Forest Degradation Monitoring Using an Optical/ Radar-based Approach

Forest Canopy Disturbance Monitoring (FCDM) Tool

ESA Land Training 2021

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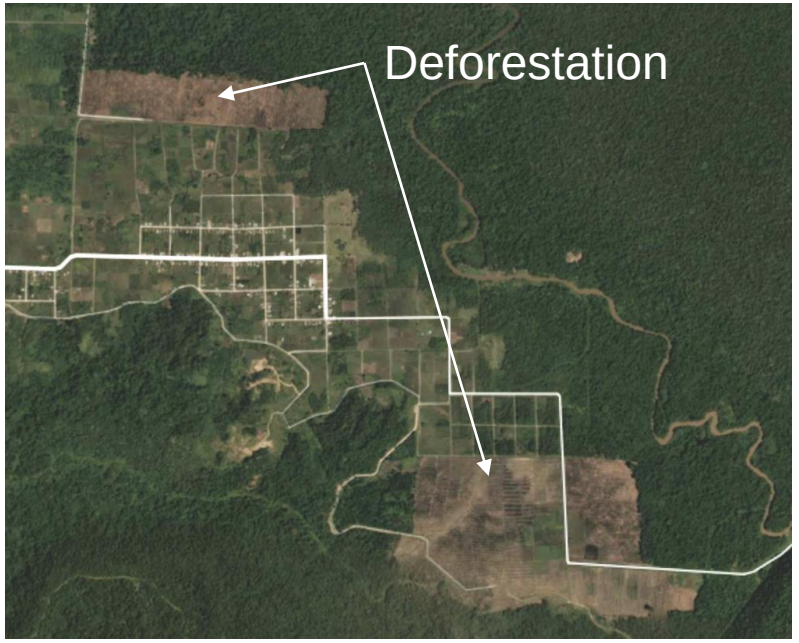
Andreas Langner, Frédéric Achard

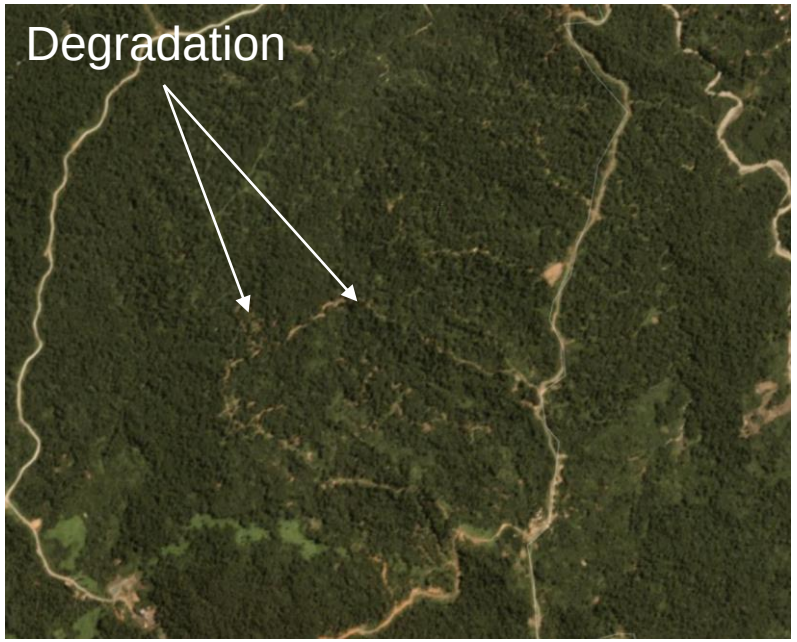
Joint Research Centre – D1

Monitoring Forest Canopy Disturbances

Problems to detect forest disturbances/ degradation

- Small-scale signal (e.g. removal of single trees)
- Weak signal (low signal-to-noise ratio)
- Signal only detectable over a short period due to
  - Fast vegetation regrowth in tropics
  - Frequent cloud coverage in tropics
- Differentiation between natural phenological changes (e.g. seasonality) and actual disturbance events





Forest Canopy Disturbance Monitoring (FCDM) Tool

FCDM Tool

FCDM-optical
(Landsat, Sentinel-2)

Already implemented on SEPAL platform

remote sensing — MDPI

Article

Towards Operational Monitoring of Forest Canopy Disturbance in Evergreen Rain Forests: A Test Case in Continental Southeast Asia

Andreas Langner [1,*], Jukka Miettinen [2], Markus Kukkonen [3,4], Christelle Vancutsem [1], Dario Simonetti [1], Ghislain Vieilledent [1,5], Astrid Verhegghen [1], Javier Gallego [1] and Hans-Jürgen Stibig [1]

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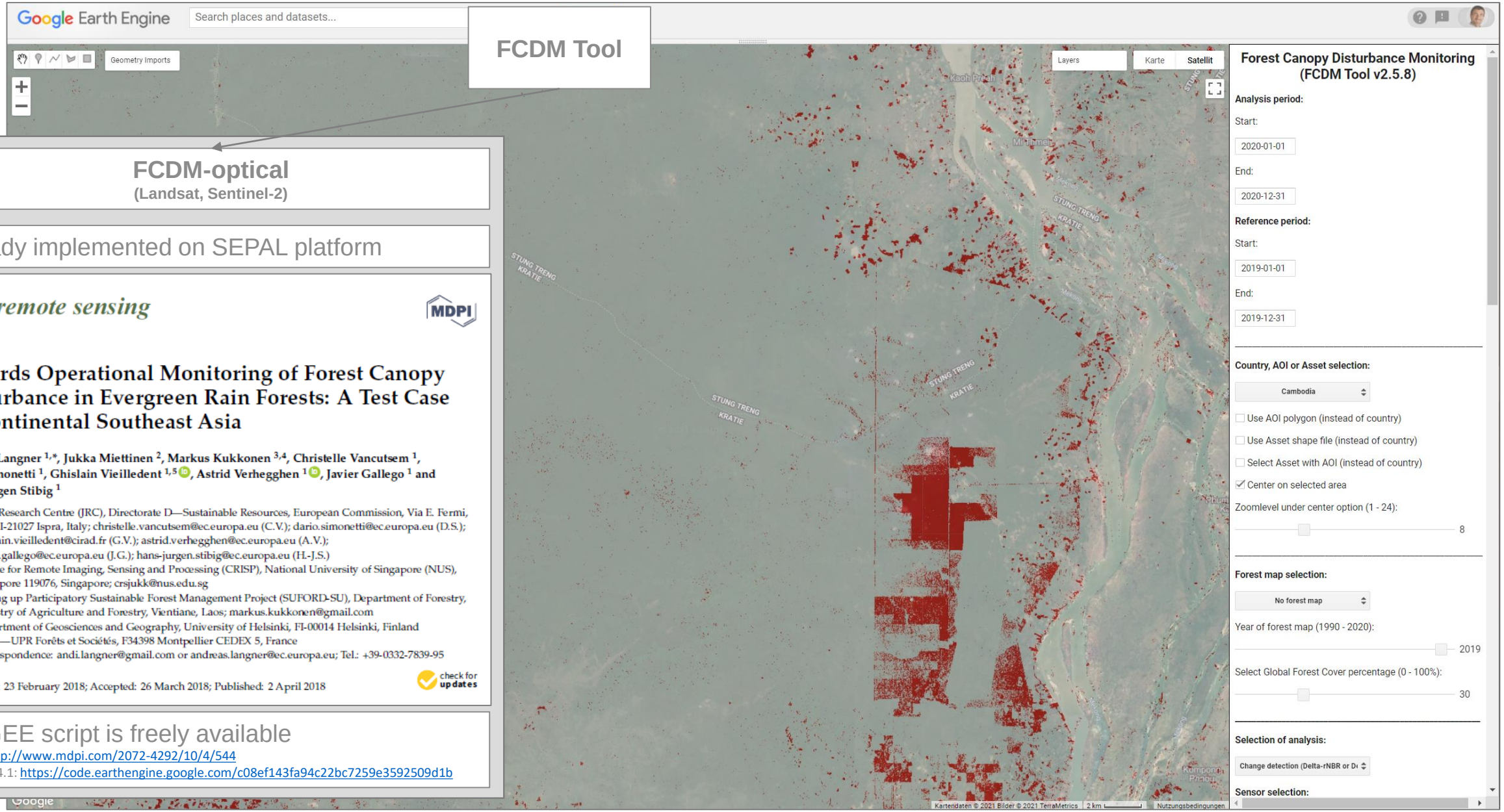
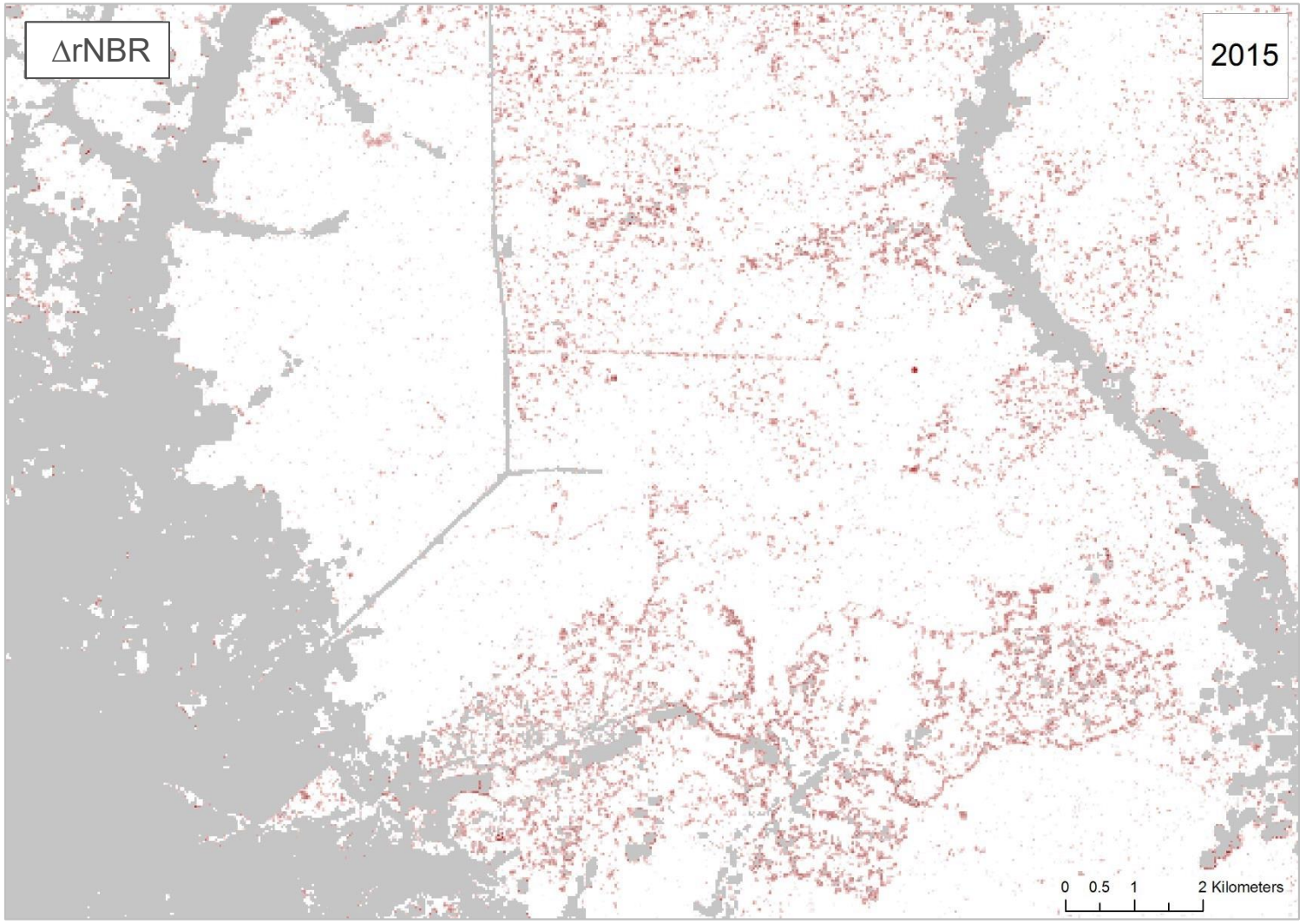


Basic Concept of the FCDM Methodology

Change Detection Approach

Basic Concept of the FCDM Methodology



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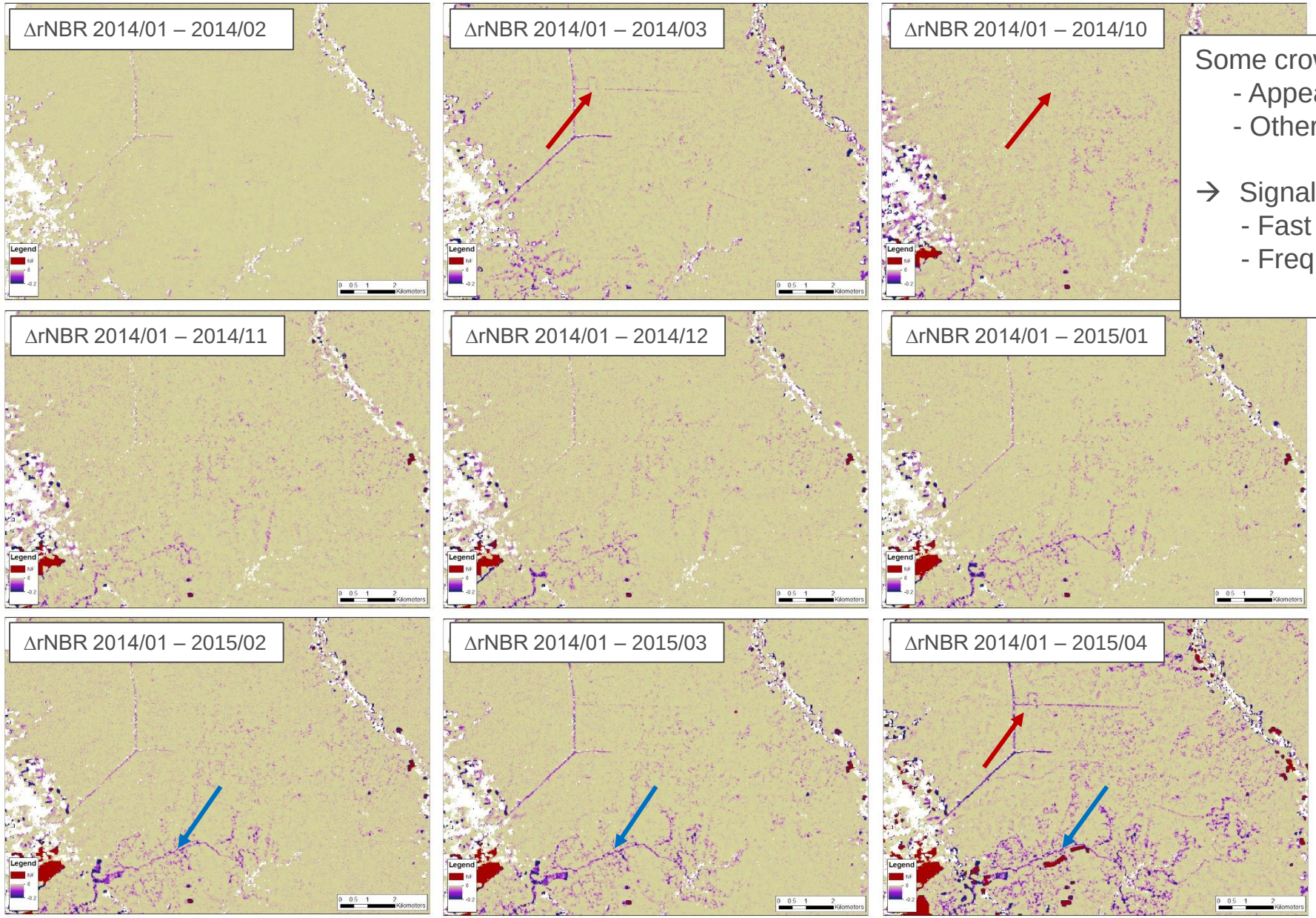
Problematic of Temporal Detectability of Signal



