Mapping the Tropical Moist Forests Extent Based on Combination of Sentinel-1 and Sentinel-2 Satellites

Author: Sourav Karmakar

Supervisor: Prof. Pierre Defourny

Co-supervisor: Baptiste Delhez

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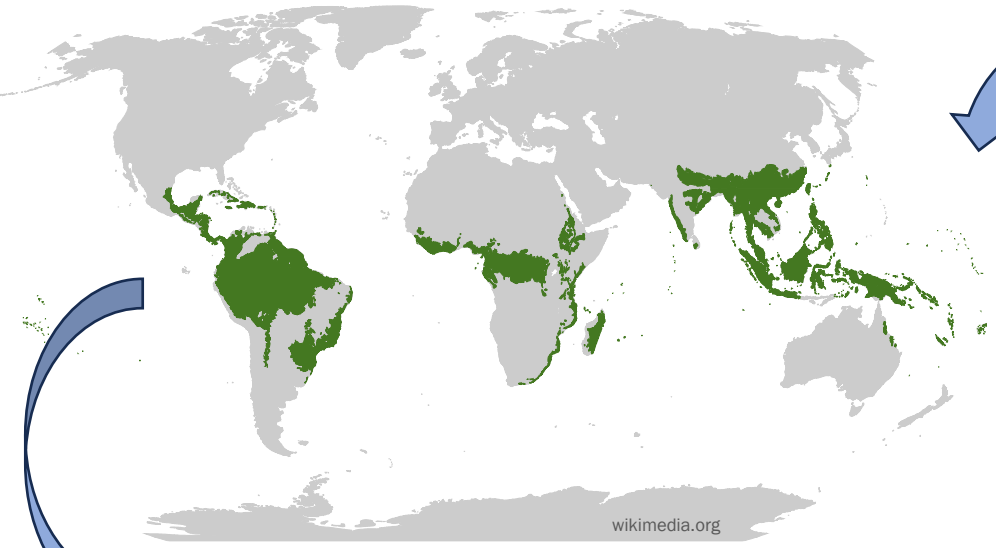
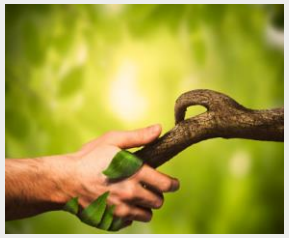
Tropical Moist Forests



Services:

Carbon storage
30% of total tree cover, 50% global tree carbon

Biodiversity
7% land cover, 50% biodiversity



Livelihood
80 million people at Congo basin

Threats:

Population growth

Agricultural expansion of commodities

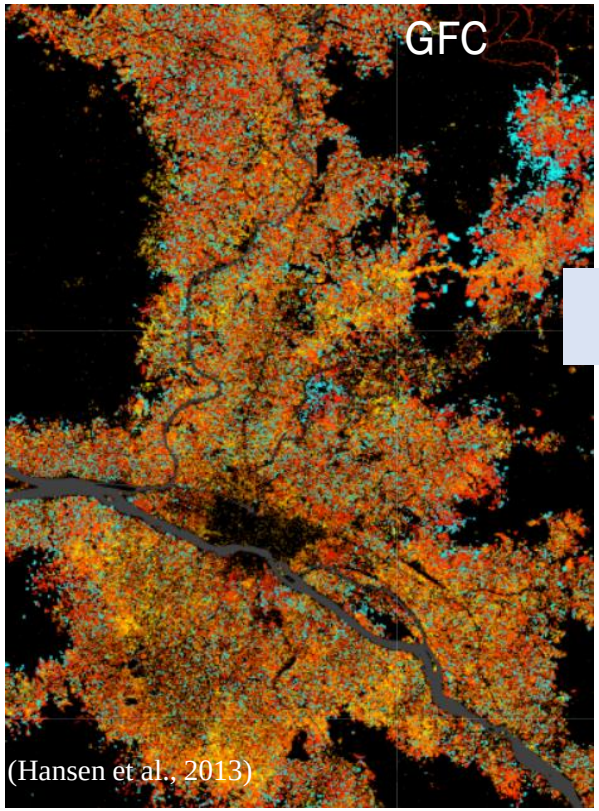
Shifting cultivation

Mining activities

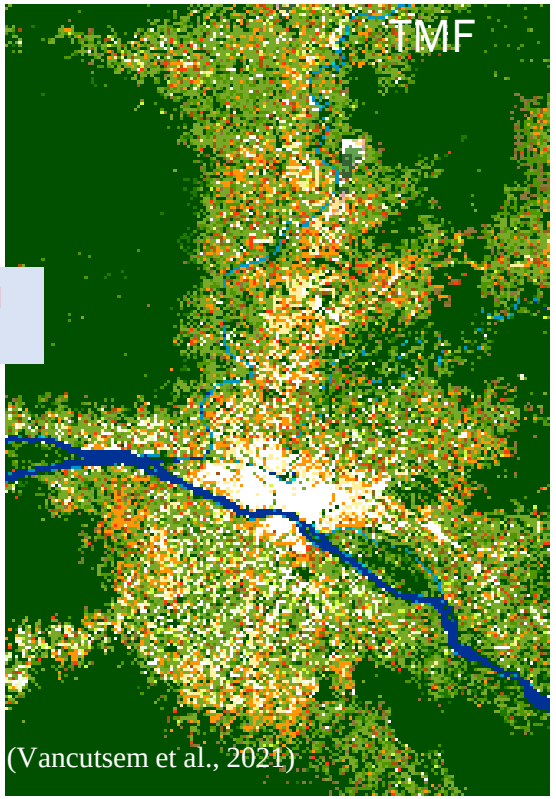
2000-2014: Congo basin TMF has lost 16 million Ha forest

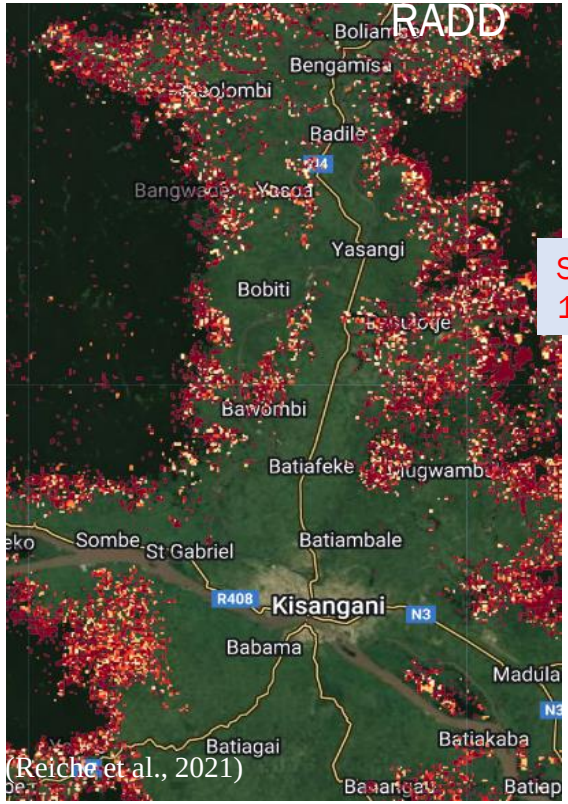
Operational products of monitoring tropical moist forest

Three best products in the research



Optical
30 m





SAR
10 m

Global Forest Change

University of Maryland
Coverage: **2000-2021**
Band: 'loss year'

Tropical Moist Forest

EC JRC
Coverage: **1990-2022**
Bands: deforestation year, degradation year

Radar for Detecting Deforestation

Wageningen University
First publicly accessible 10m radar product
Coverage: **2019-latest S1 image**

But they do not agree at landscape level

Purpose of the study

Develop forest extent map considering an adaptive method of combining optical and SAR data at the landscape level

