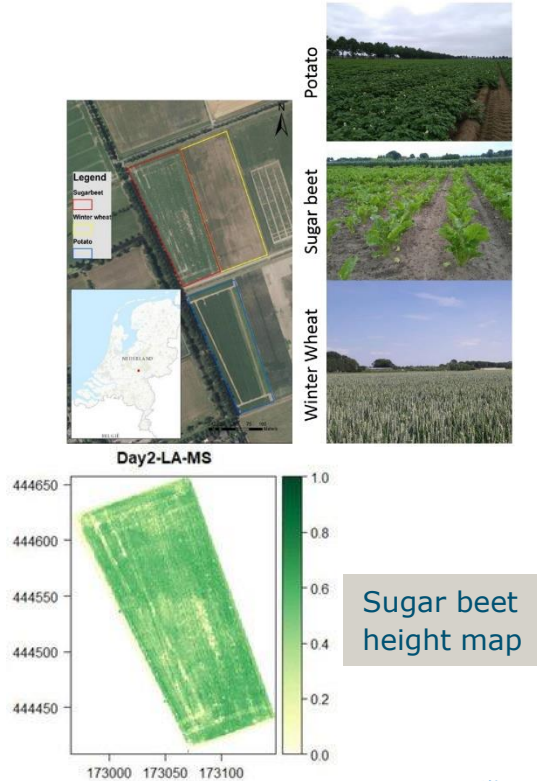


Vegetation structure monitoring and characterization

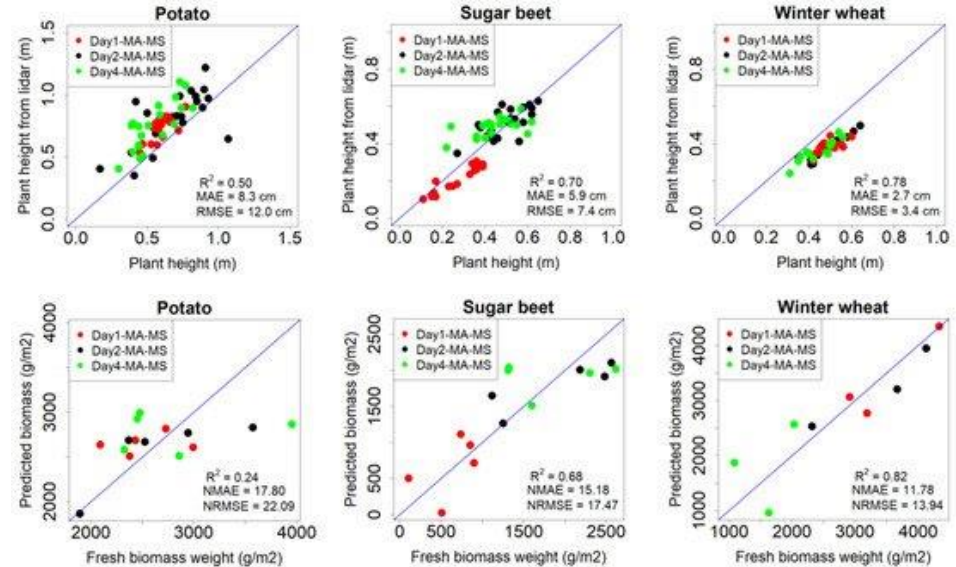




Biomass and Height Estimation of Crops and Trees Using UAV-Based Lidar



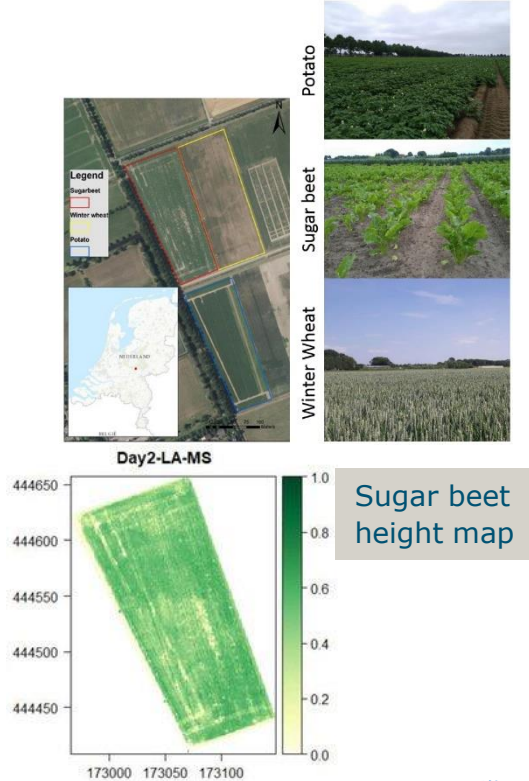
Sugar beet height map



Source: Ten Harkel, Bartholomeus, Kooistra, 2020. RS
 WUR drone facility (10 years): www.wageningenur.nl/uarsf
 WUR High-throughput phenotyping: <https://www.npec.nl/>



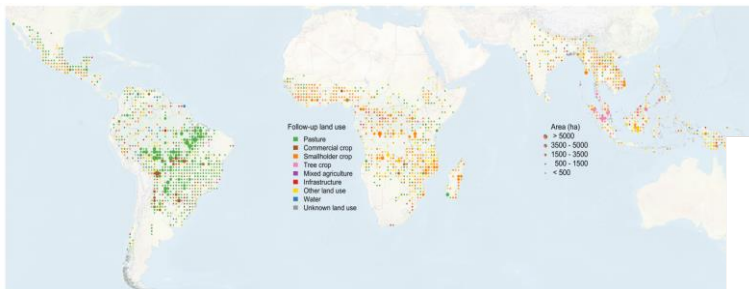