Some crown cover disturbances:
- Appear/ disappear/ reappear (red arrows)
- Others accumulate over time (blue arrows)

→ Signal only detectable over short periods due to:
- Fast vegetation regrowth in tropics
- Frequent cloud coverage in tropics

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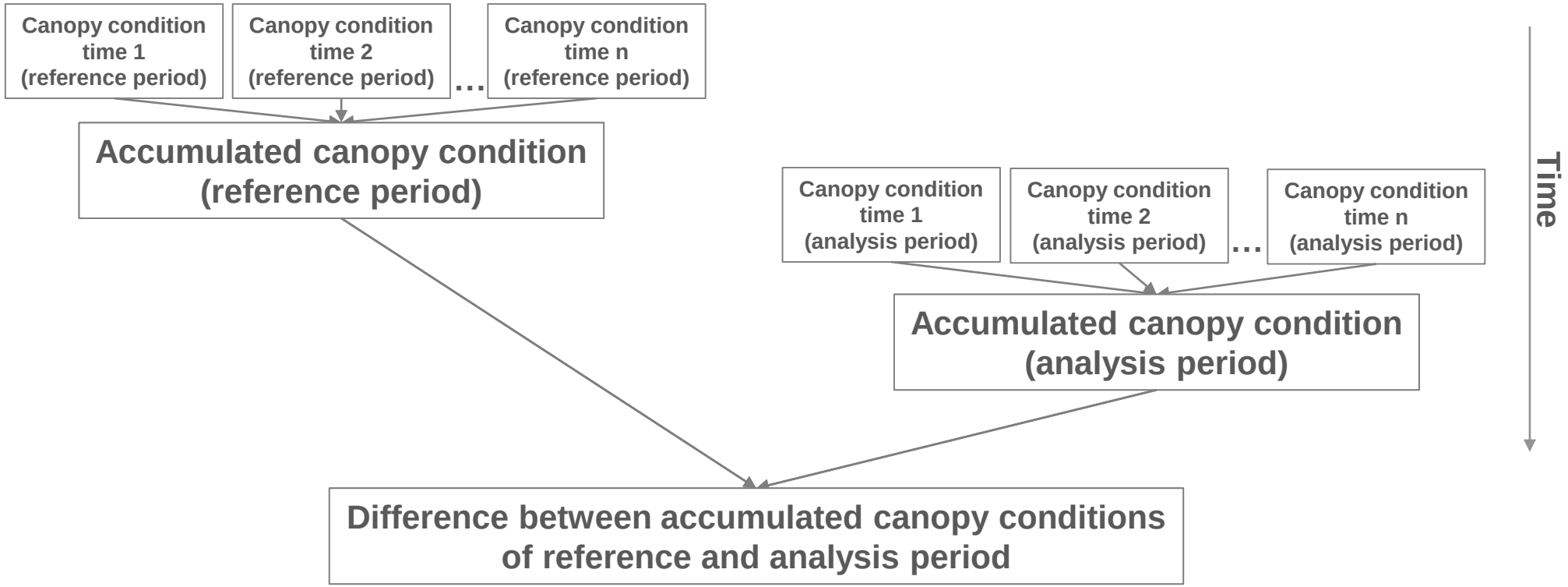
Basic Concept of the FCDM Methodology



	Reference period	Analysis period	FCDM result
Canopy Opening	No	Yes	Disturbance
	Yes	No	Regrowth*
	No	No	No change
	Yes	Yes	No change

Activity Data

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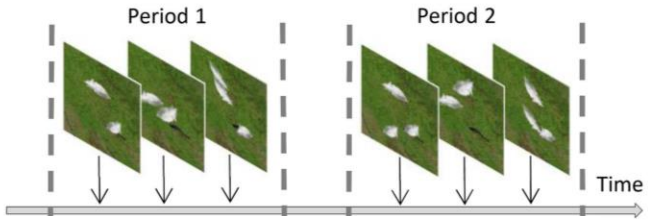
Major Processing Steps of the FCDM Approach

1. a) Accessing satellite data (per study area and investigation period)



$$NBR = \frac{NIR - SWIR_2}{NIR + SWIR_2}$$

NBR is sensitive to bare soil or non-photosyntetic vegetation

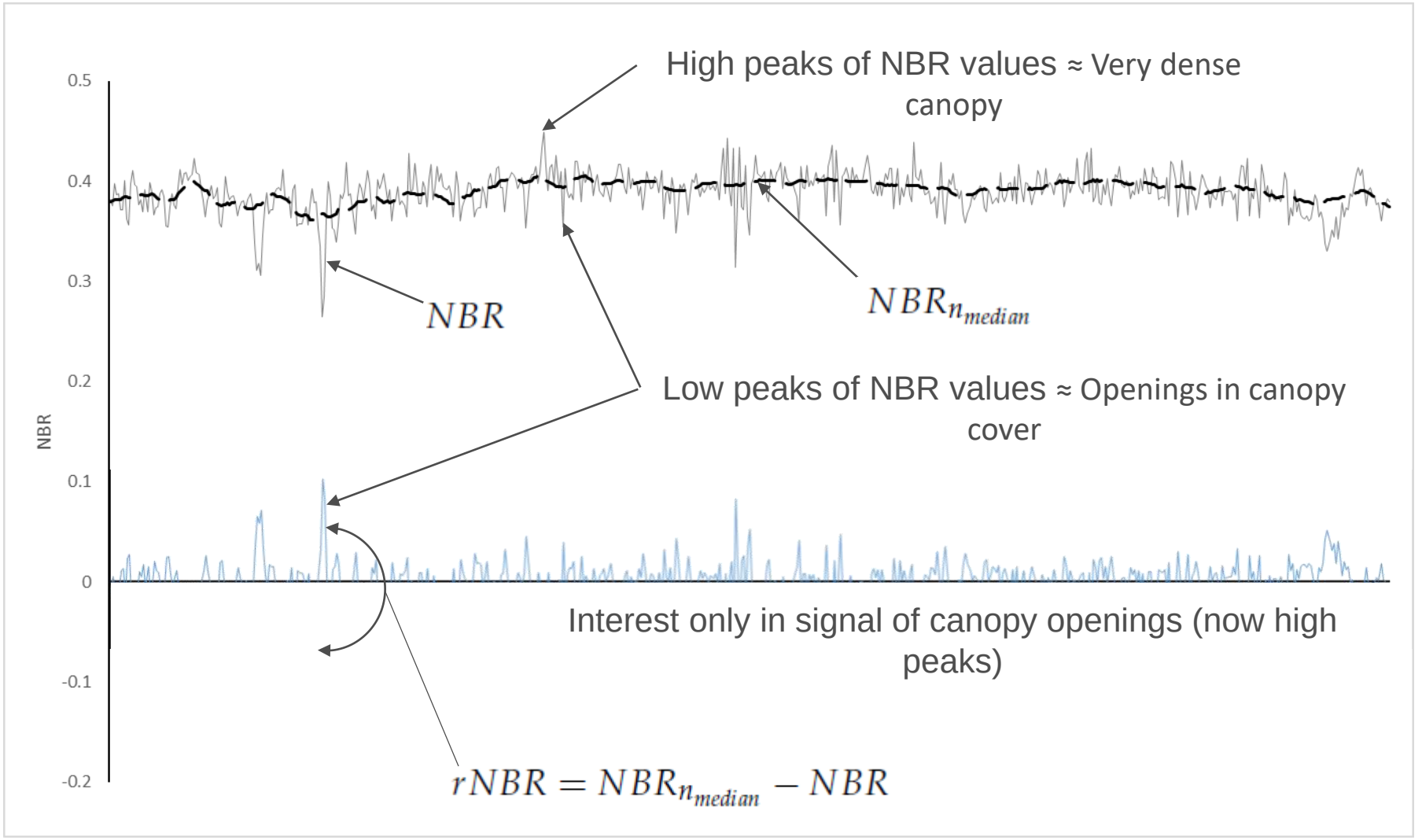
→ Allows detecting changes in forest canopy due to logging events

$$rNBR = NBR_{n_{median}} - NBR$$

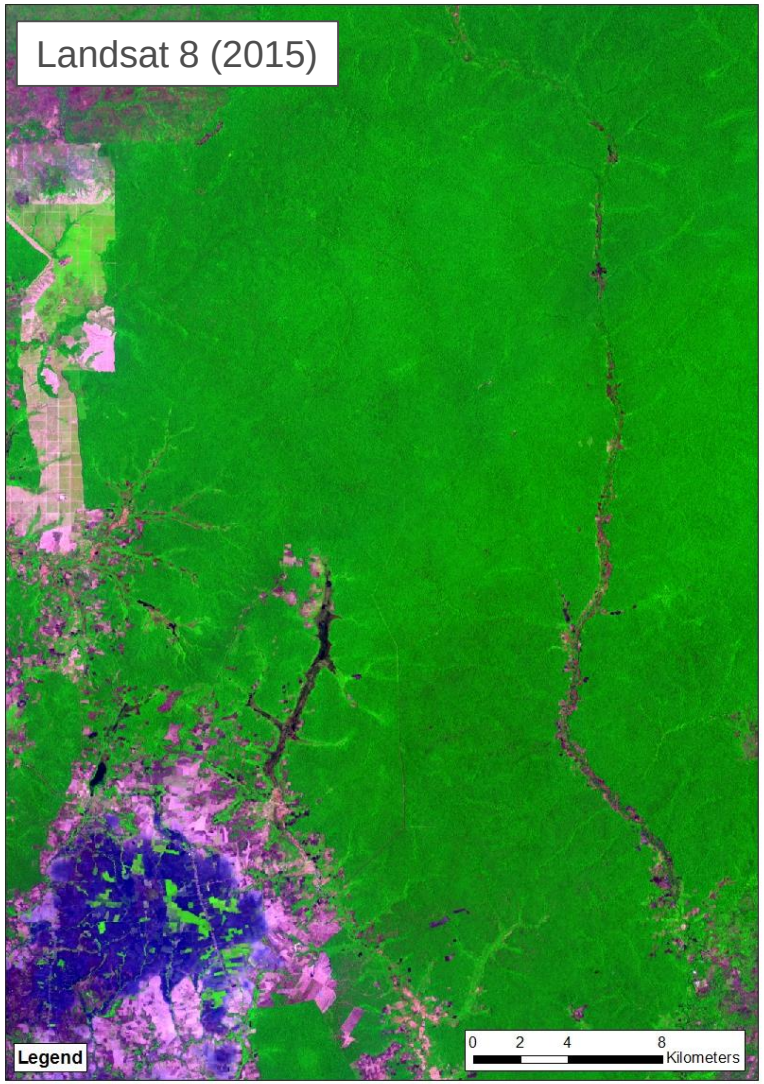
Self-referencing step allows inter-scene comparison

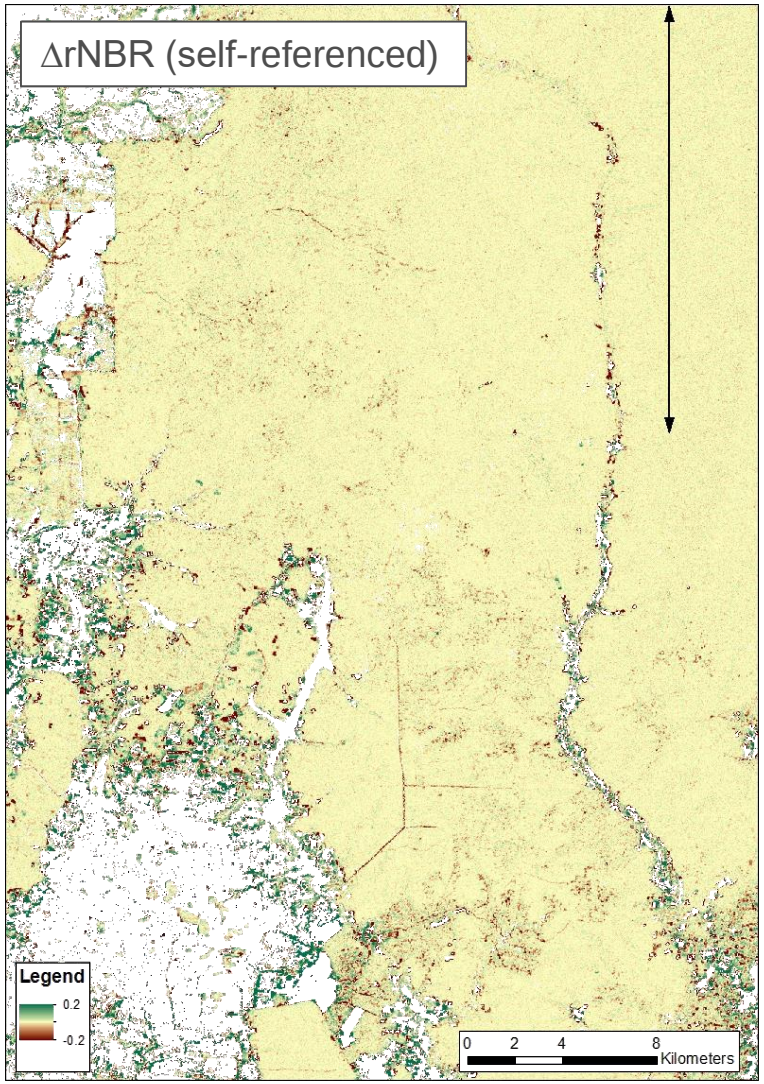
→ Scenes become comparable over space and time