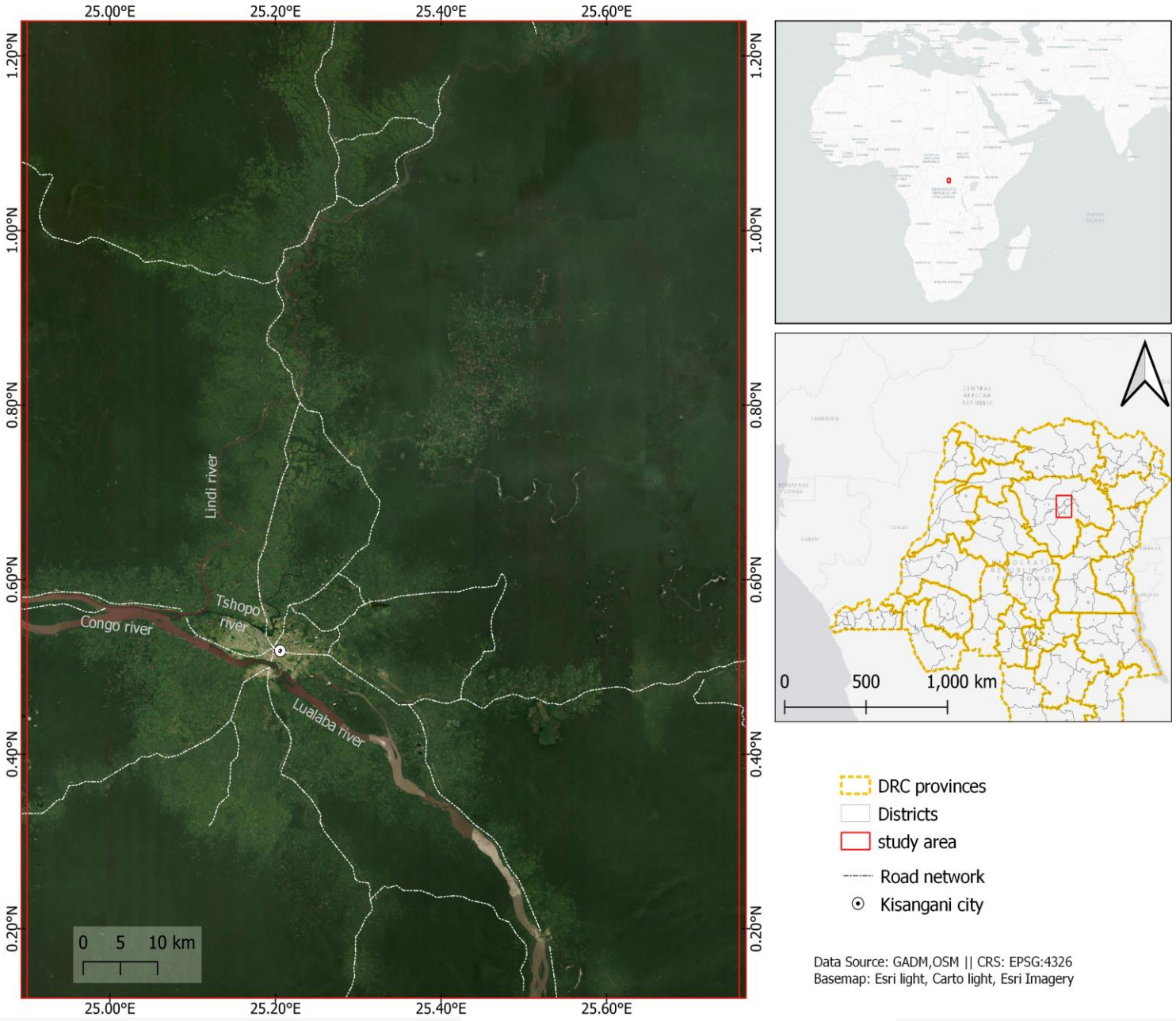
- Assessing the **performance of optical and SAR products** to determine the most effective deforestation product at landscape level

- Producing a **forest extent classification map** from high-resolution satellite data building on the comparison at landscape level

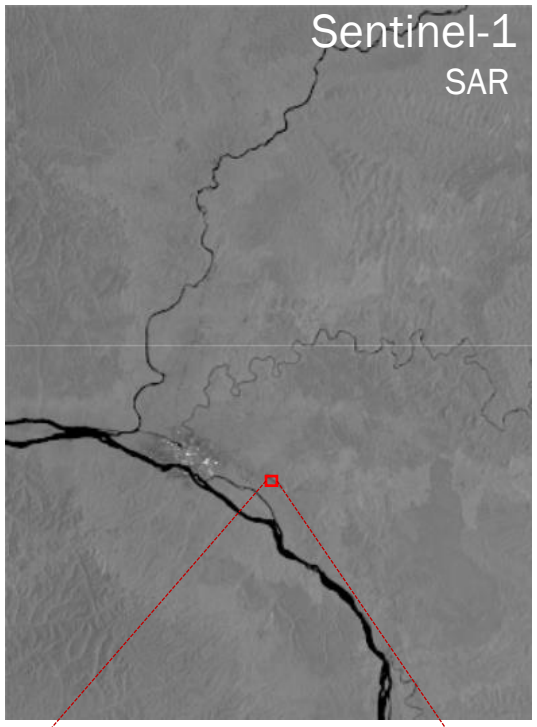
Study area

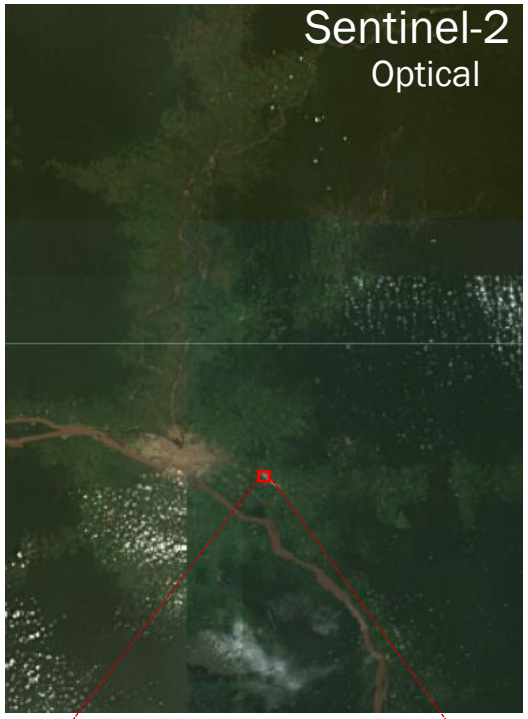
Tshopo province, Democratic Republic of Congo

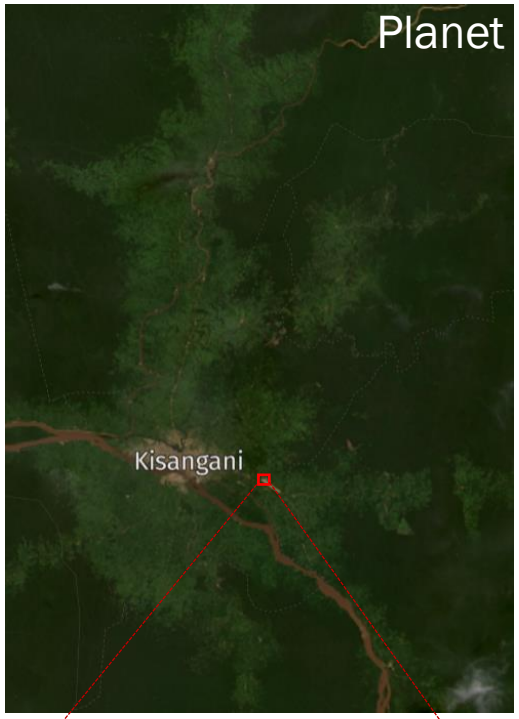
- 90% forest area
- Commercial hub
- 2001-2021: **296 Kha** Tree cover loss (20*Brussels region size)



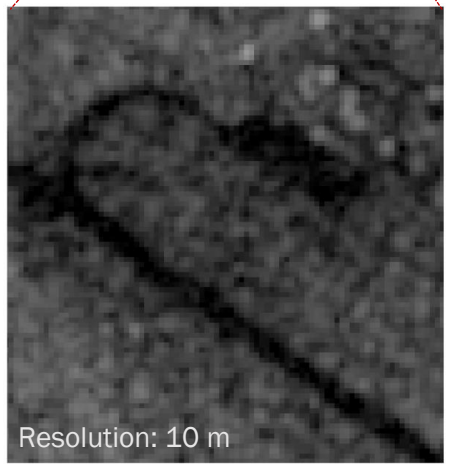
Data Sources







VV
VH
VV/VH
RVI



NDVI, NDWI, Brightness, NBR, BAIS2, SWI

Validation

Process flow diagram

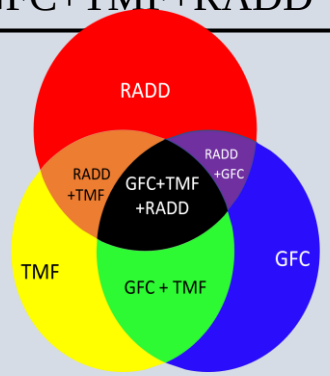
Comparison of existing deforestation products