Biomass and Height Estimation of Different Crops and Trees Using UAV-Based Lidar



1. Ryegrass biomass estimation (de Alckmin et al., 2020, Precision agriculture)
2. Evaluating plant-soil feedback in ag-systems: (Nuijten, et al. 2019, Drones)
3. Modeling woody volume and biomass of trees from drone-based LIDAR (Brede et al., 2019 RSE)
4. Large-area palm species mapping in tropical forests (Tagle-Casapia et al., 2020, RS)

Land use monitoring

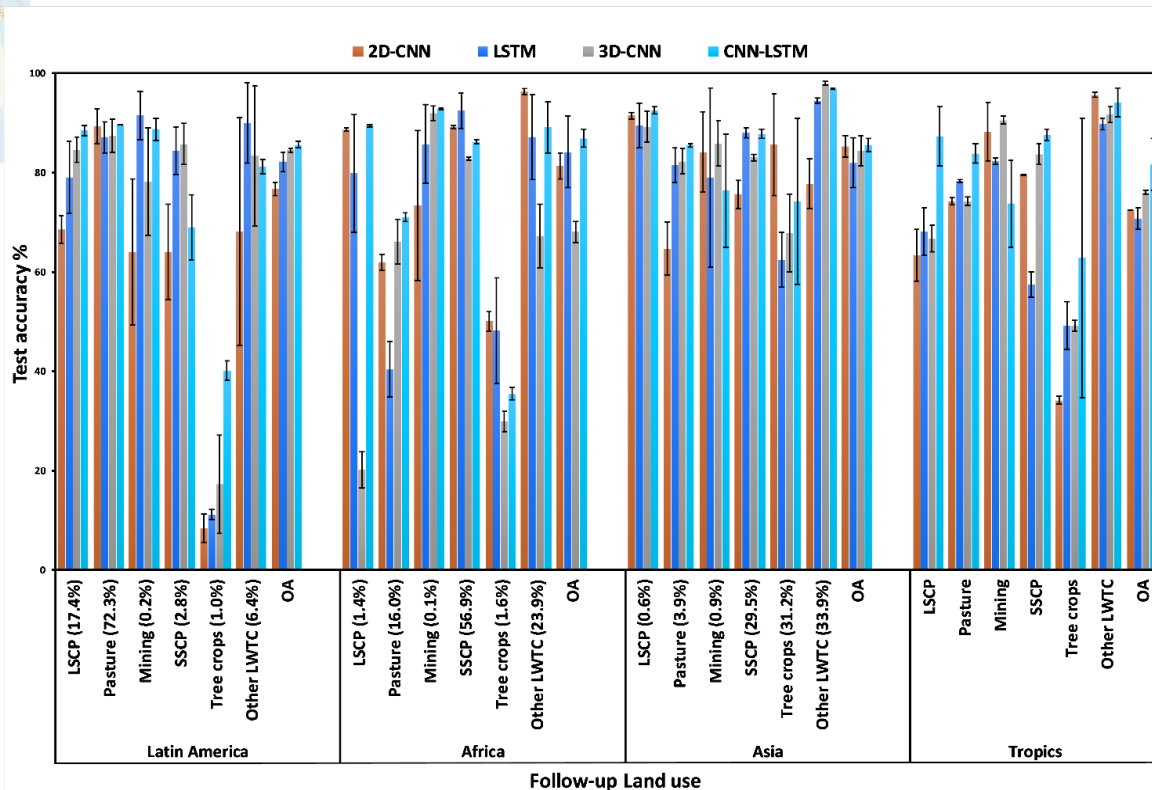
Masolele et al. (subm.)