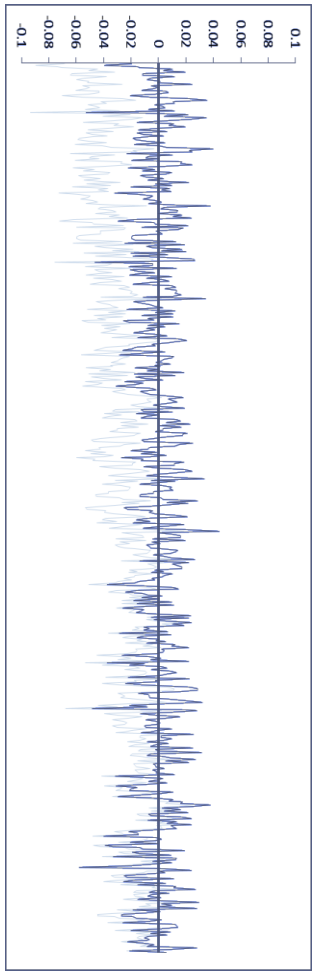
Self-Referencing Step of the FCDM Approach



Self-Referencing Step of the FCDM Approach







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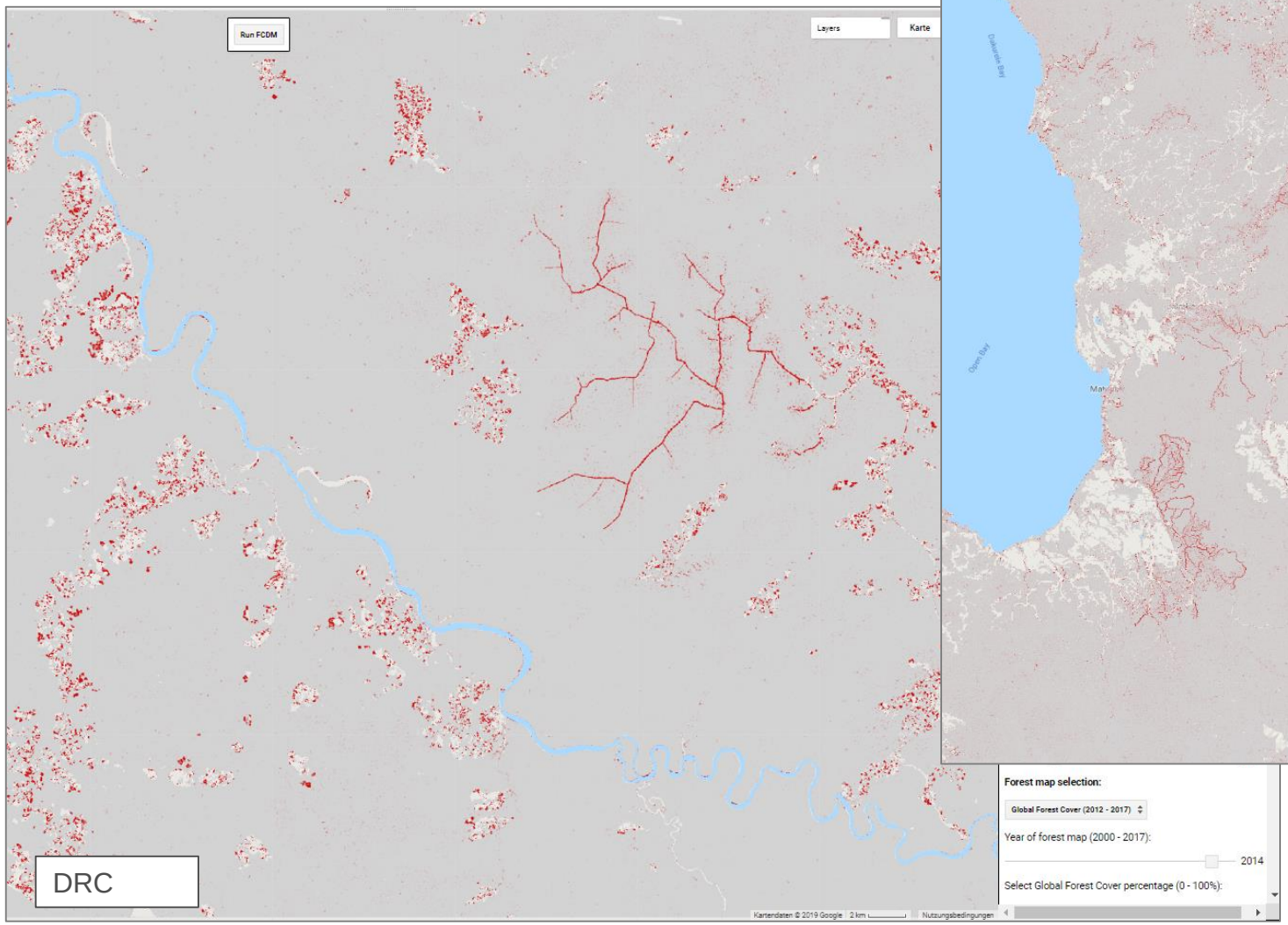
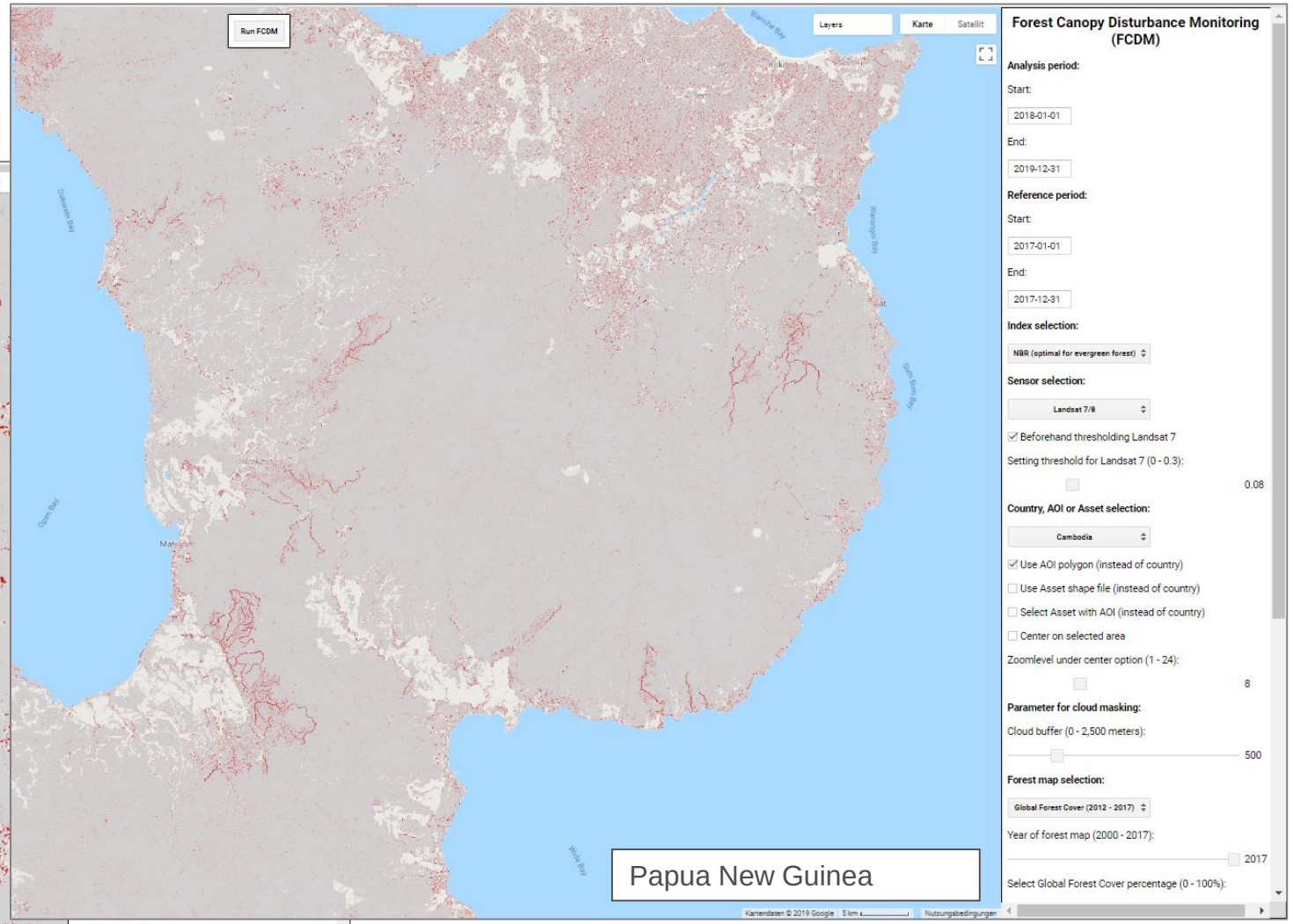
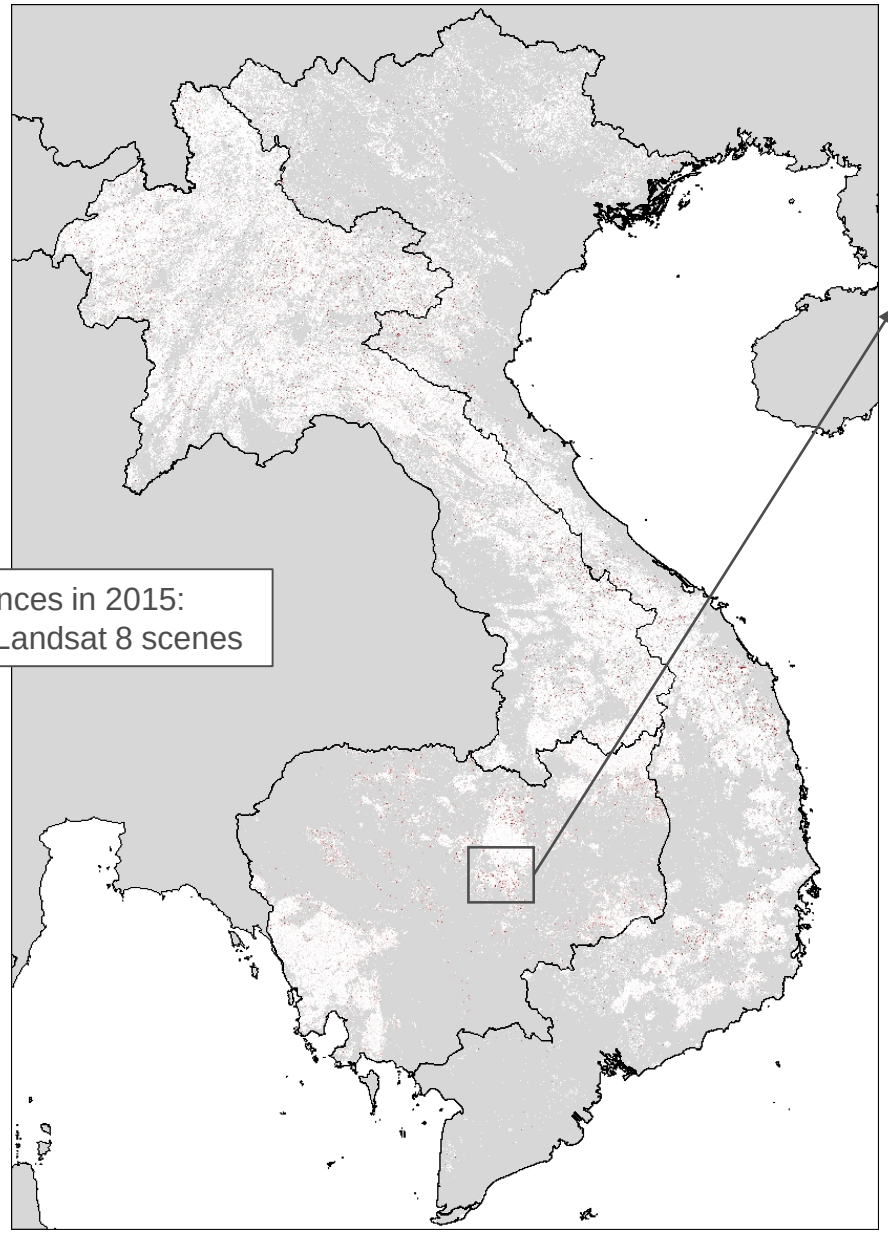
Pan-tropical Applicability of FCDM Approach



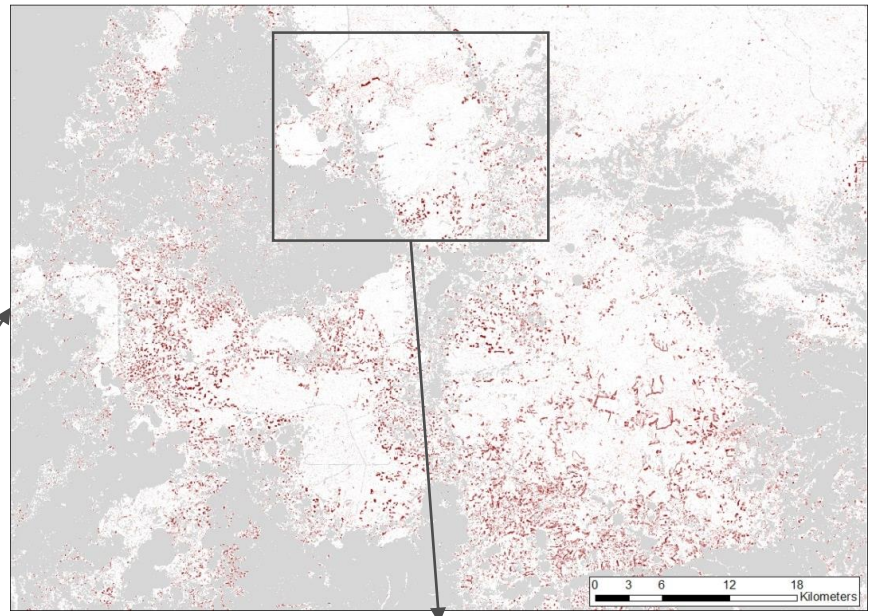


European Commission

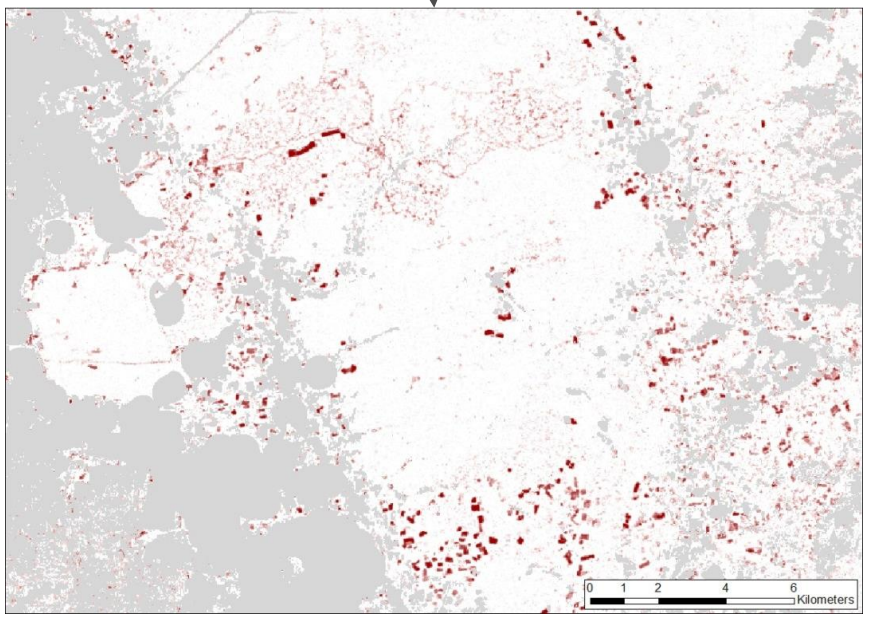
Pan-tropical Applicability of FCDM Approach – Cont. SE-Asia