GFC

TMF

RADD

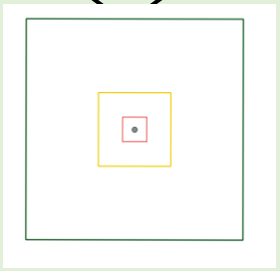
GFC, TMF, RADD,
GFC + TMF,
GFC+ RADD, TMF+ RADD
GFC+TMF+RADD



Choosing best deforestation layer

Sample 20 points and Draw10m*10m, 30m*30m, 90m*90m buffer grid

Validate every layer



Forest extent classification

Sentinel 2 MSI dataset

Sentinel 1 GRD

S2 Stack

S1+S2 Stack

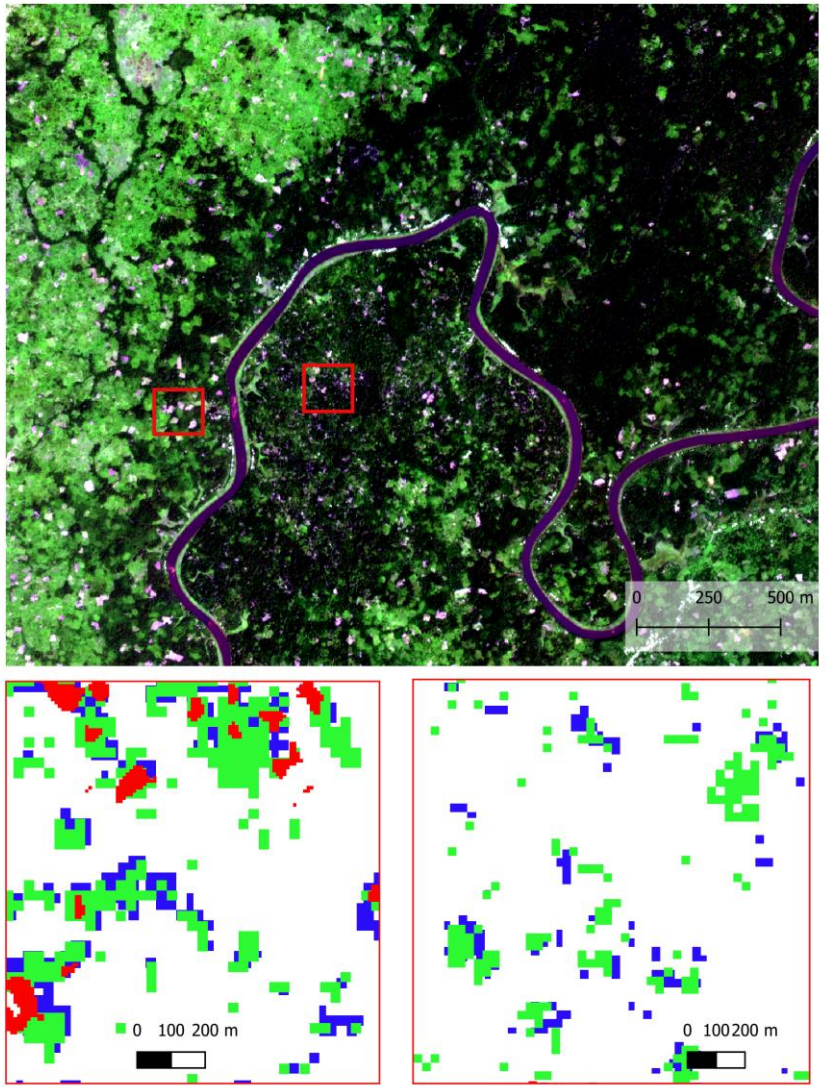
S1 Stack

Training and Validation samples for LS

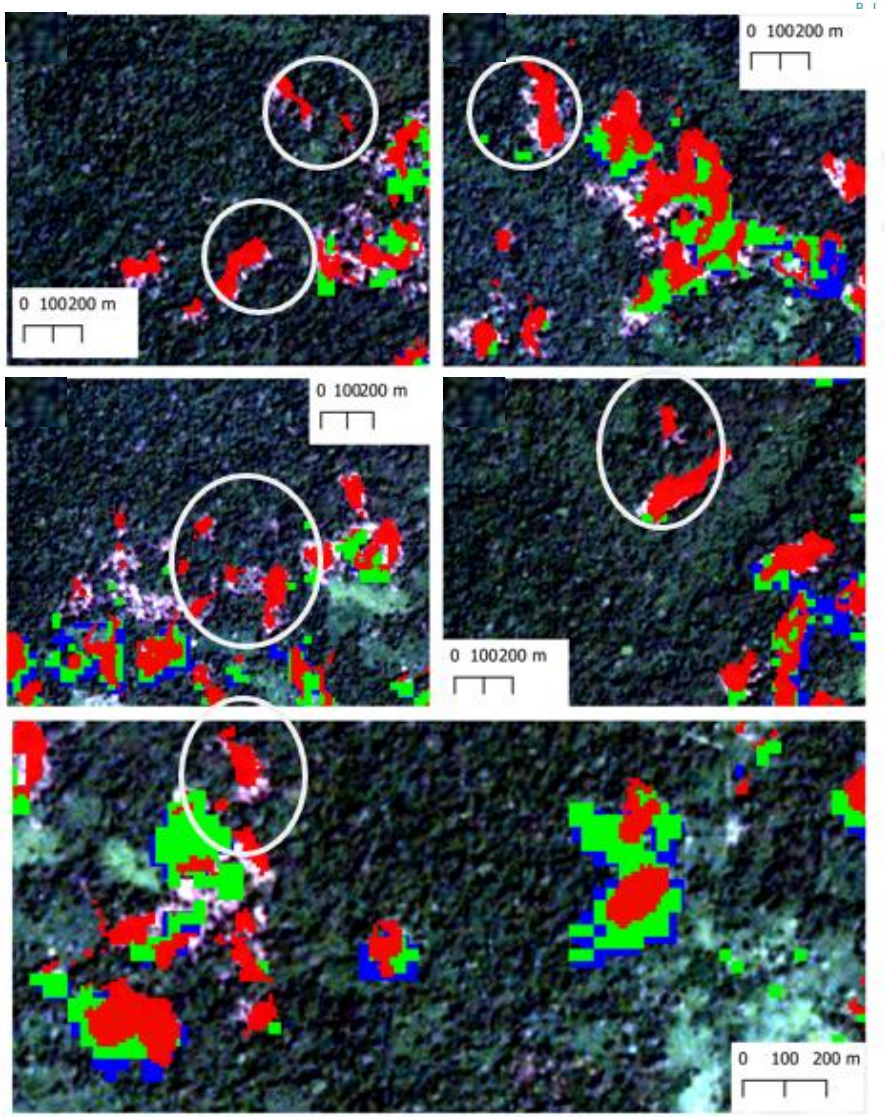
Random Forest Classification

Accuracy assessment

Analysis of existing deforestation products



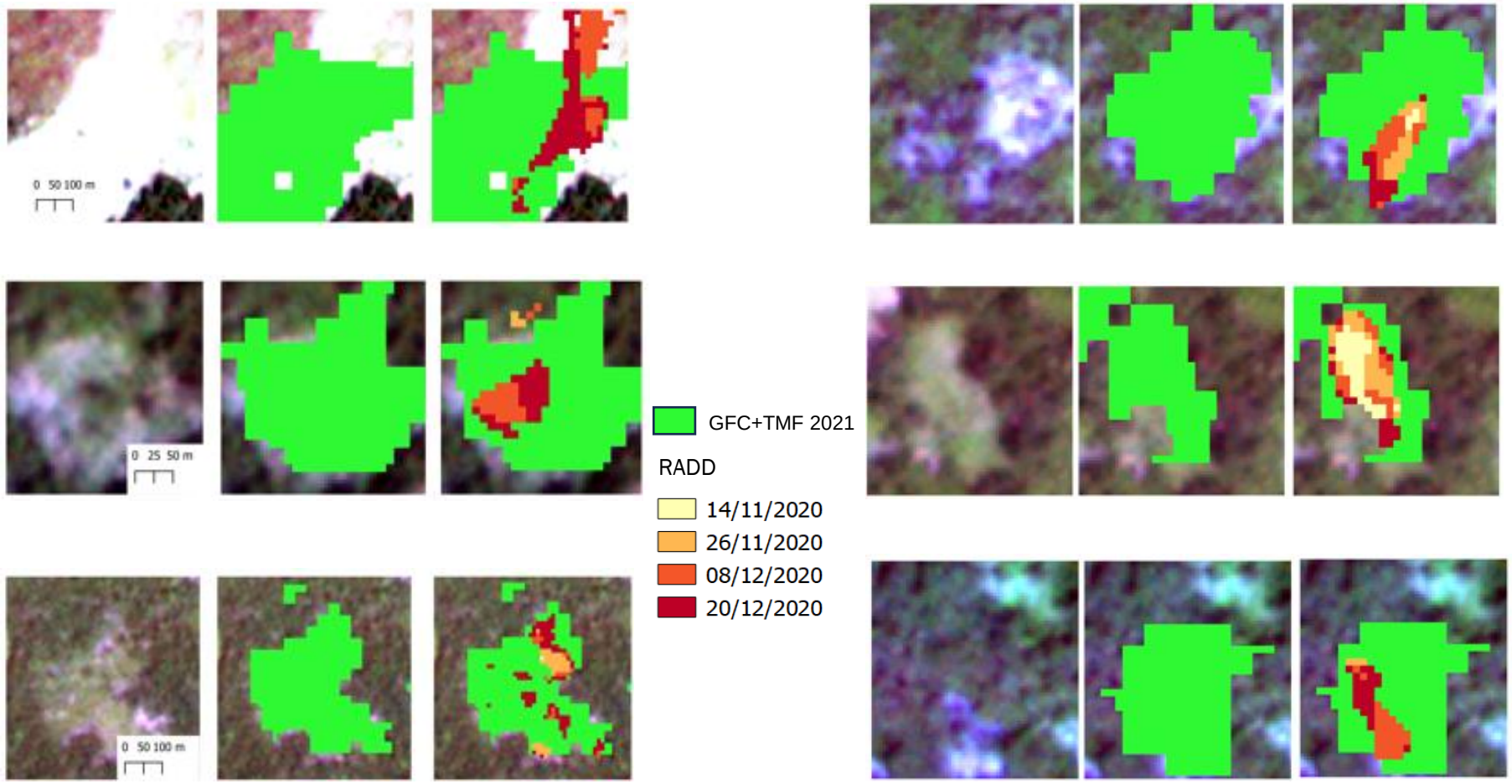
RADD 2020+2021
TMF 2020+2021
GFC 2020+2021