Accuracies of land use classification (in percentages) of four deep learning methods for continental and pan-tropical scale.

- LSCP: large-scale/commercial cropland
- Pasture
- Mining
- SSCP-small-scale cropland
- Other LWTC-Other land with tree cover
- Tree crops
- OA- for overall accuracy.

In brackets are the percentages of each FLU class over each continent.



Linking data science and physical/process modelling

- Evolution of deep learning and computer vision applied to large EO archives
- Linking data science/AI approaches and physical/process modeling:
 - Machine “learning” -> limited capability for extrapolating
 - Trying to overcome the black box (“interpretable/explainable AI”)
 - Models vs. data: limitations in current process modeling adopting EO data streams and fully capture complexity
 - Little concrete examples of hybrid modeling, physics-aware machine learning (Reichstein et al., 2018, Nature)
 - Use error function of CNNs to avoid physically meaningless outcomes (thematically, temporally)
 - Linked physical simulations and inclusion in probabilities

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Differentiated observations needs along the policy cycle



➤ **Awareness/problem definitions:**

- Land change trends/GHGs
- IPCC, IPBES etc.

➤ **Policy options/activities:**

- Nat. determined contributions (NDCs)
- Activities, hotspots for mitigation/adaptation

➤ **Implementation:**

- Local data supporting land management
- Regular progress tracking, transparency

➤ **Evaluation/performance:**

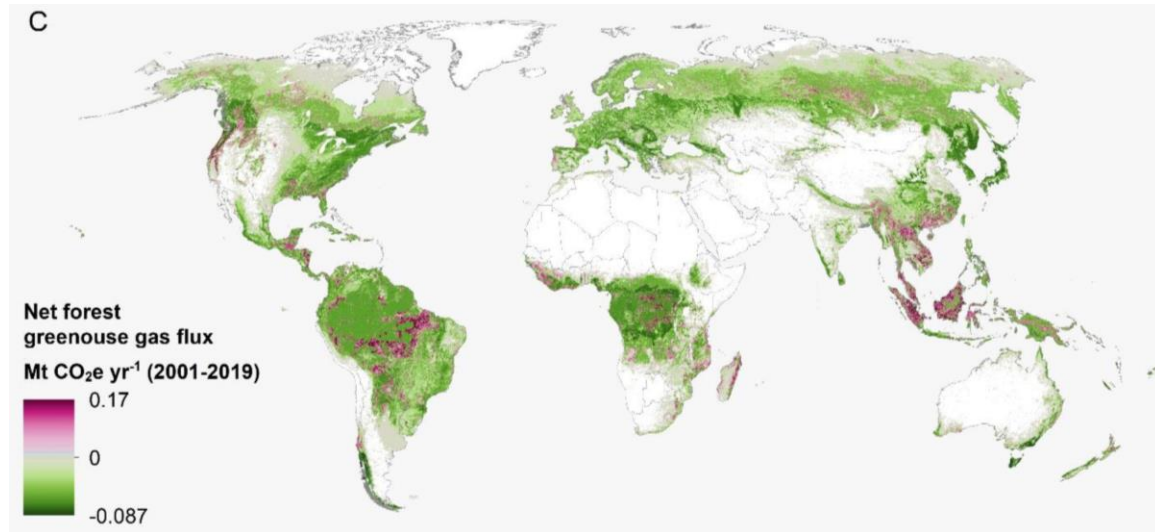
- National: GHG inventories, SDG reports
- Global: UNFCCC stocktake (2023+)

Towards data-driven, spatially explicit GHG inventories

Integration of key data sources:

- Forest change
- Drivers of deforestation
- Forest plantations
- Biomass stocks
- Biomass burning/burnt area
- Peatlands, Mangroves
- Soil carbon
- ...