Disturbances in 2015:
> 3,000 Landsat 8 scenes



Subset



Subset

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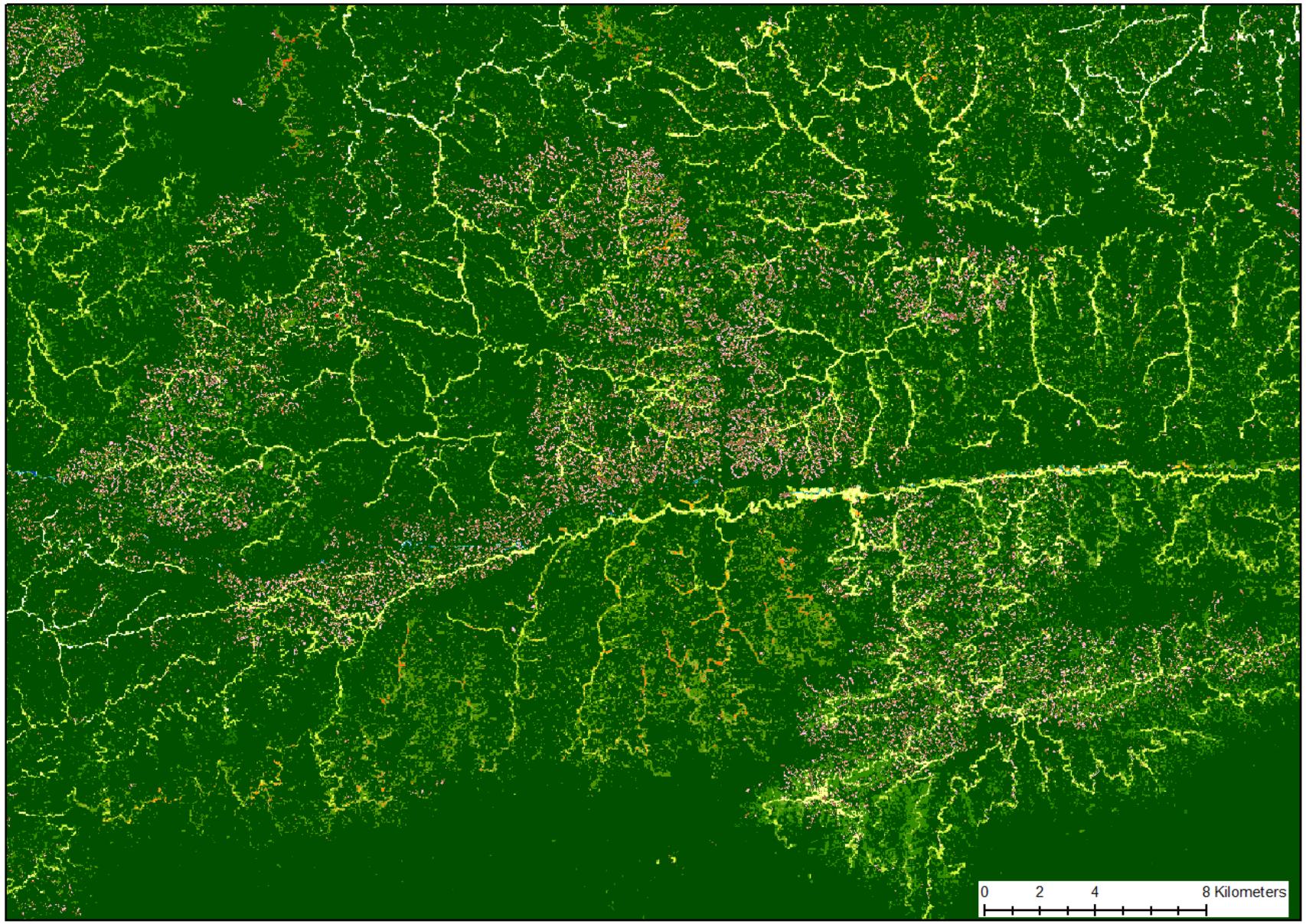
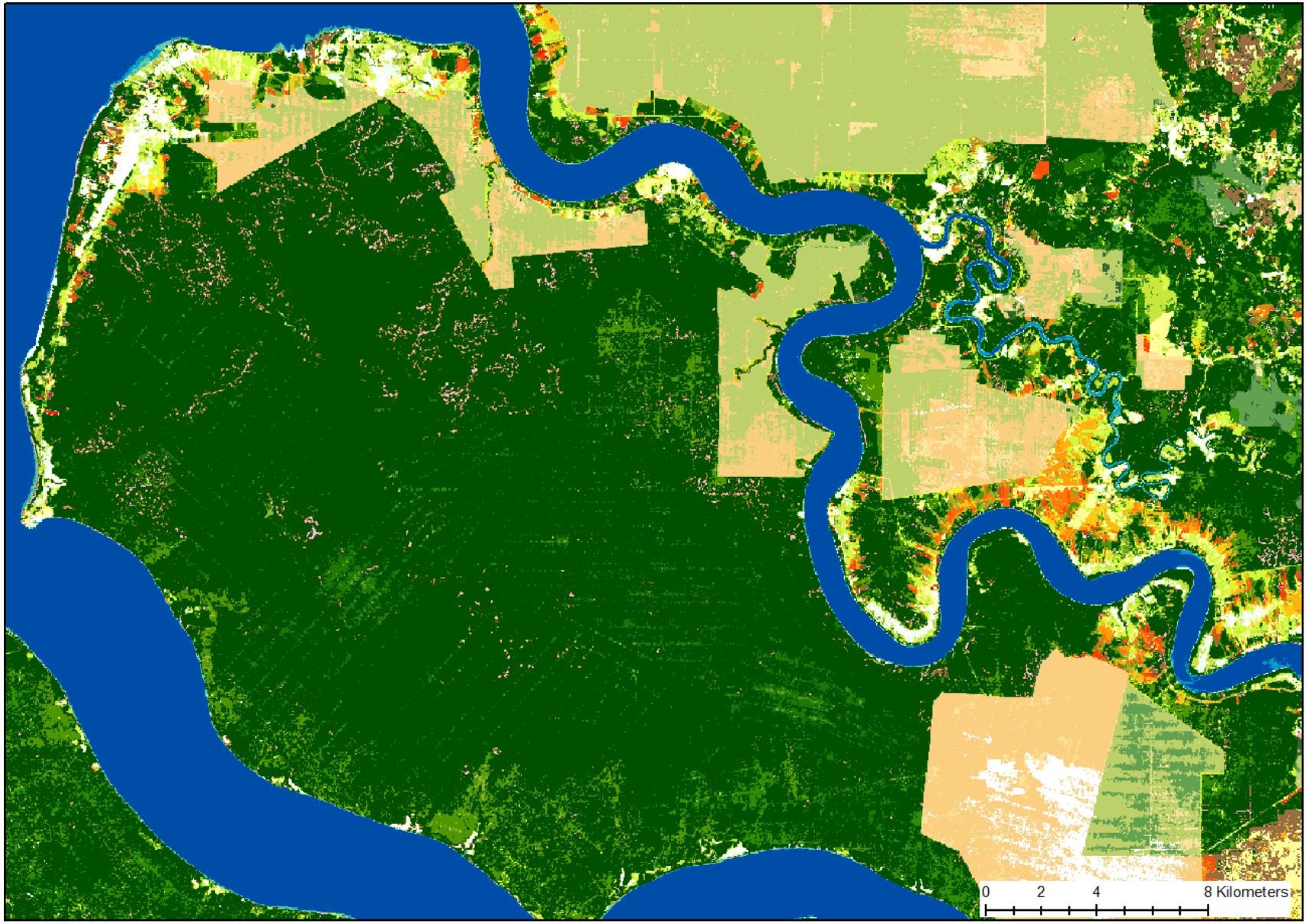
Border Malaysia – Central Kalimantan, Indonesia



FCDM Disturbance
(2016-2017)
+
TMF
(Status 1990-2017)

Maludam National Park (IUCN II) – Sarawak, Malaysia



FCDM Disturbance
(2016-2017)
+
TMF
(Status 1990-2017)

Accuracy Assessment of FCDM (Brazil)

Table 2. Area-adjusted accuracies for the maps of forest canopy disturbance obtained from Landsat 8 (**a**) and Sentinel-2 data (**b**). CE: Commission error, OE: omission error, and OA: overall accuracy.

(a)

Landsat 8

Classification	Undisturbed	Disturbed	Total	User's Accuracy (%)	CE (%)
Undisturbed	0.906	0.035	0.941	96.3	3.7
Disturbed	0.008	0.051	0.059	87.1	12.9
Total	0.913	0.087	1.000		
Producer's accuracy (%)	99.2	59.3			
OE (%)	0.8	40.7			
OA (%)	95.7				

(b)

Sentinel-2

Classification	Undisturbed	Disturbed	Total	User's Accuracy (%)	CE (%)
Undisturbed	0.927	0.023	0.950	97.6	2.4
Disturbed	0.010	0.040	0.050	80.0	20.0
Total	0.937	0.063	1.000		
Producer's accuracy (%)	98.9	63.3			
OE (%)	1.1	36.7			
OA (%)	96.7				