Existing products do not agree

Temporal comparison of existing products

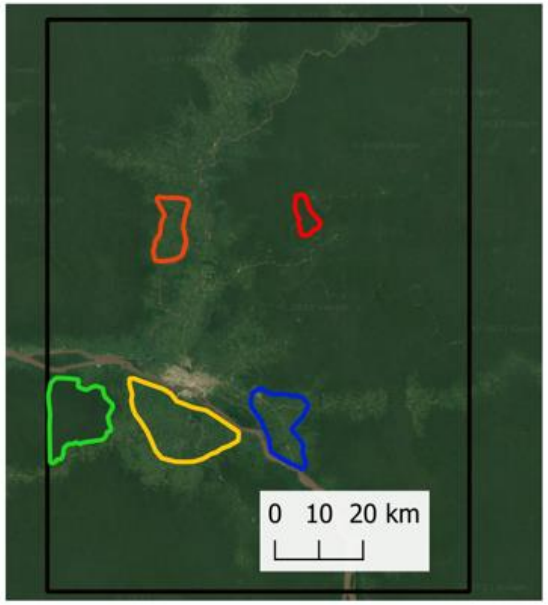
- SAR products detected deforestation at least 2 months earlier than optical products

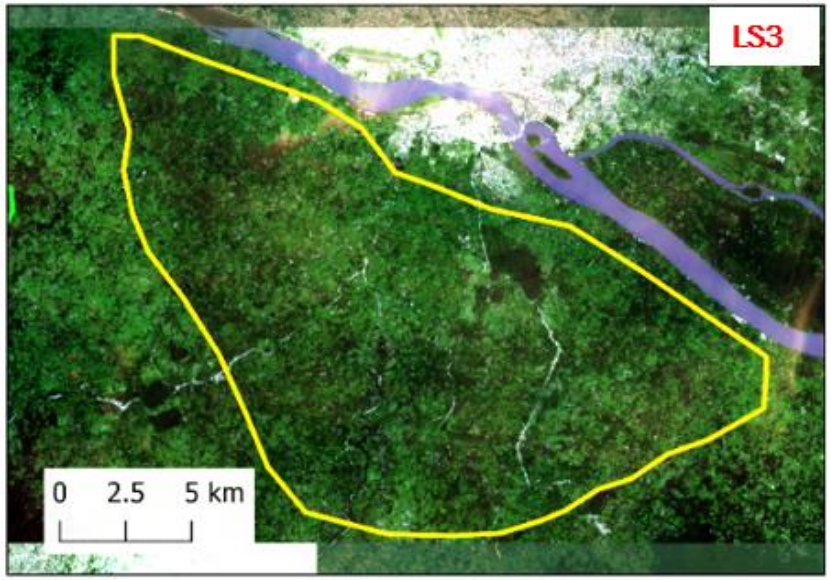


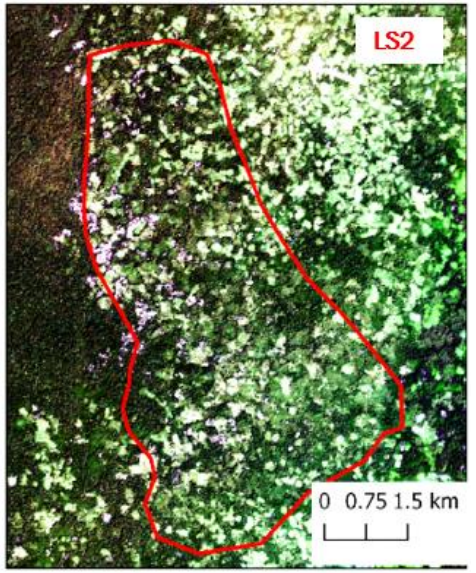
Selection of 5 different landscapes

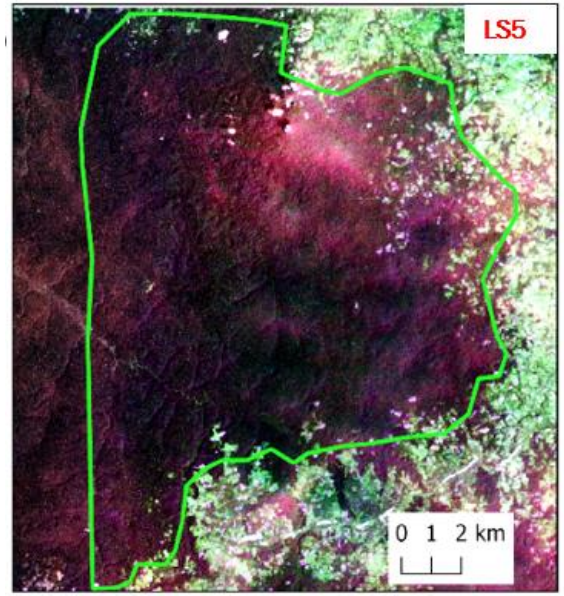
Optical and SAR signal have different coverage in different landscape level

- LS1: agriculture and sparse vegetation
- LS2: degraded forest
- LS3: agriculture and palm tree plantation
- LS4: mixed landcover
- LS5: intact forest