Combine data to provide forest related gross emissions, removals, and net GHG from 2001 annually at 30 m resolution, building upon IPCC GPG reporting framework



Forest-related net GHG (LULUCF) flux from 2001 to 2019 (Harris et al., in rev.)

Climate Smart Land Use options: Livestock sector in Kenya

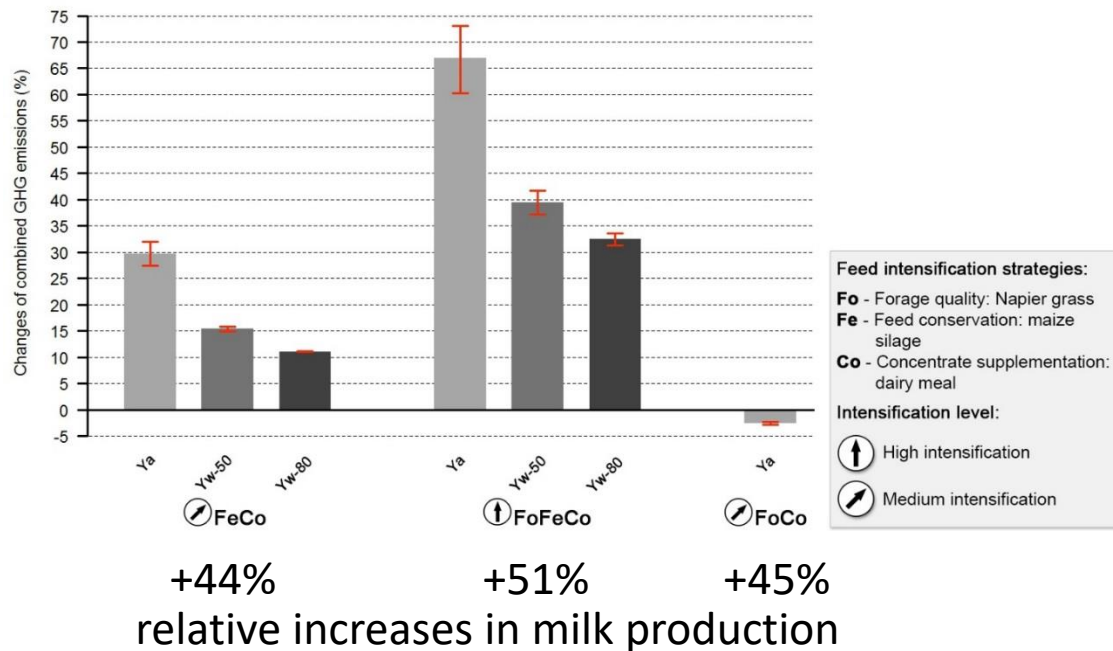
Mitigation scenario:

- Increase milk yield
- Feed intensification (quality, conservation)
- Reduce yield gap
- Reduce forest grazing -> create a forest sink

Brandt et al., 2020. GCB

Data sources:

- Livestock data
- Forest remote sensing
- Farm surveys



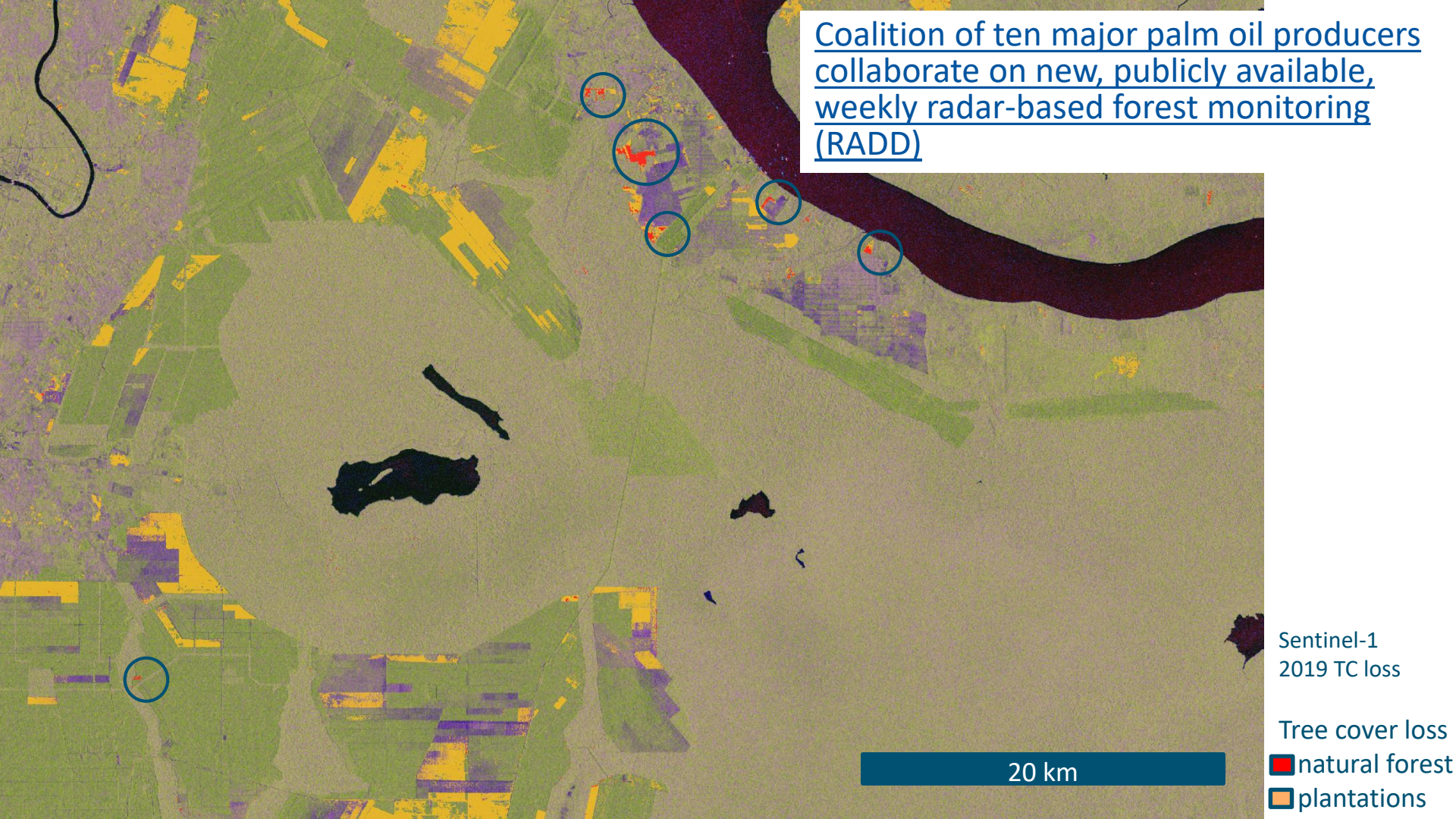
Radar-based weekly forest change alerts, Sumatra based on open-source data and methods



Sentinel 1
weekly forest
loss alerts

Reiche et al. 2018, RS

Coalition of ten major palm oil producers collaborate on new, publicly available, weekly radar-based forest monitoring (RADD)



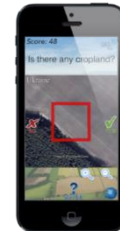
Sentinel-1
2019 TC loss

Tree cover loss
■ natural forest
■ plantations

20 km

Interactive/participatory monitoring: linking data to action

- Operational monitoring in Kafa Biosphere Reserve, Ethiopia in near-real time mode since Oct. 2014
- System at national and local level in Peru incentivising indigenous communities to protect forests
- Alert-driven monitoring for land cover/use mapping and sustainable oil palm sourcing in Indonesia and Malaysia (<https://landsense.eu/>)
- PLOS-One collection of twelve research papers on case studies:
<http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0176897>