Lima et al. 2019
https://www.mdpi.com/2072-4292/11/8/961/htm

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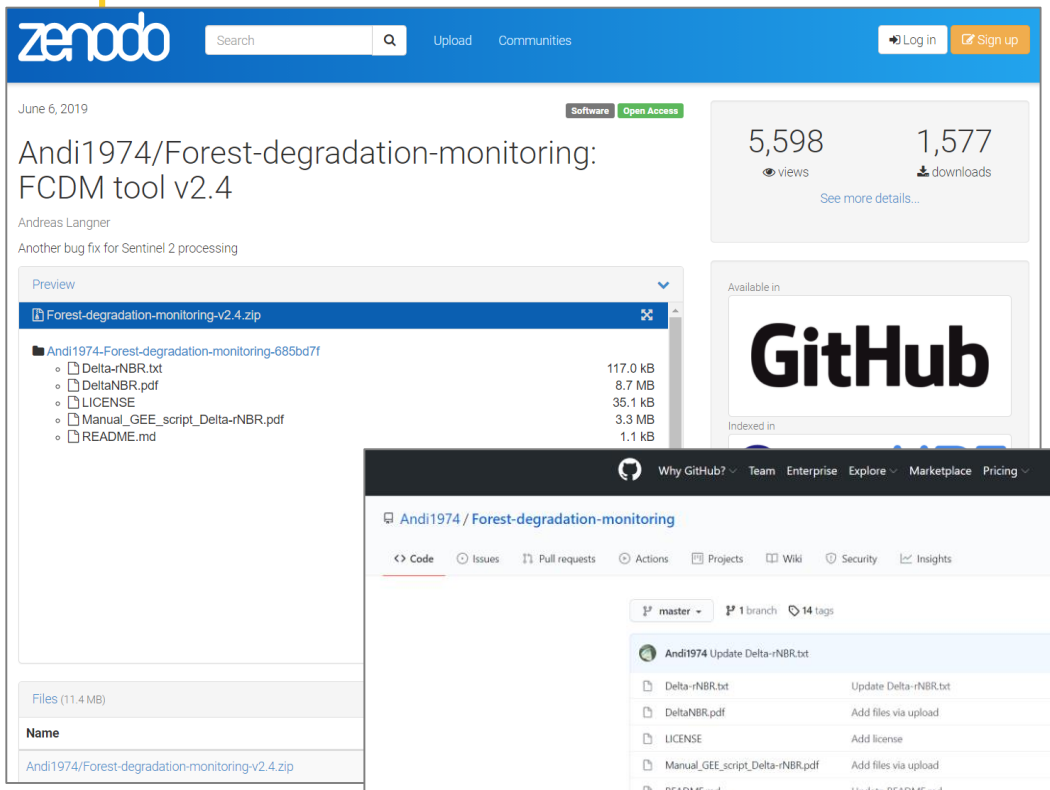
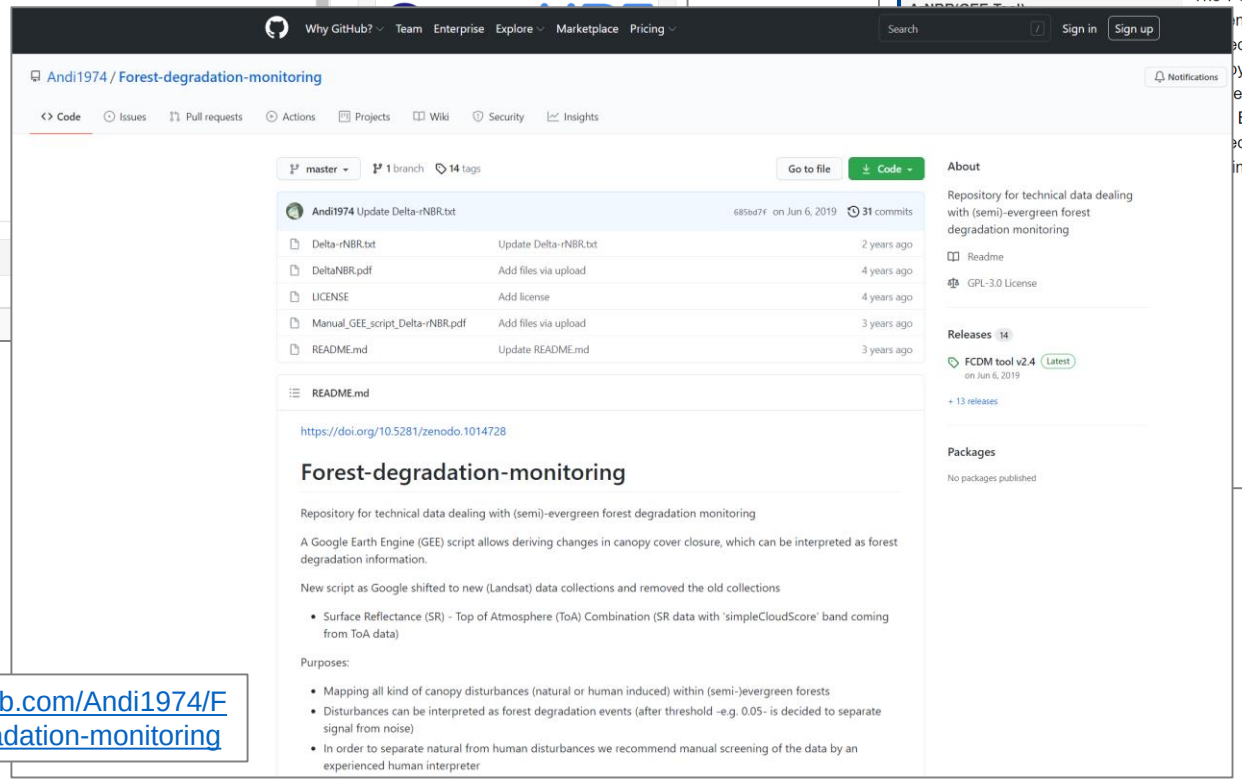
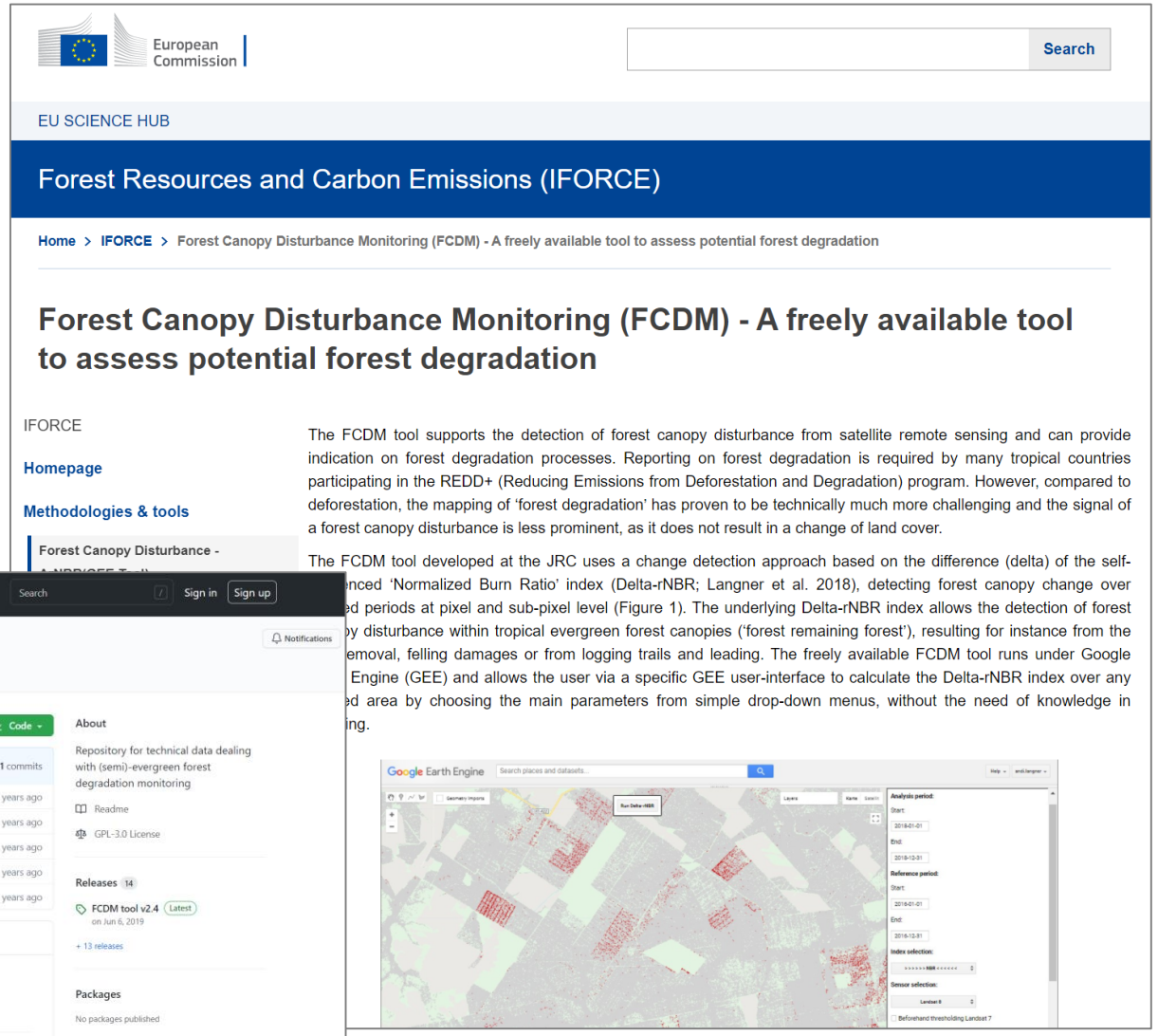
Documentation of FCDM



https://zenodo.org/record/3240021#.YMsoCagzaJY



https://github.com/Andi1974/Forest-degradation-monitoring



https://forobs.jrc.ec.europa.eu/iforce/dNBR.php

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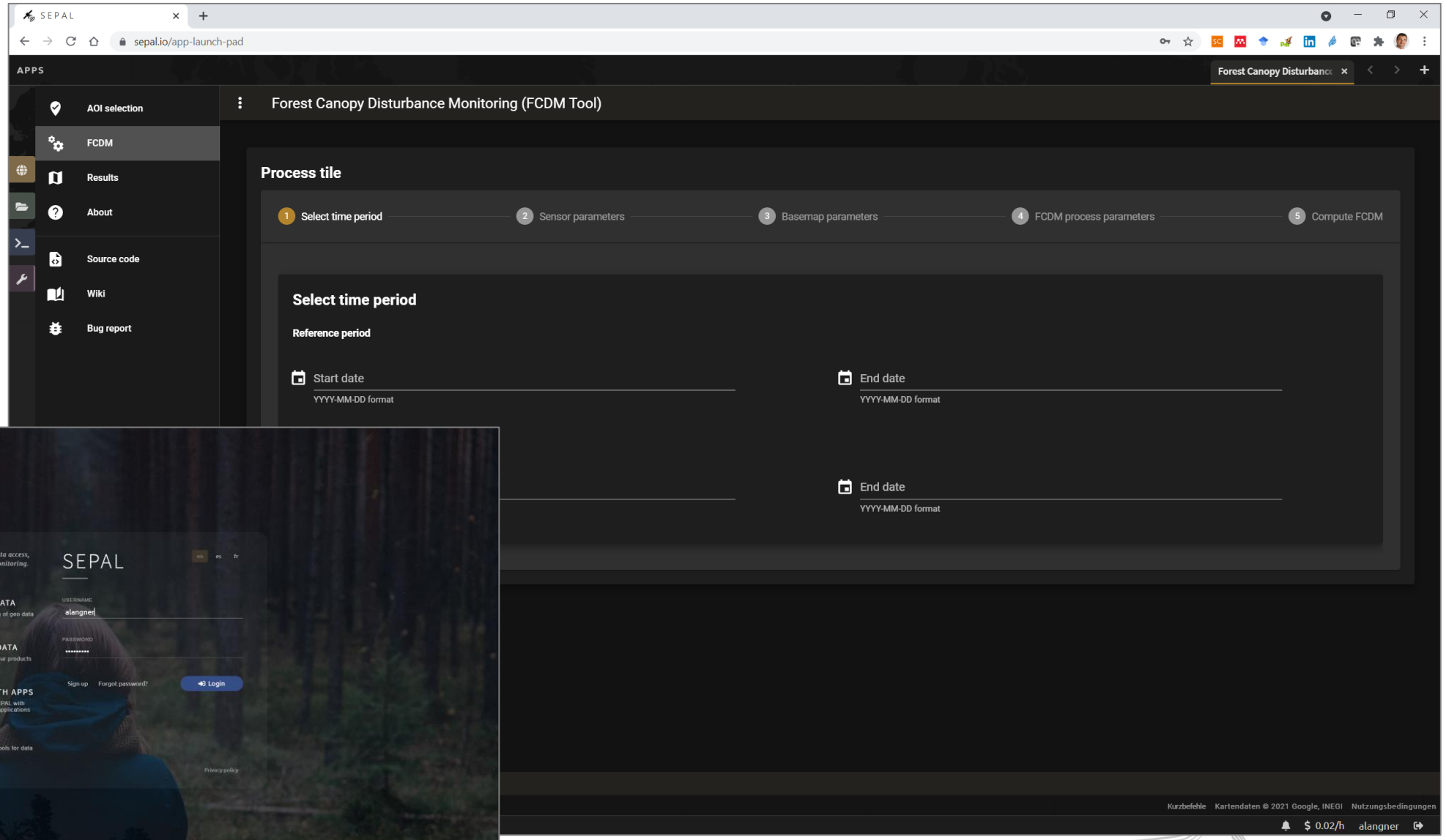
FCDM Implemented on SEPAL Platform



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Application of FCDM

- **Vietnam**:
  - **Forest Inventory and Planning Institute (FIPI)**
- **Laos:**
  - **Department of Forest Inspection (DOFI)**
  - **Forest Inventory and Planning Division (FIPD)** of the Department of Forestry and **F-REDD (JICA Japan)** with **SilvaCarbon (USAID)**
  - **Pro-FLEGT (GIZ Germany)** together with **Aruna Technology**
- **Cambodia:**
  - **General Directorate for Nature Conservation and Protection (GDANCP)** of the **Ministry of Environment (MoE)**
  - **CEEJA project (Copenhagen University, DANMISSION)**
- **Thailand + Myanmar:**
  - **Royal Forest Department (RFD), Department of National Park, Wildlife and Plant Conservation (DNP)** and **Forest Department** (**MoNREF)**
- **Indonesia:**
  - **DG Forest Planning (MEF)** and **DG Climate Change (MEF)**
- **EU Horizon 2020 REDDCopernicus Project** (Brazil, Central Africa, East Africa, SADC, Continental + Insular Southeast Asia)

Ongoing Research/ Developments of FCDM Tool

FCDM Tool

FCDM-optical
(Landsat, Sentinel-2)

Already implemented on SEPAL platform

remote sensing — MDPI

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FCDM-radar
(Sentinel-1)

Publication of FCDM-radar in preparation

→ GEE script will be freely available after publication

→ Possible implementation on SEPAL platform

https://forobs.jrc.ec.europa.eu/iforce/docs/JRC-Technical-Report_Assessment-Cambodia-Prey-Lang-Sanctuary.pdf

JRC TECHNICAL REPORT

Forest encroachments and logging activities within the Prey Lang Wildlife Sanctuary, Cambodia

Assessment of a new monitoring approach: radar-based Forest Canopy Disturbance Monitoring (FCDM-radar)

IGARSS BRUSSELS 2021

FOREST DEGRADATION DERIVED BY A NEWLY DEVELOPED SENTINEL-1 CHANGE DETECTION APPROACH

Andreas Langner, Silvia Carboni

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ABSTRACT

Forest degradation often surpasses the area affected by deforestation and is therefore important under REDD+ monitoring, reporting and verification (MRV). Many studies dealing with forest degradation monitoring require the collection of sample data for algorithm training. The newly developed synthetic aperture radar (SAR)-based Forest Canopy Disturbance Monitoring (FCDM-radar) approach, implemented in Google Earth Engine and processing Copernicus Sentinel-1 data, allows the operational monitoring of evergreen and deciduous forest types without the need of collecting training data for calibration purposes. With a spatial resolution of 10 m it is able to detect small-scale forest canopy disturbance events such as single tree removals of 0.03 ha. Within a study area in central Cambodia (Prey Lang Wildlife Sanctuary), covering evergreen to semi-deciduous forests which are strongly affected by illegal selective logging activities, small-scale forest disturbances were successfully detected with an overall accuracy of 96.3% (user accuracy of 94.0%, producer accuracy of 79.1%).

Keywords: Sentinel-1, SAR, FCDM, forest degradation, deforestation, seasonal forests

1. INTRODUCTION

Compared to deforestation, forest degradation activities can affect similar or even larger areas as has been shown by a recent study for the Brazilian Amazon [1]. So the capacity to correctly monitor forest degradation events is crucial for carbon accounting under the REDD+ scheme (Reducing Emissions from Deforestation and Forest Degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries). Various studies are already available that deal with the technically challenging topic of forest degradation monitoring using satellite remote sensing, thereby using optical as well as radar satellite imagery [2]. Most of them require the collection of sample data to train the algorithm for better performance [3][4][5][6]. Furthermore, many approaches have a restricted sensitivity for detecting especially small-scale events [7][8]. This is not the case for the newly developed Forest Canopy Disturbance Monitoring (FCDM)-radar approach, which is implemented in a Google Earth Engine script processing Copernicus Sentinel-1 radar data [9]. This new approach has been developed to overcome the restrictions of the publicly available FCDM-optical approach [10][11], which is limited to monitoring forest disturbances within evergreen forests. The FCDM-radar approach can be applied without prior knowledge of the analyzed forest type or disturbance regime.

2. STUDY SITE AND DATA

The newly developed monitoring approach was tested within the Prey Lang Wildlife Sanctuary, situated in the central plains of Cambodia. The sanctuary has a total size of 431,683 ha of which a large share is still covered by natural forests [9].

Two periods from January 2018 – February 2019 (referred as the 2018 result) as well as from March 2019 – February 2020 (referred as the 2019 result) have been analyzed with the FCDM-radar tool using 544 and 719 Sentinel-1 (S1) scenes respectively.