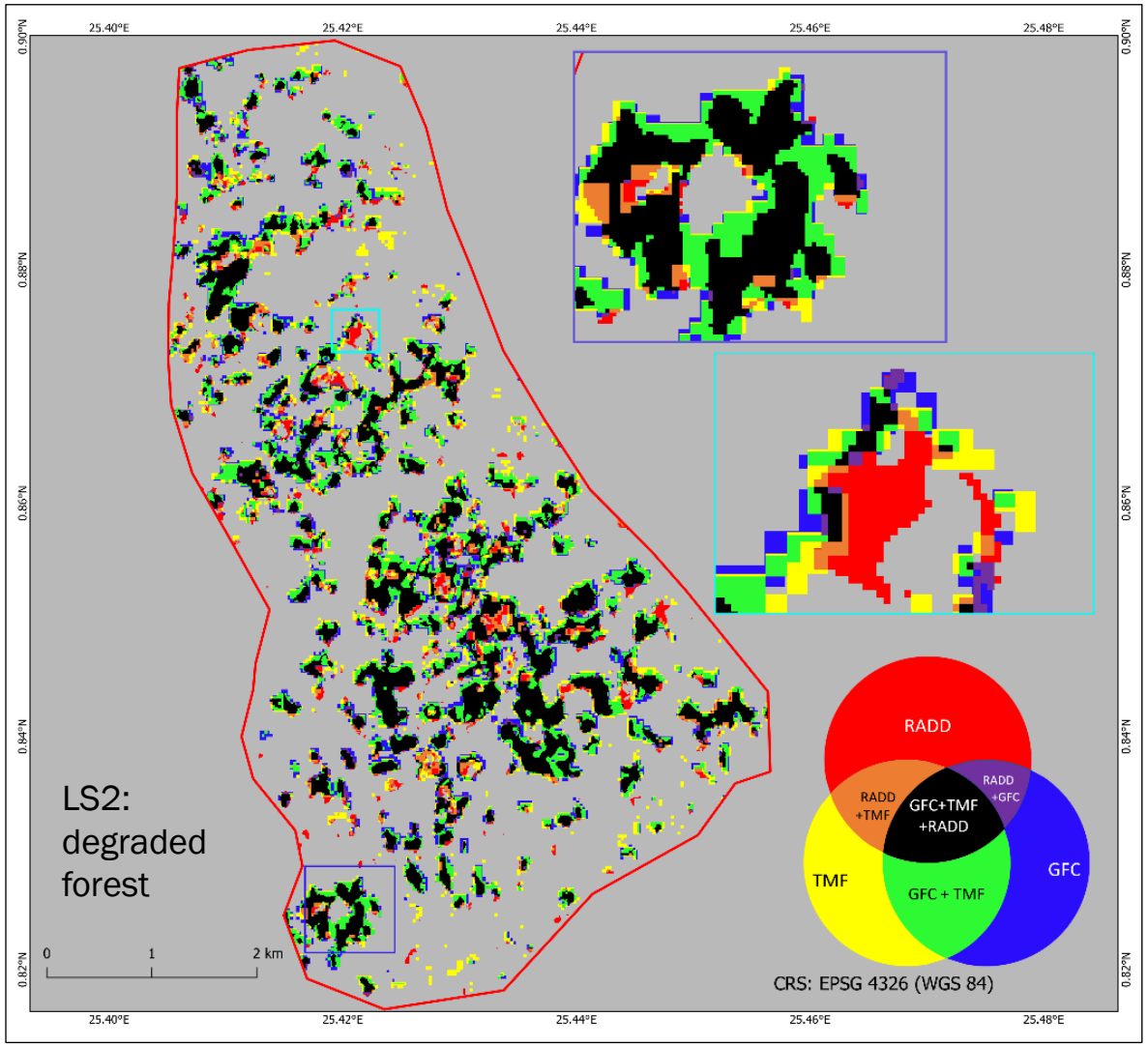




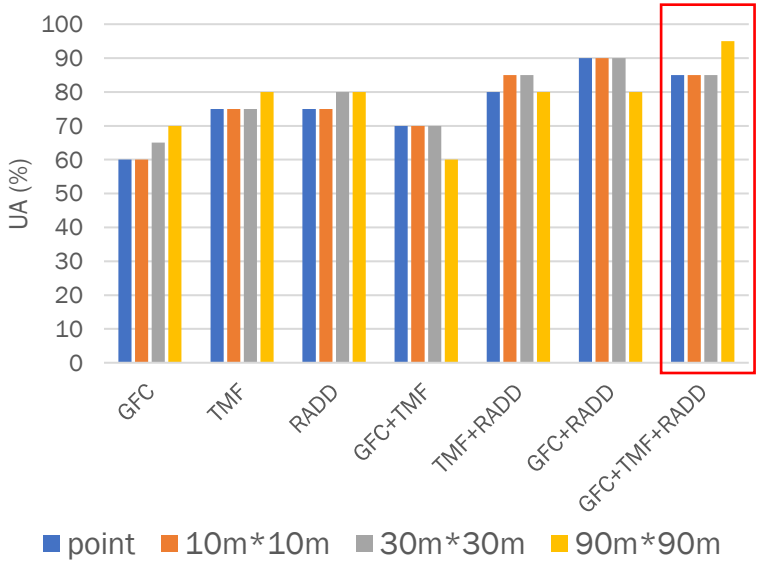




Performance of deforestation products in degraded forest landscape



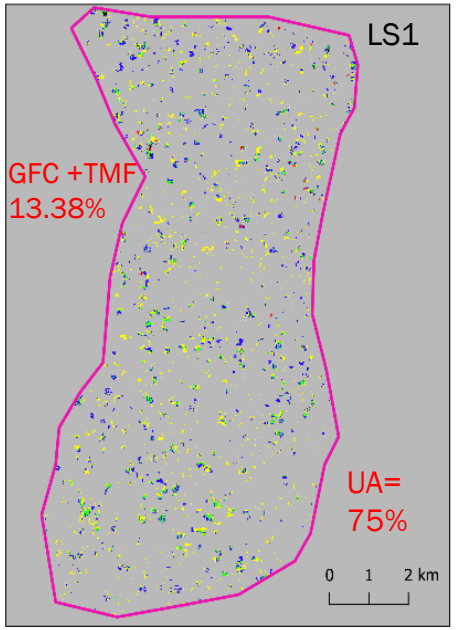
Area coverage	% of total detected deforestation
TMF	20.36
GFC	19.48
GFC+TMF	15.50
RADD	13.46
TMF+RADD	11.22
GFC+RADD	10.36
GFC+TMF+RADD	9.62

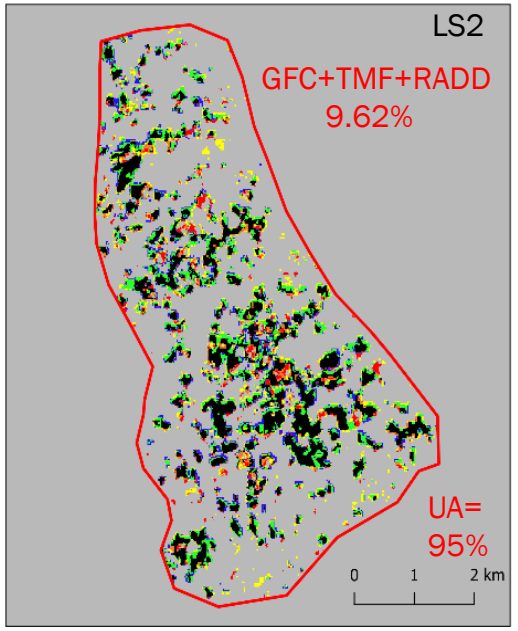


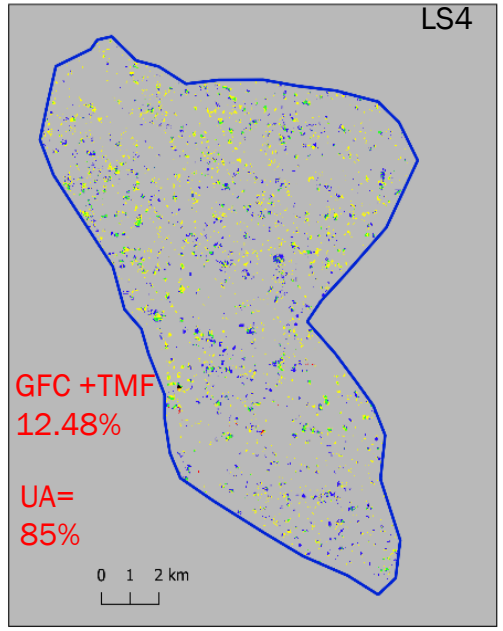
Very minor convergence (<10 %) of the 3 products but greater accuracy (~95 %) for these 10% convergence

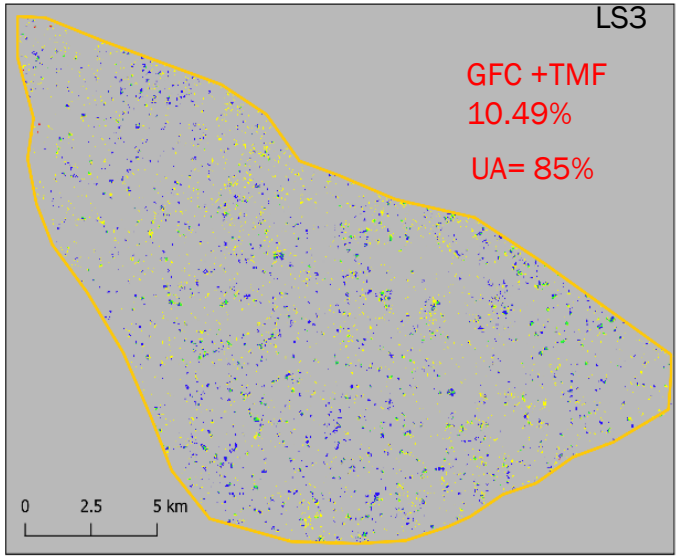
Different performances of 3 products in 5 landscapes

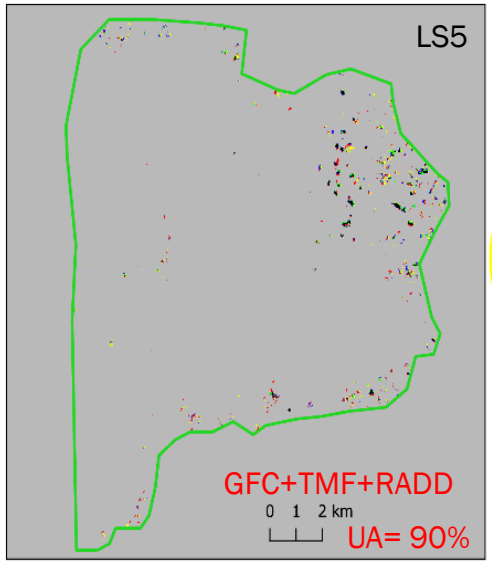
- Accuracy increased when optical and SAR deforestation products are combined (GFC+TMF+RADD)