GOFC-GOLD

Global Observation of Forest Cover and Land Dynamics



Land Cover
Project Office



European Space Agency
Agence spatiale européenne

World bank REDD+ monitoring training materials

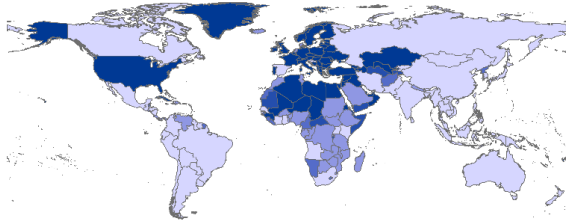
- 14 modules (lectures, country examples, exercises)
- 3 Languages (English, French, Spanish)
- 30+ authors, regular updates incl. scientific synthesis
- Training the trainer workshops, webinars etc.

http://www.gofcgold.wur.nl/redd/Training_materials.php

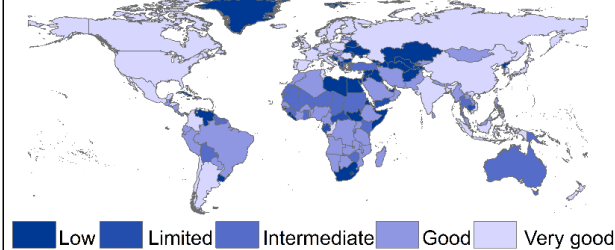
<https://www.forestcarbonpartnership.org/redd-training-material-forest-monitoring>

Changes in country forest monitoring capacities (FAO FRA 2020)

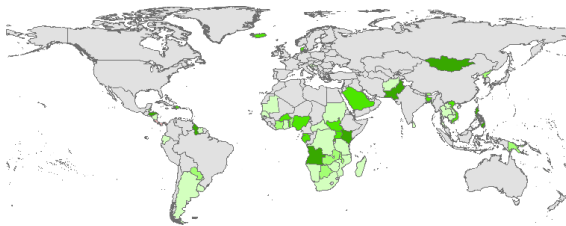
(1b) Remote sensing capacity 2020



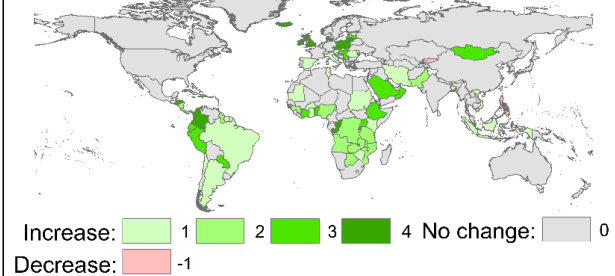
(2b) NFI capacity 2020



(1c) Capacity changes 2005 - 2020



(2c) Capacity changes 2005 - 2020



- Continuous improvement in the use of RS for area change estimation (in particular for Africa with room for improvements)
- NFI data improvements widespread in tropics but also Europe
- Almost no decline in capacity
- North/south capacity differences turn into methodological differences

Nesha et al., 2020 (subm.)

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Sensing for sustainability: summary I

- Availability of dense/long archives of satellite, time-series analysis algorithms, and EO-big data analytics
- Global data with local relevance: dynamics, different types and speed of changes
- Improved linking of dynamic information to human actions
- Terrestrial and drone-based systematic observations: enhance rapid local data and physical underpinnings
- New data science/AI opportunities need to be linked with process understanding/modeling
- Europe is leading the way for the “golden age” of Earth Observations

Sensing for sustainability: summary II

- Supporting sustainability:
 - Differentiated observation support: problem – policy – implementation - evaluation
 - Sustainable supply chain monitoring
 - Climate change mitigation and conservation (i.e. REDD+, landscape restoration, nature-based solutions)
 - Data driven underpinnings: forest/agriculture nexus
 - Implementing and reporting of SDGs
- Enhancing transparency and “actionable” information as catalyst for transformational change and local actions
- Sensor-system for a self-aware Earth

THANK YOU