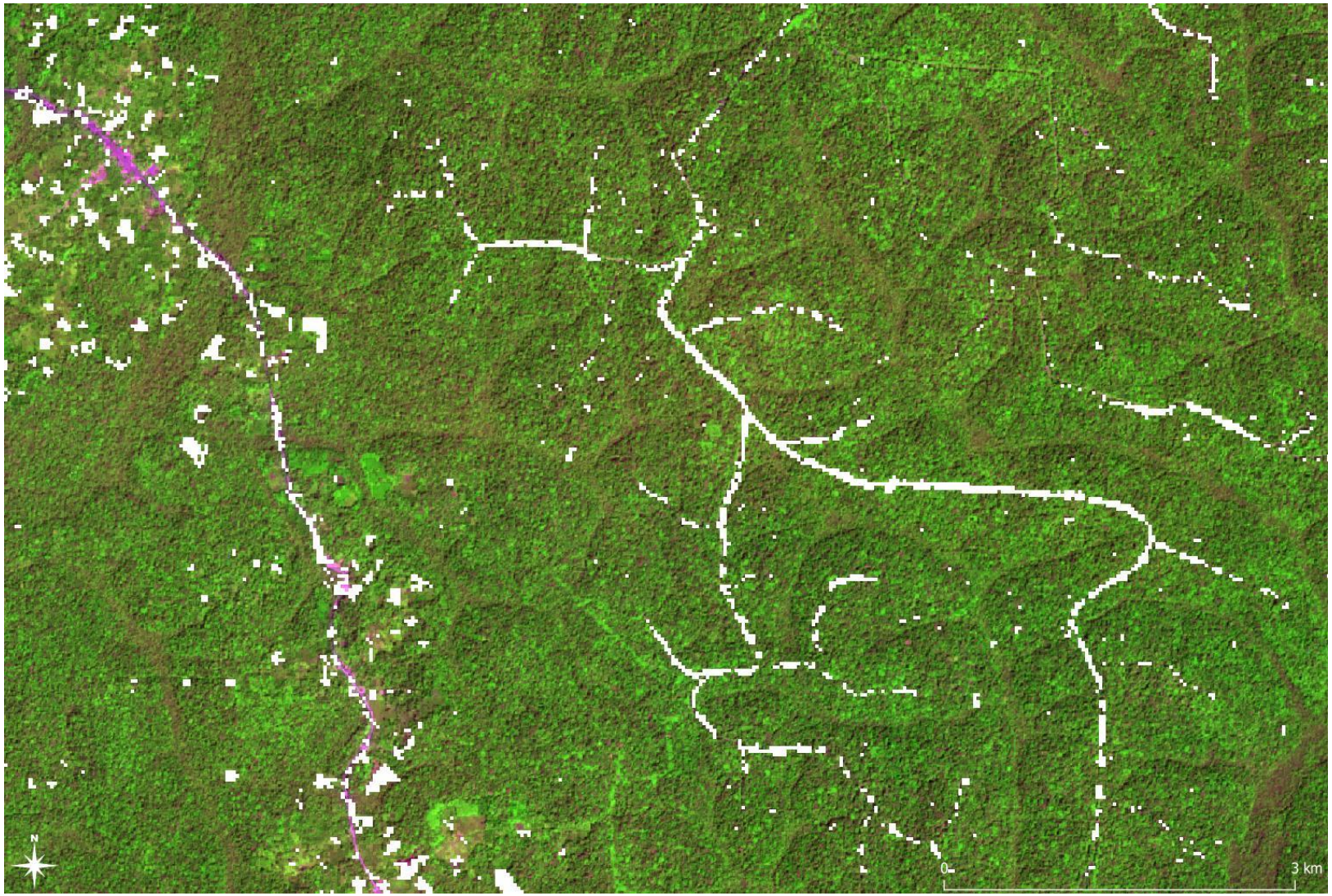
Sentinel-2 (S2) imagery was used for validation purposes but also for deriving a forest mask that combines seasonal and non-seasonal forests [9].

3. METHODOLOGY

According to [3] deforestation events cause a short-term (4-6 months) decrease in C-band SAR backscatter. Basic concept of the FCDM-radar methodology, which is working with S1 C-band data (Interferometric Wide (IW) swath mode in dual polarization VV and VH at 10 m spatial resolution), is a change detection approach between an analysis and a reference period that is able to identify the SAR backscatter drop, thus allowing to screen for changes in the forest canopy cover.

The FCDM-radar approach itself consists of four steps: (1) The backscatter signal of the forest canopy is normalized by the average scene backscatter and temporally filtered in order to make scenes comparable to each other and to remove sensor noise. (2) Subtracting the reference period from the analysis period derives the delta of the SAR backscatter

Comparison between FCDM-optical and FCDM-radar



Cameroon:
Analysis period:
01.01.2020 – 31.12.2020

- Planet data (01.12.2020)
- FCDM-optical (L7/ L8) 2020

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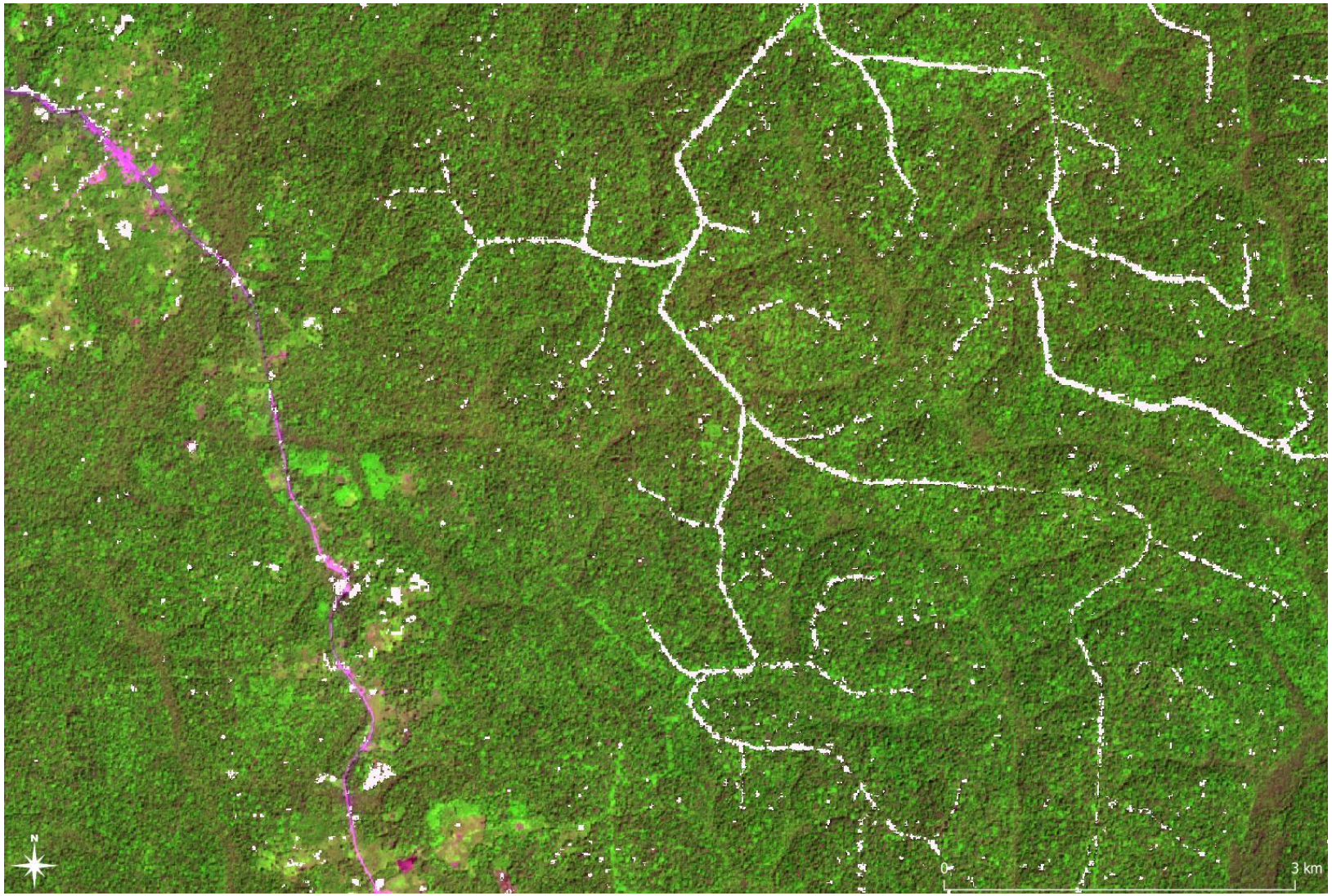
Comparison between FCDM-optical and FCDM-radar



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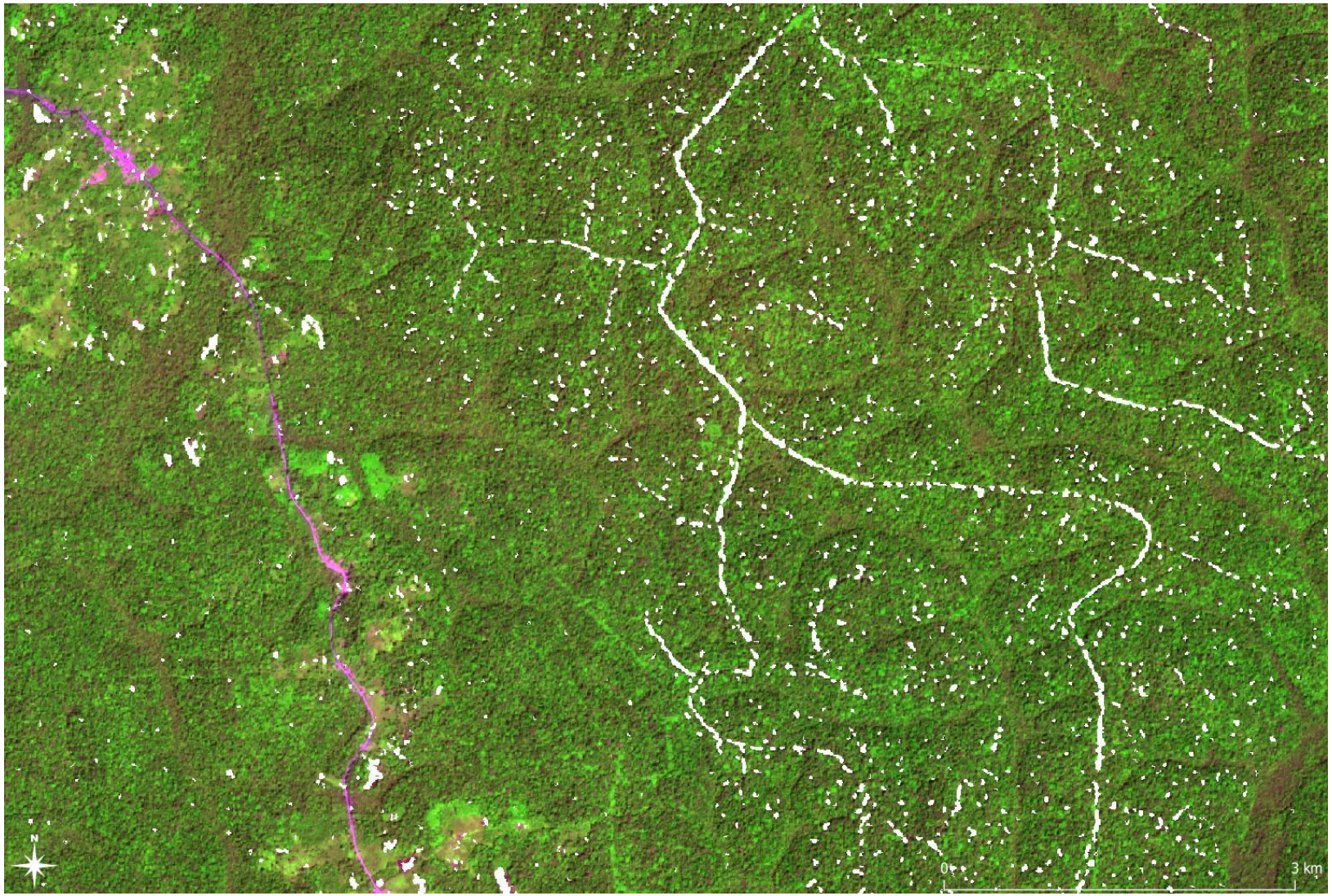

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- Planet data (01.12.2020)