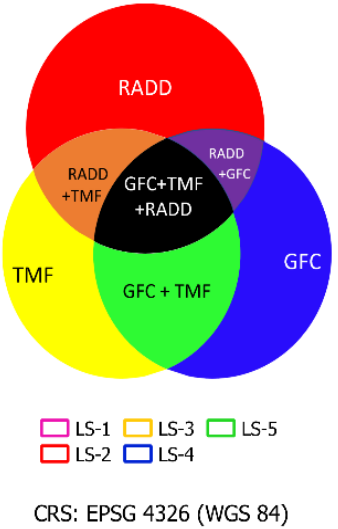








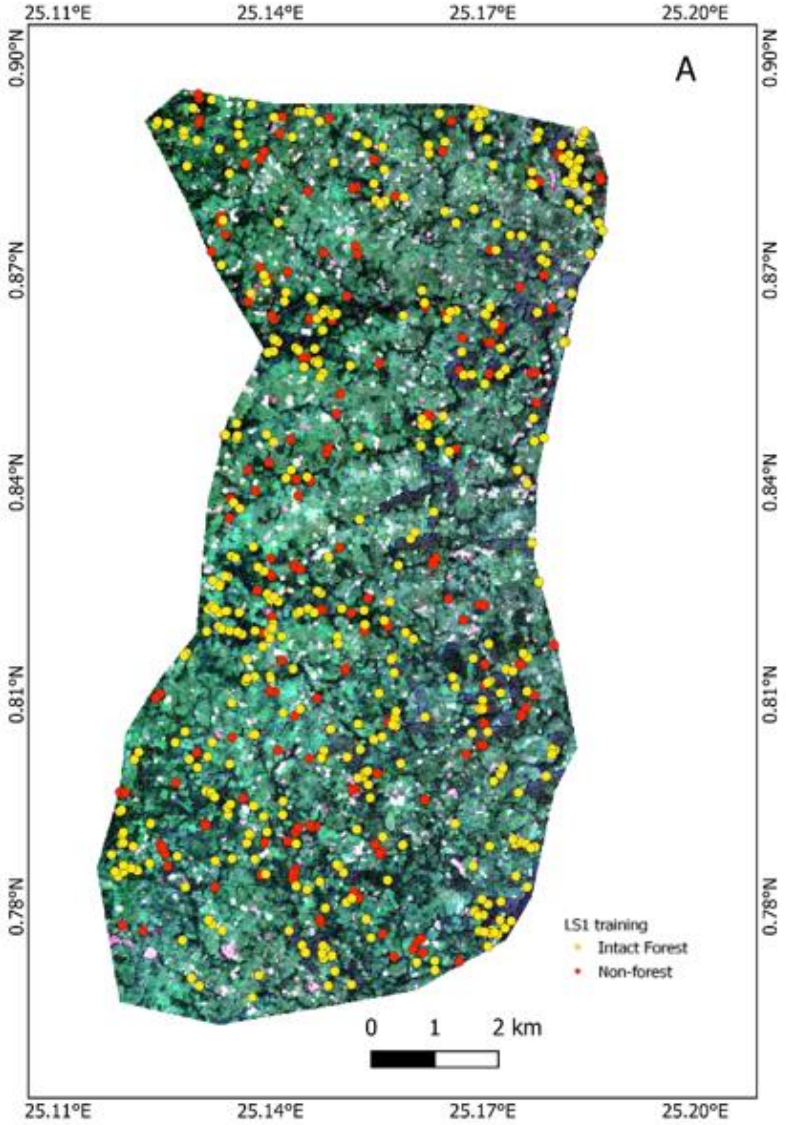




LS1: agriculture and sparse vegetation
LS2: degraded forest
LS3: agriculture and palm tree plantation
LS4: mixed landcover
LS5: intact forest