- FCDM-optical (L7/ L8) 2020
- FCDM-optical (S2) 2020
- FCDM-radar (S1) 2020

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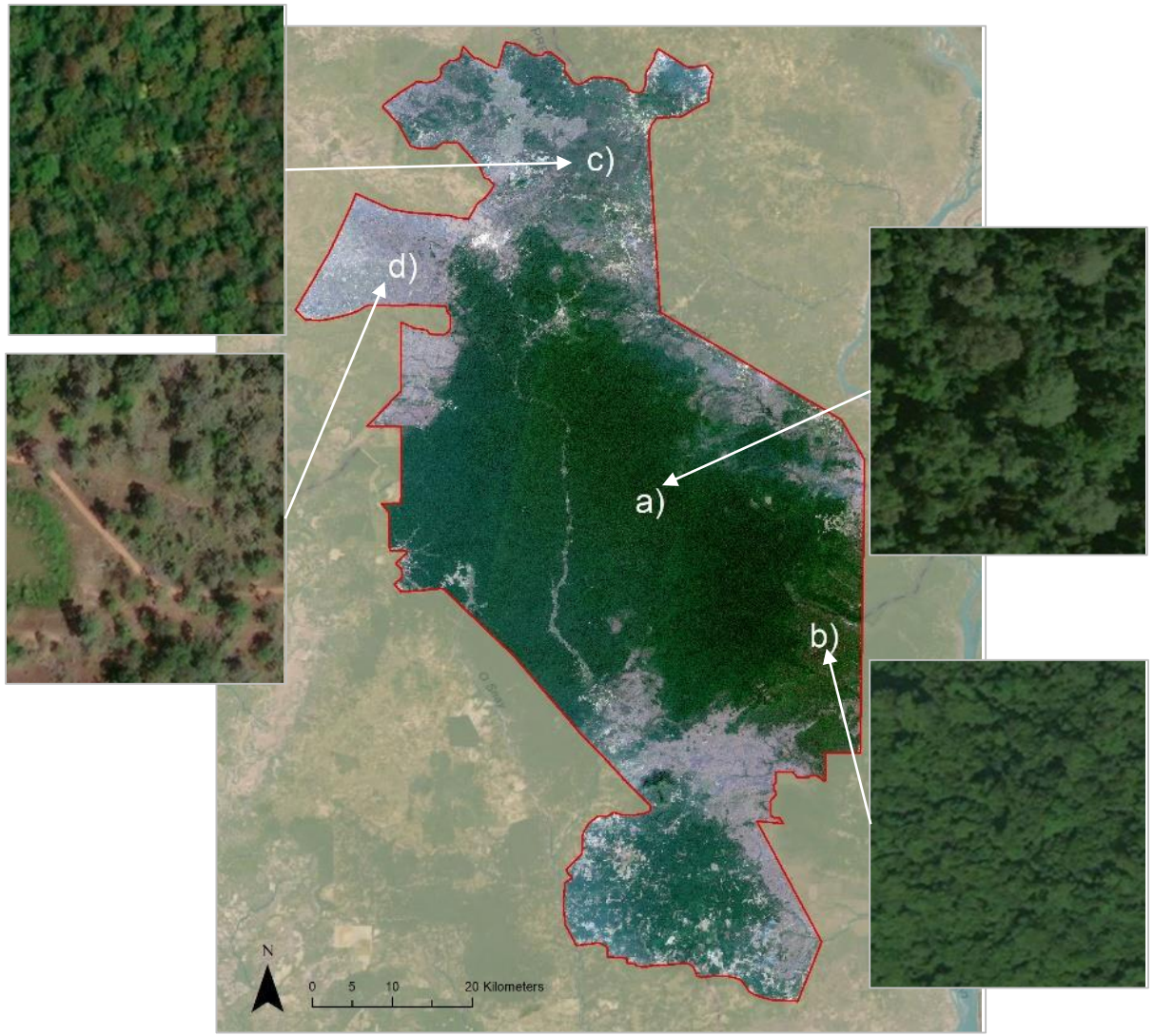
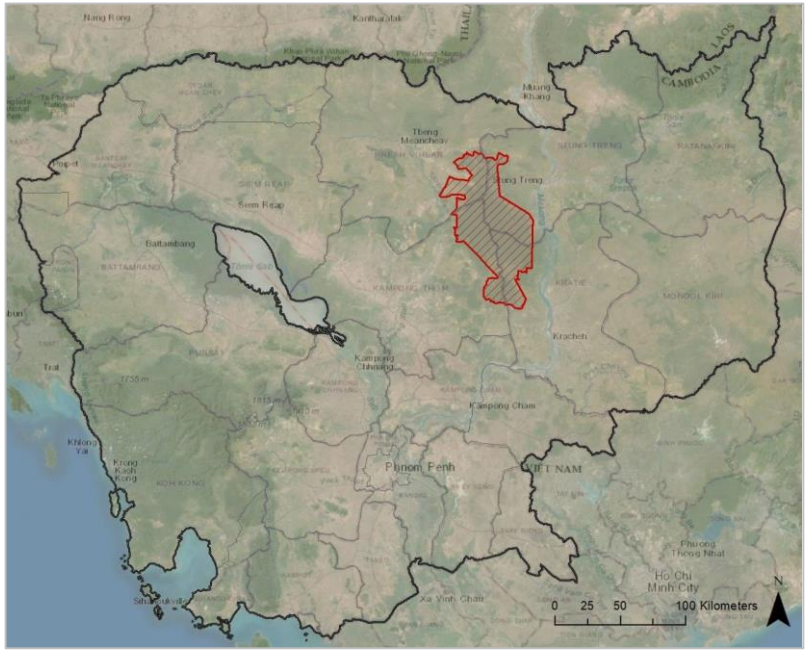
Comparison of FCDM with Other Monitoring Approaches – Example of Prey Lang, Cambodia





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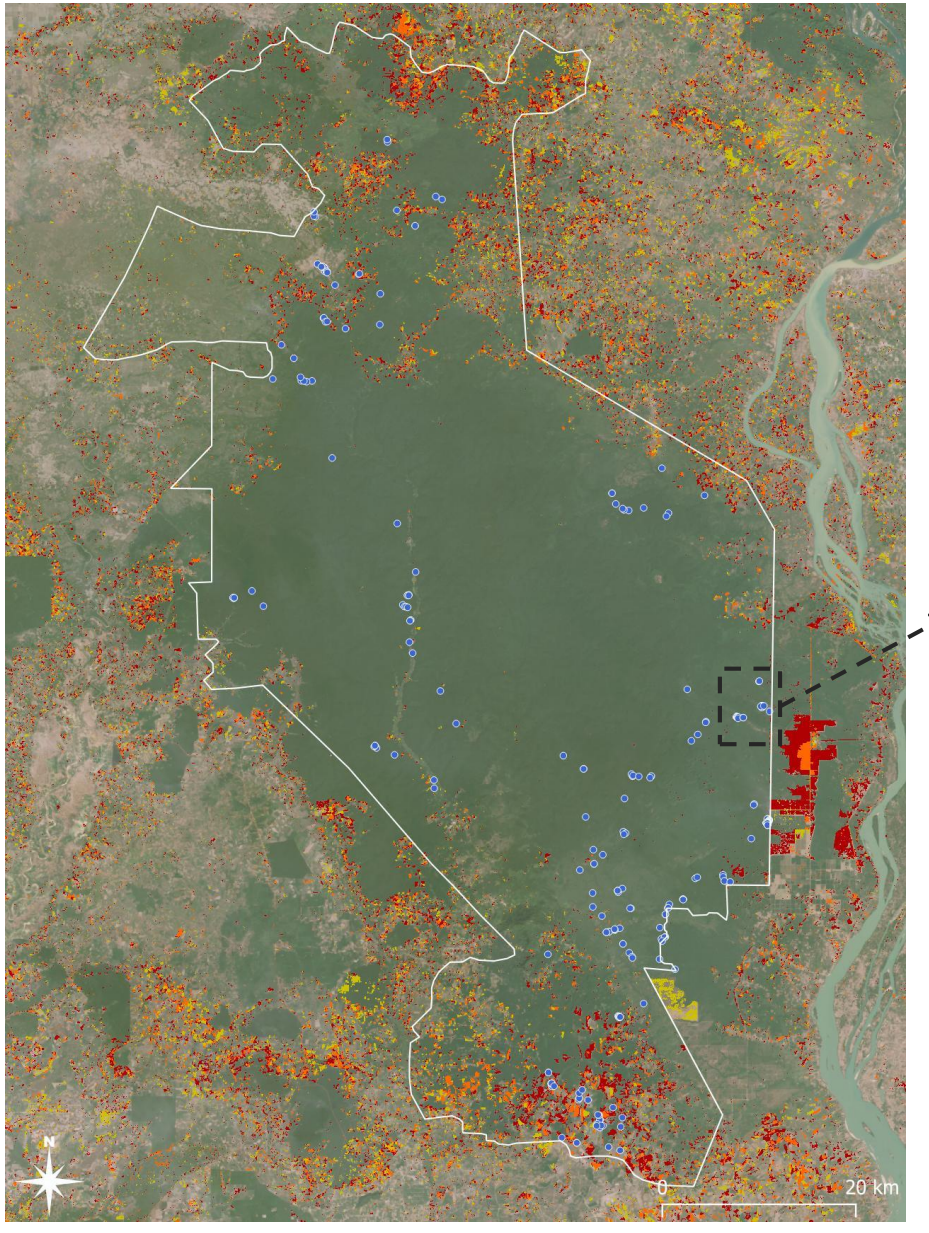
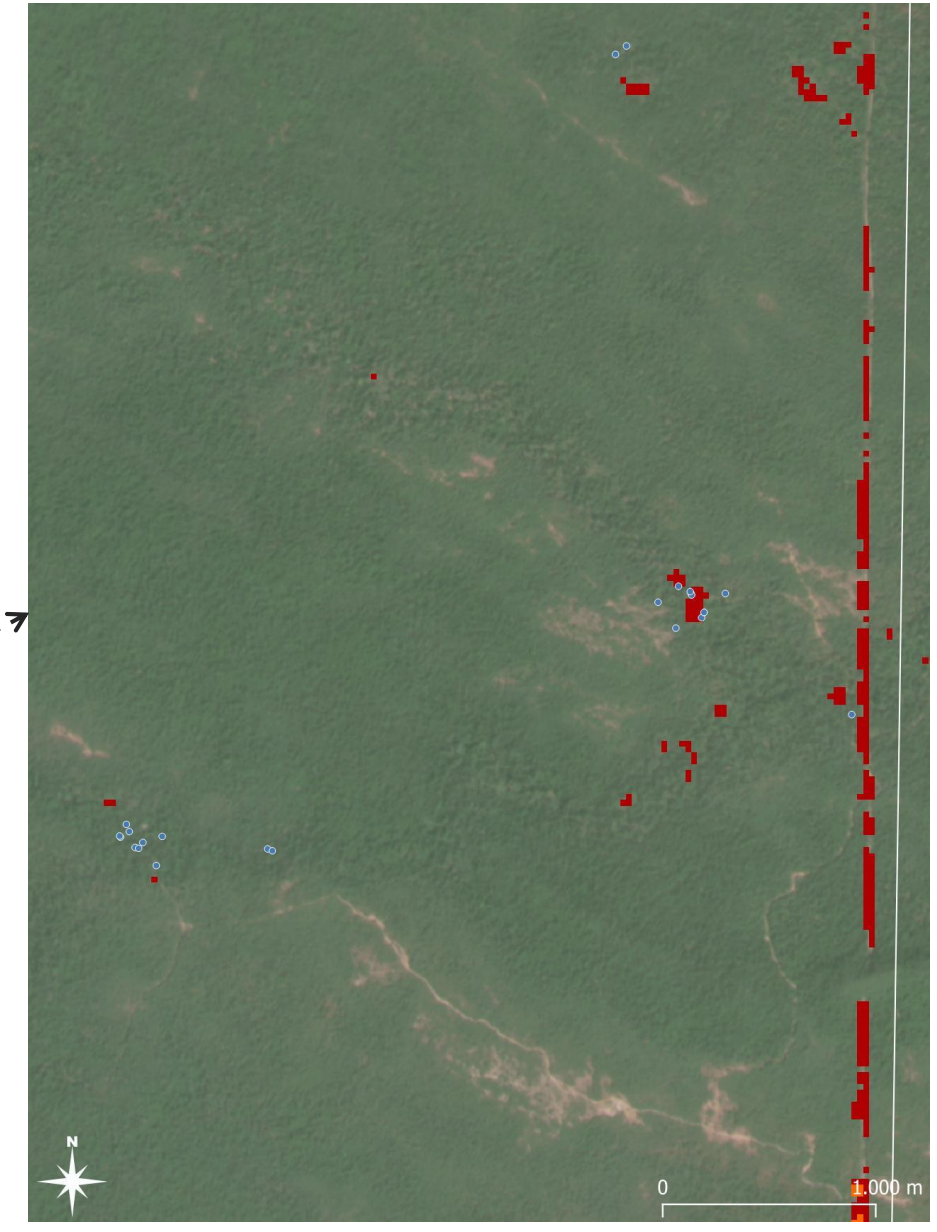




- Planet data (12.2020)
- Field plots (2018-2020) (thanks to PLCN)

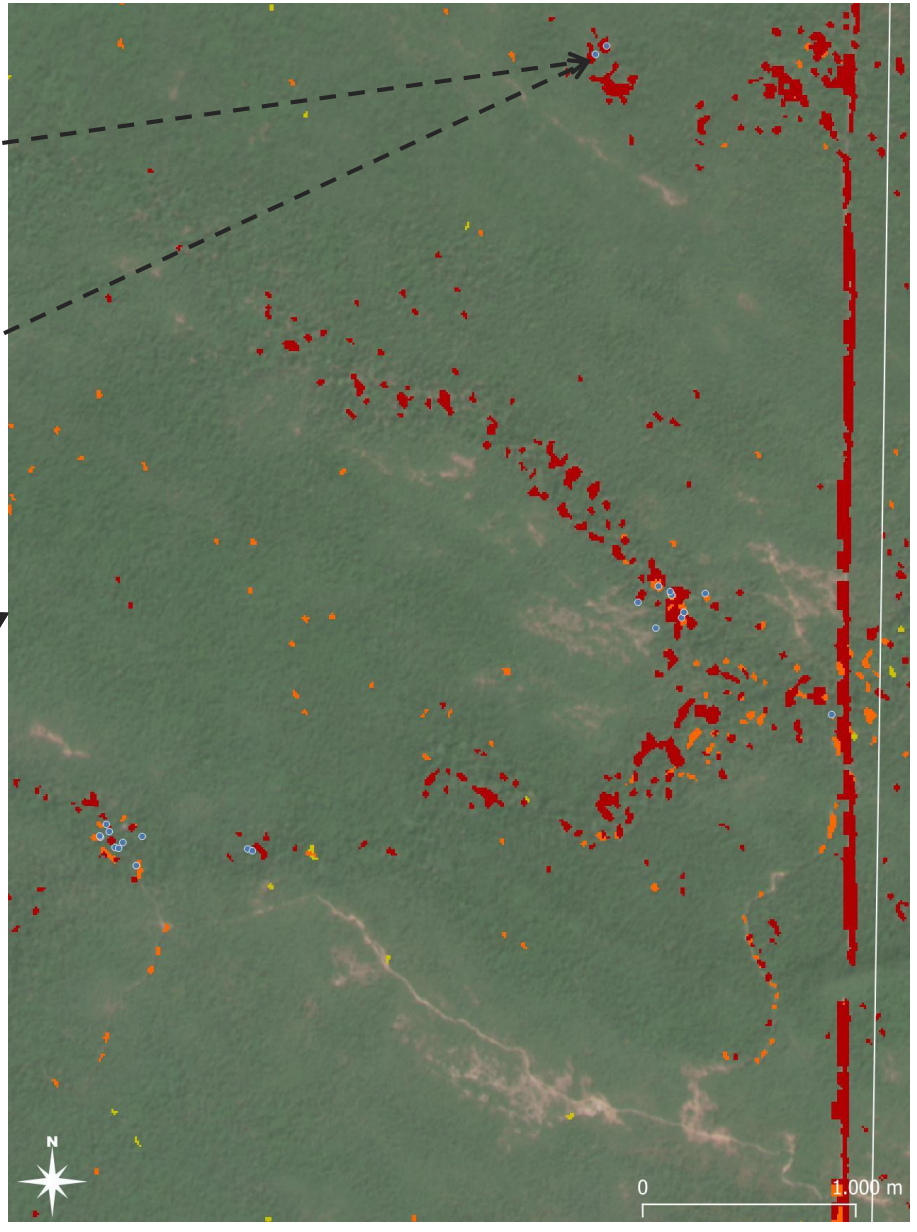
- GFW (2018-2020)
- GLAD (2020)