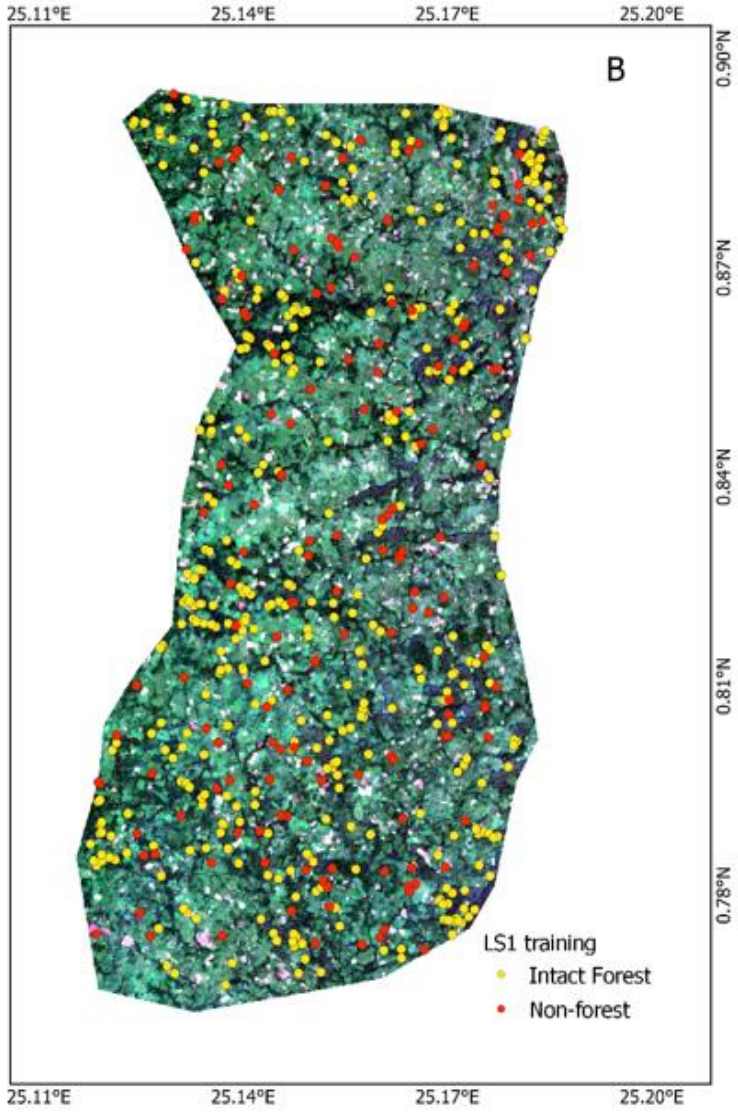
Training samples for classification

Classification based on both carried out where only S2 used for classification



Training sample based on two classes

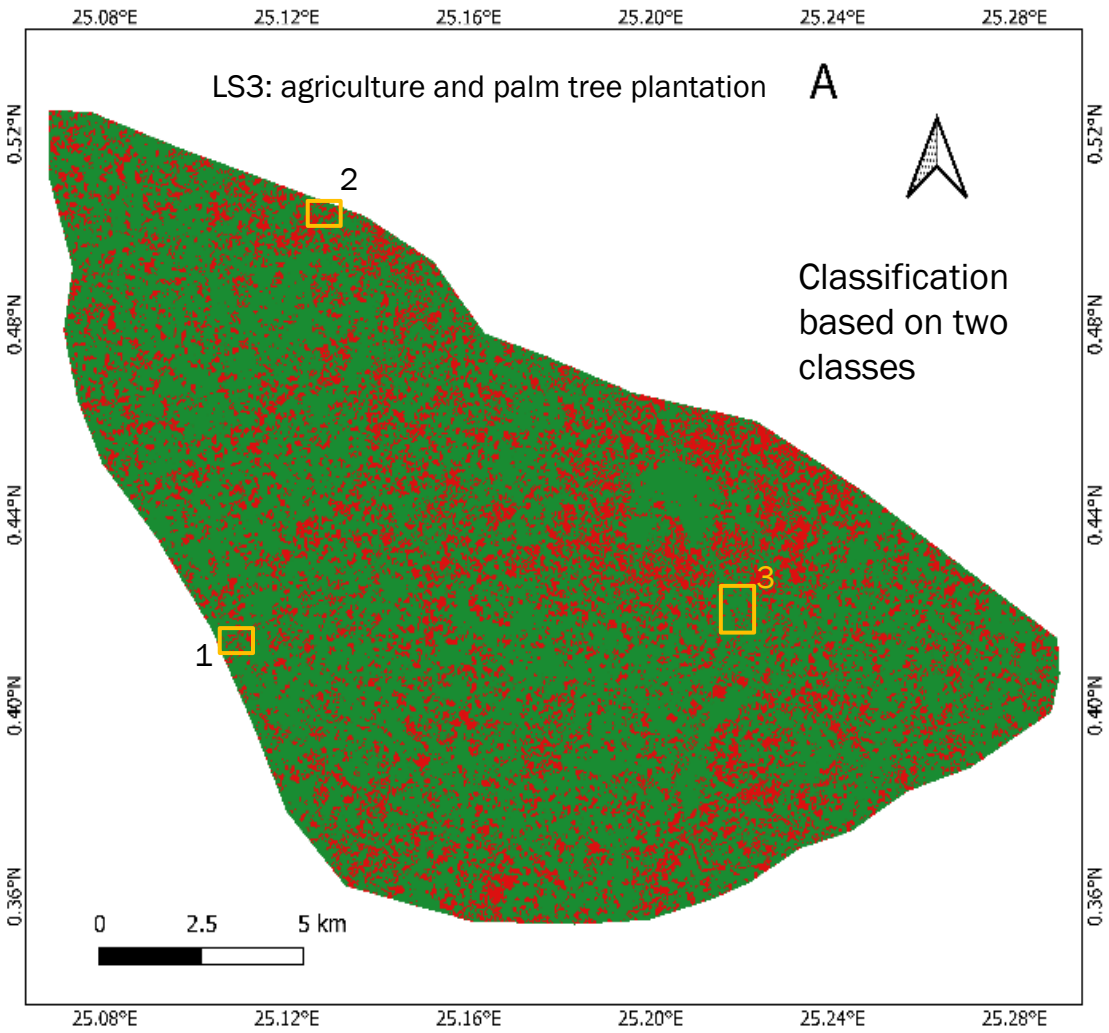
Non-forest = deforestation



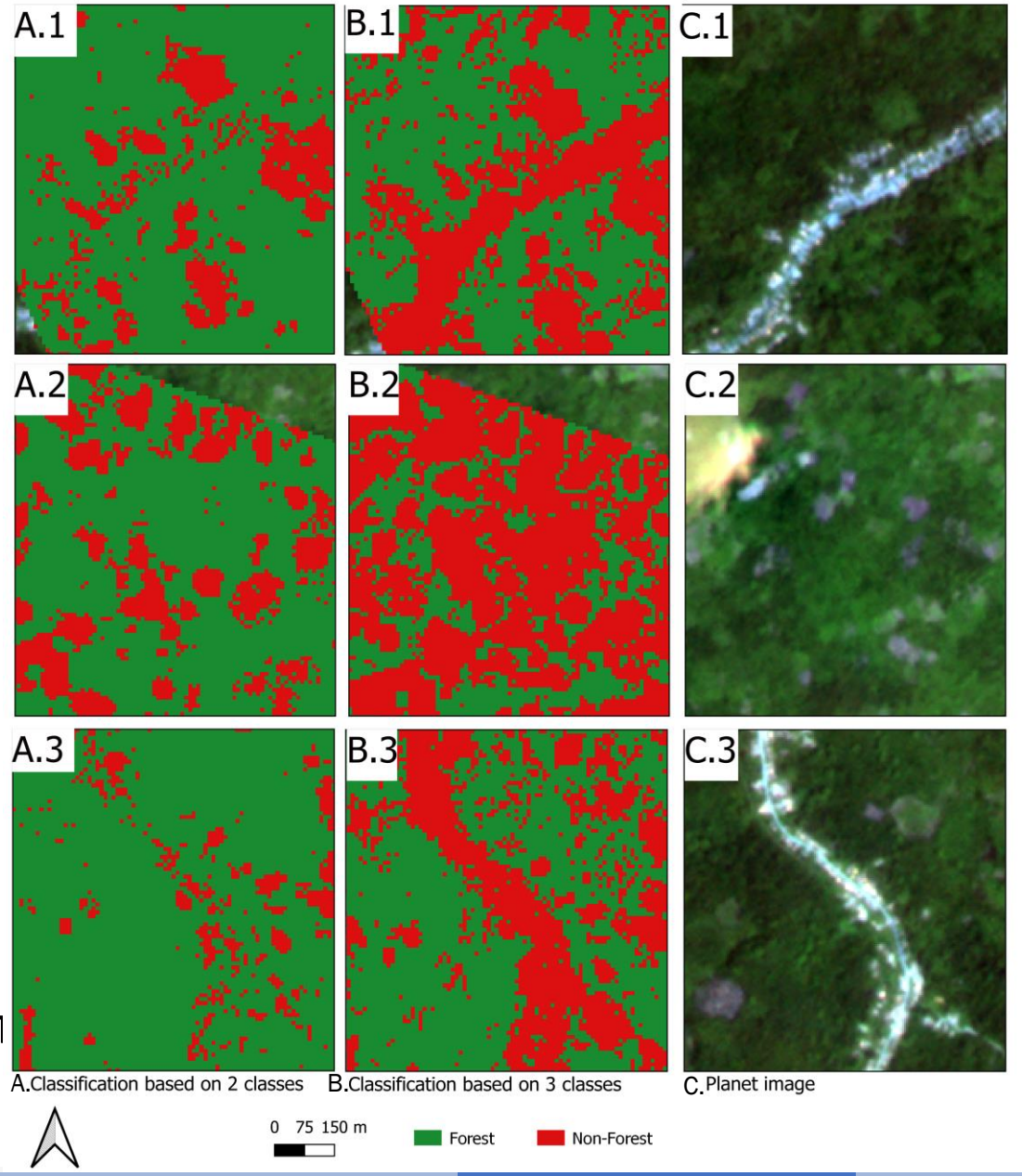
Training data based on three classes

Non-forest = deforestation + Other LC

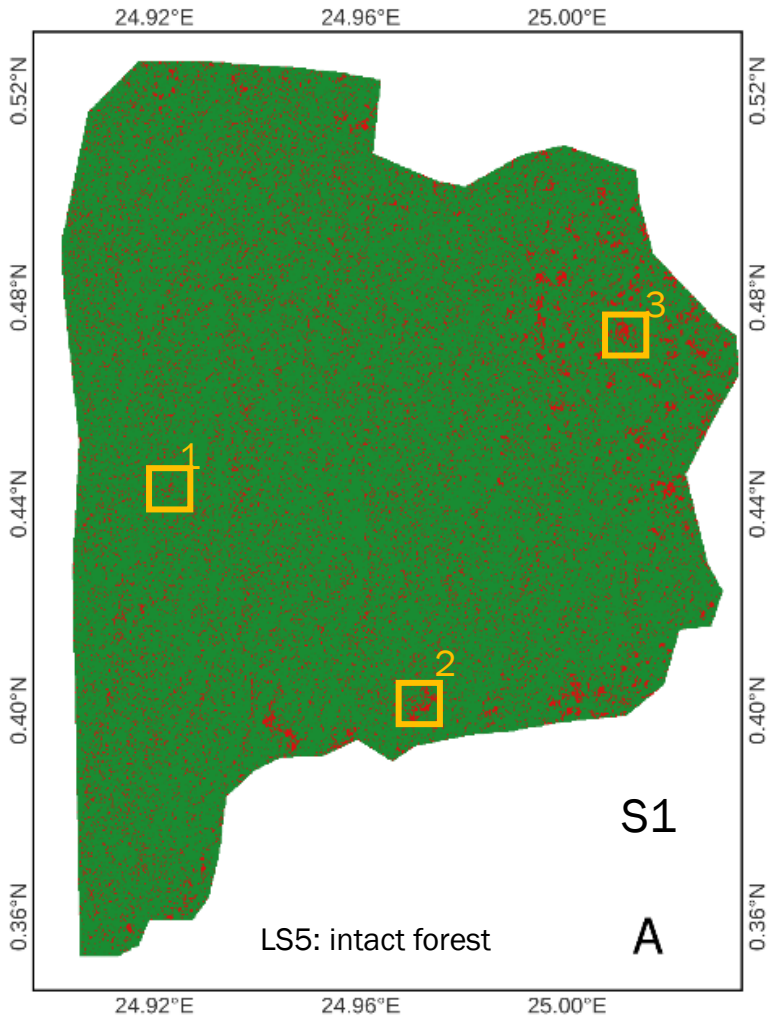
S2 based classification in LS3



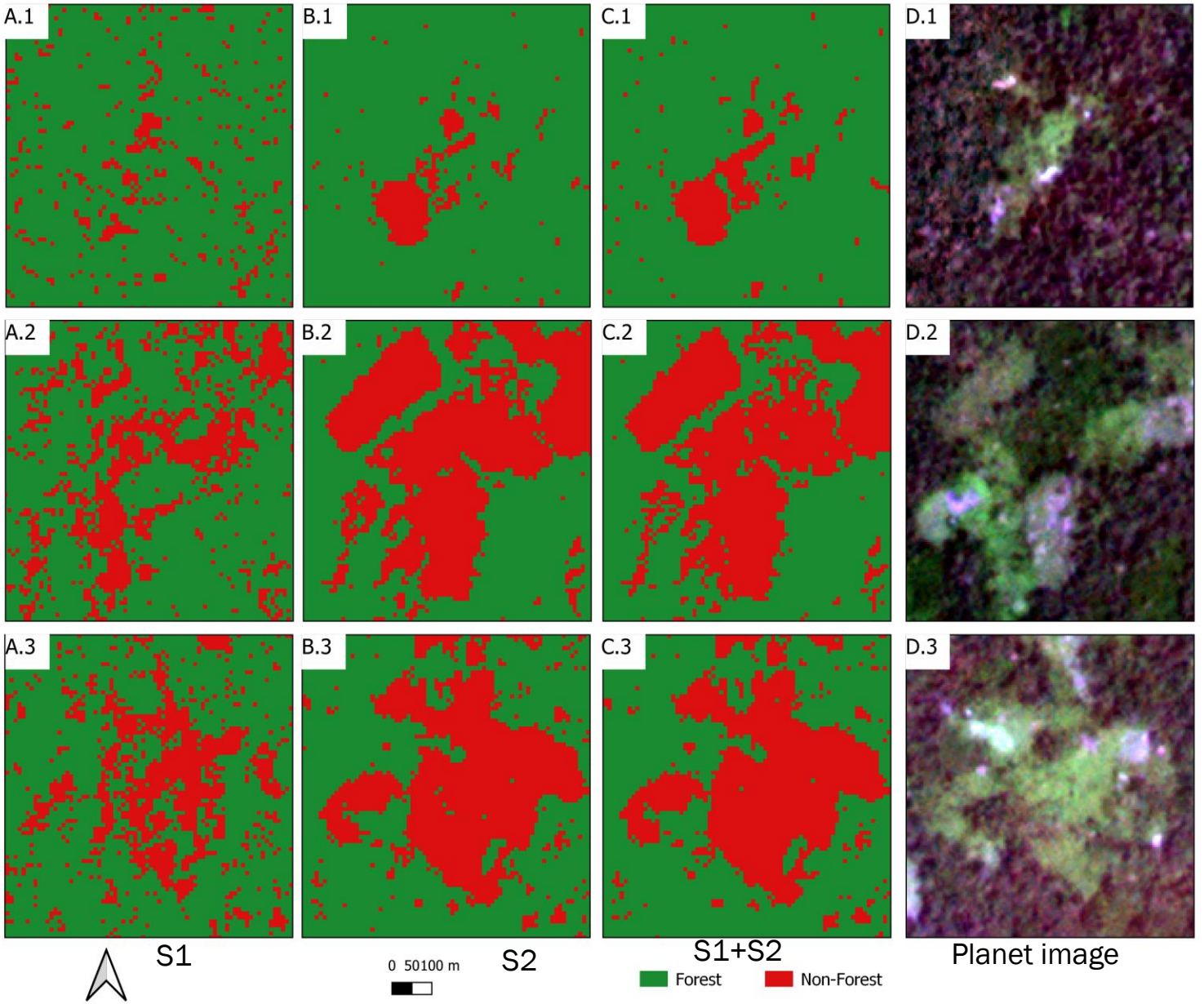
LS-3 (%)	OA	F-score (F)	F-score (NF)
S2 2 classes (A)	85	89	74
S2 3 classes (B)	83	88	73