18
19
20

GLOBAL FOREST WATCH

European Commission

Comparison of FCDM with Other Monitoring Approaches – Example of Prey Lang, Cambodia



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18
19
20

GLOBAL FOREST WATCH

- FCDM-radar (2018-2020)

18
19
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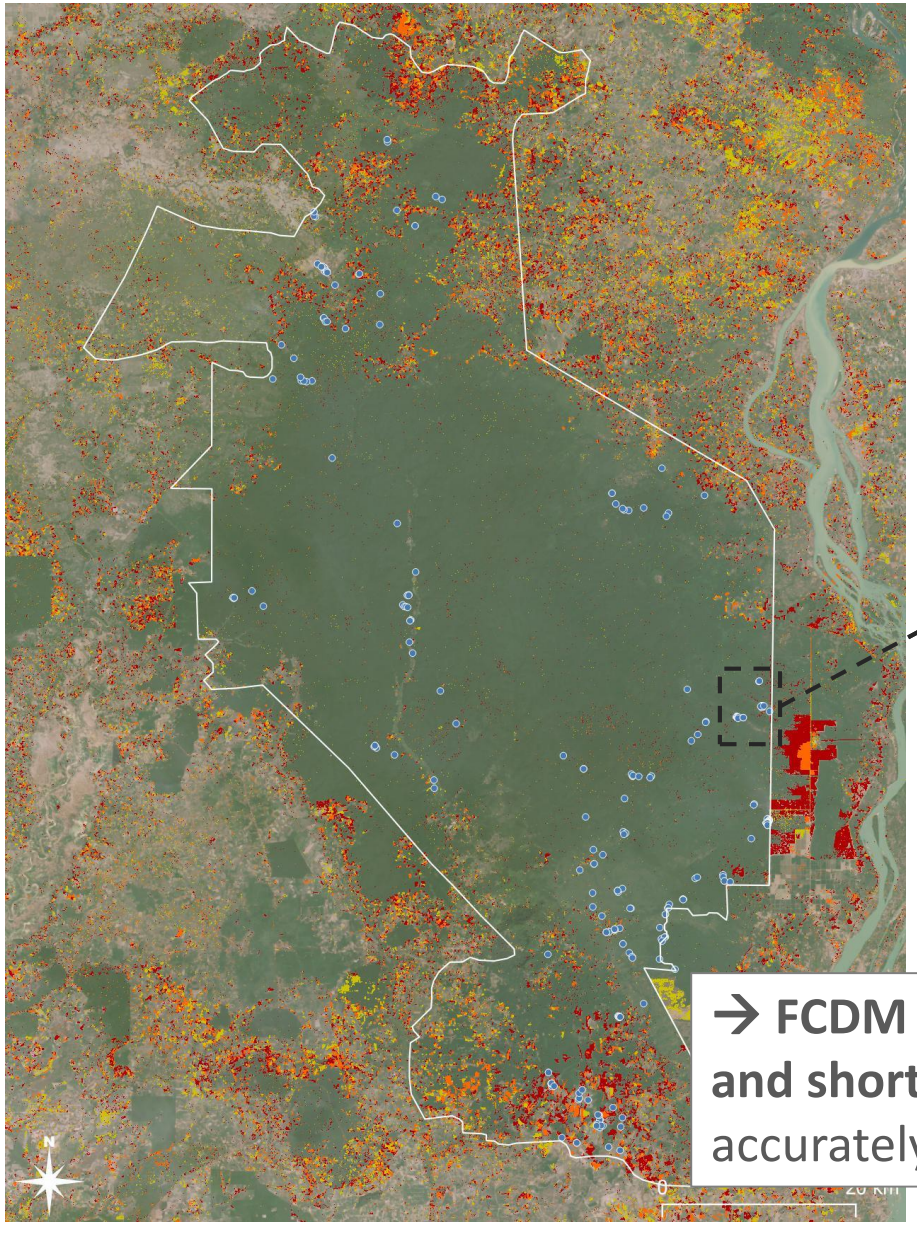
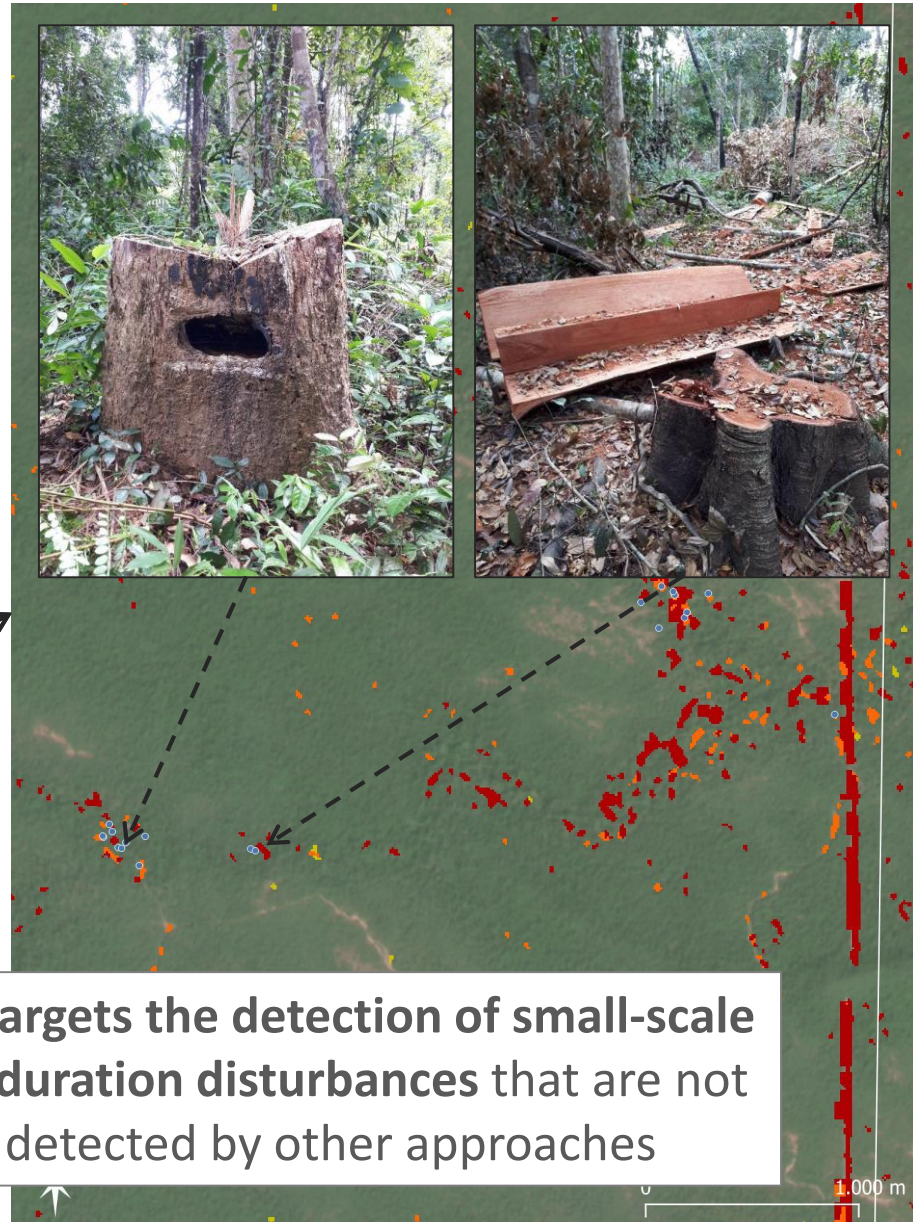
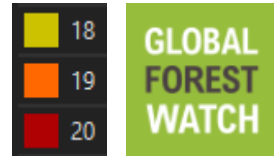
Comparison of FCDM with Other Monitoring Approaches – Example of Prey Lang, Cambodia



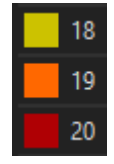


- Planet data (12.2020)
- Field plots (2018-2020) (thanks to PLCN)

- GFW (2018-2020)
- GLAD (2020)



- FCDM-radar (2018-2020)



→ **FCDM targets the detection of small-scale and short duration disturbances** that are not accurately detected by other approaches

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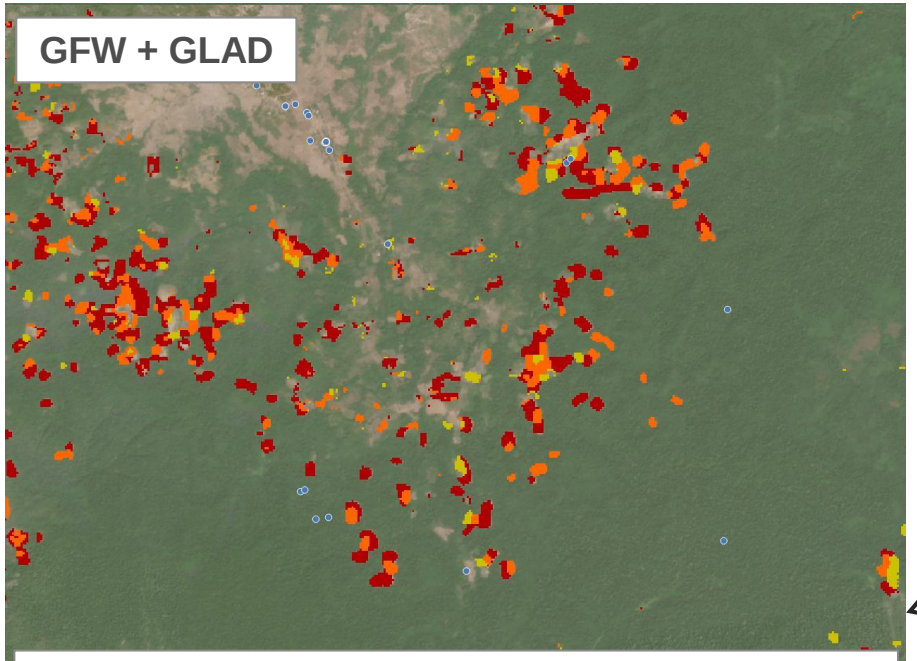
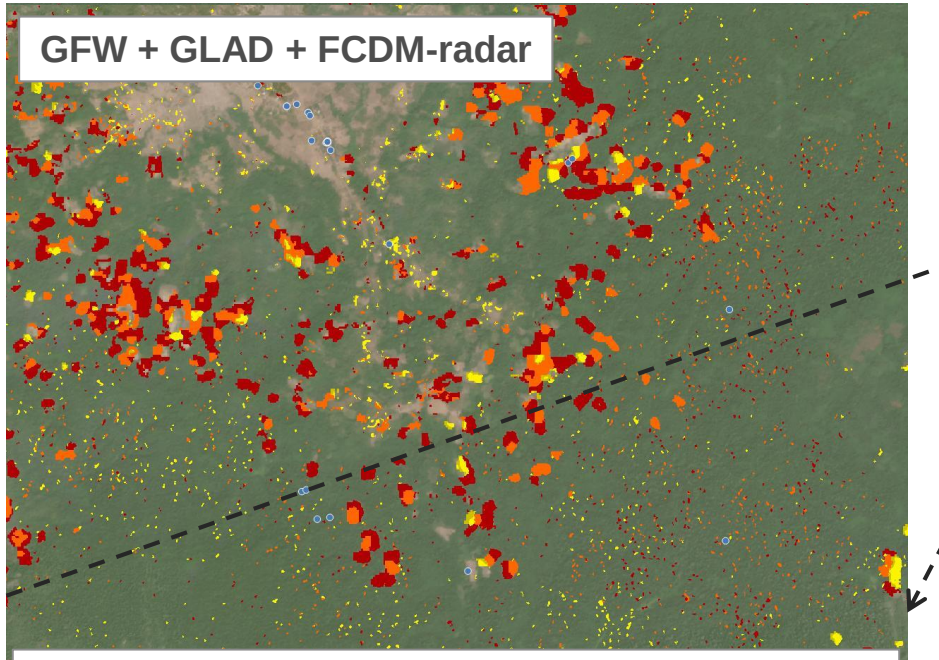
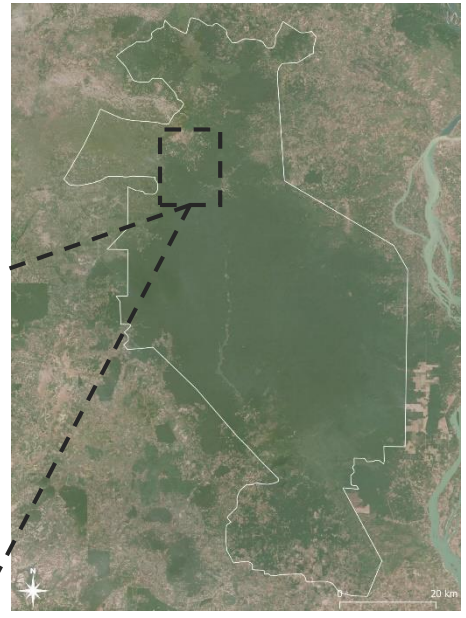
Synergistic Effects by Combination Monitoring Approaches







Disturbance area based on GFW+GLAD

2020: 9,992 ha (without area-correction)

Disturbance area based on GFW+GLAD+FCDM

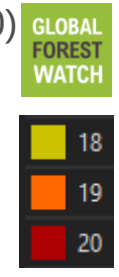
2020: 13,194 ha (without area-correction)
→ **increase of overall detections by 32%**

TAKE HOME MESSAGES:

→ **FCDM-radar monitoring approach allows properly detecting even small-scale disturbances**

→ **Detection of small-scale disturbances is essential as their average biomass is expected to be higher than the average biomass of a clear-cut event** (to be confirmed)

- Planet data (12.2020)
- GFW (2018-2020)
- GLAD (2020)
- FCDM-radar (2018-2020)
- Field plots (2018-2020) (thanks to PLCN)



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Conclusion

FCDM approach has capacity to detect forest disturbances/ degradation

- Change detection approach is sensitive to small-scale and/ or weak signal (e.g. removal of single trees)

- Change detection approach analyzes every available image over analysis period → Detection of even short-term disturbances
- **Spoiler alert for radar-based approach:**
  - Radar-based approach allows monitoring independent of cloud coverage (supporting BFAST in areas of frequent cloud coverage)
  - Radar-based approach allows differentiation between seasonal changes and actual disturbance events