S1 and S2 based classification in LS5

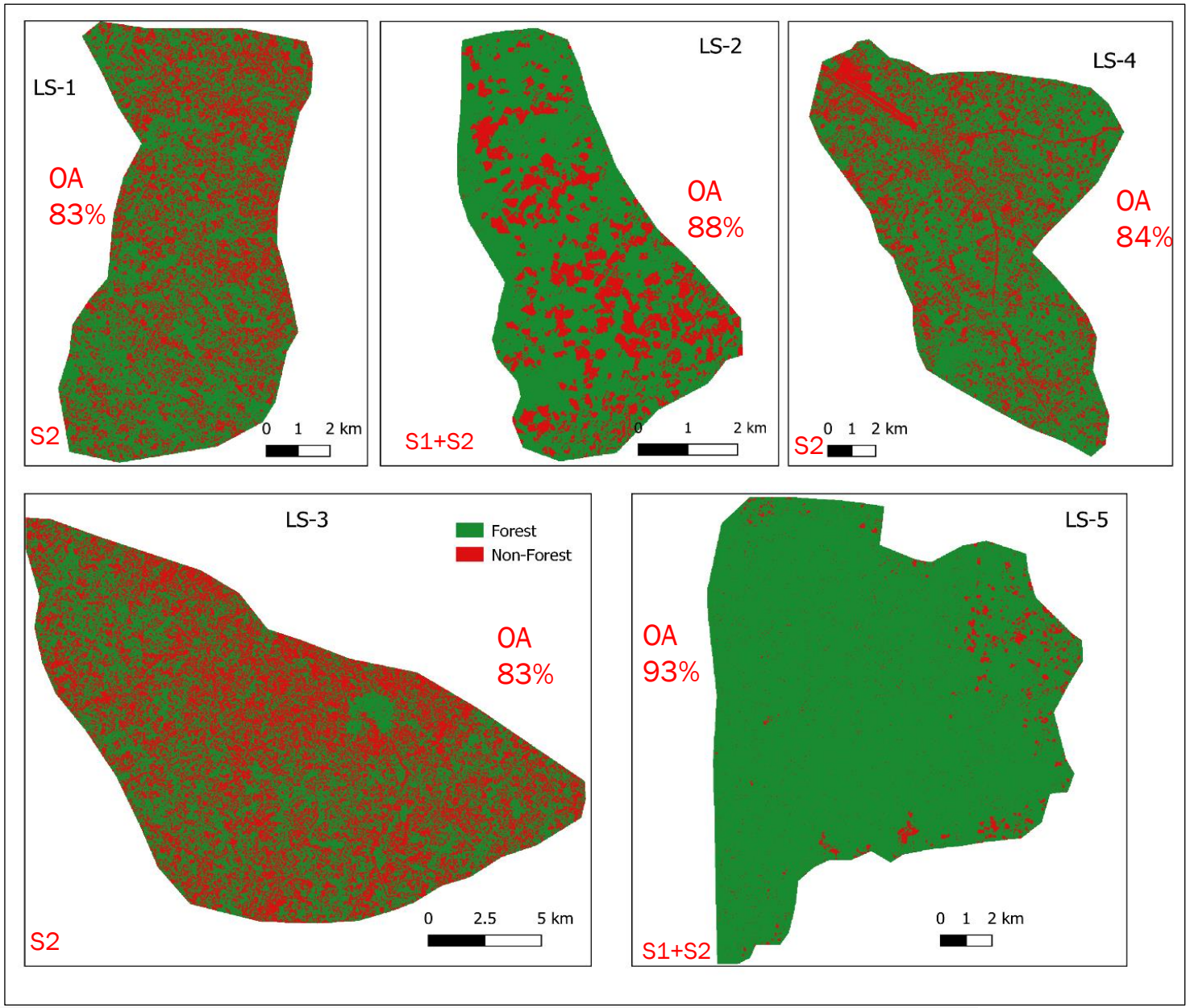


LS-5 (%)	OA	F-score (F)	F-score (NF)
S1	80	86	66
S2	91	93	86
S1+S2	93	94	89



The best classification result in every landscape

- Higher accuracy obtained with S1 and S2 combination



Forest cover

LS1: 55.08%

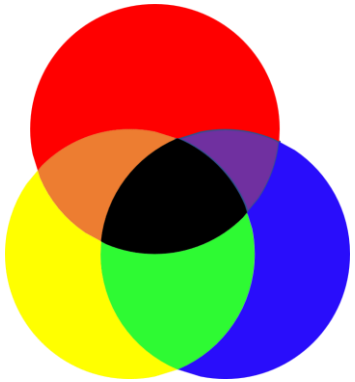
LS2: 73.69%

LS3: 54.54%

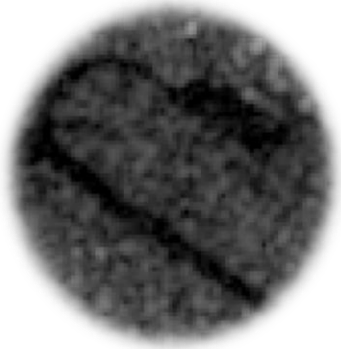
LS4: 67.13%

LS5: 95.90%

Findings

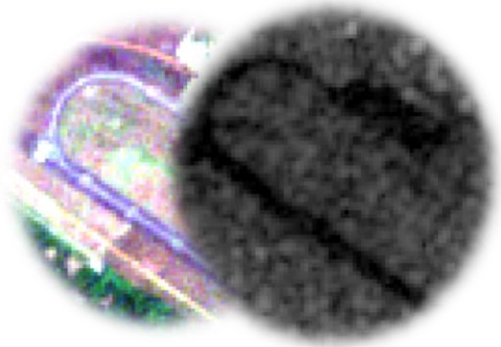


Results are Landscape-specific



S1 produced lower accuracy

S2 produced better agreement with three-class based training



Best overall accuracy with S1+S2

Limitations and future work

- **Inconsistencies** in the deforestation products = inconsistencies in reference data (need for independent dataset)
- **Sensitivity analysis** based on good reference data would tell us which combination of optical and SAR feature can be used for better performances
- **Advance fusion approaches** based on deep learning

“Destroying rainforest for economic gain is like burning a Renaissance painting to cook a meal” --- E. O Wilson

THANK YOU
for your patience

Predicted value	Reference value				
	LS1 2 classes	Forest	non-Forest	total	UA
	Forest	84	6	90	93.33
	non-Forest	17	34	51	66.67
	total	101	40	141	
	PA	83.17	85.00	OA	83.69
		Forest	non-Forest	total	UA
	Forest	82	6	88	93.18
	non-Forest	15	25	40	62.50
	total	97	31	128	
	PA	84.54	80.65	OA	83.59

Predicted value	Reference value				
	LS4 2 classes	Forest	non-Forest	total	UA
	Forest	67	13	80	83.75
	non-Forest	12	23	35	65.71
	total	79	36	115	
	PA	84.81	63.89	OA	78.26
	LS4 3 classes	Forest	non-Forest	total	UA
	Forest	84	11	95	88.42
	non-Forest	10	33	43	76.74
	total	94	44	138	
	PA	89.36	75.00	OA	84.78

Predicted value	Reference value				
	LS5 S1	Forest	non-Forest	total	UA
	Forest	78	7	85	91.76
	non-Forest	18	24	42	57.14
	total	96	31	127	
	PA	81.25	77.42	OA	80.31
	LS5 S2	Forest	non-Forest	total	UA
	Forest	81	4	85	95.29
	non-Forest	7	35	42	83.33
	total	88	39	127	
	PA	92.05	89.74	OA	91.34
	LS5 S3	Forest	non-Forest	total	UA
	Forest	82	3	85	96.47
	non-Forest	6	36	42	85.71
	total	88	39	127	
	PA	93.18	92.31	OA	92.91

Reference value					
LS3 2 classes	Forest	non-Forest	total	UA	
Forest	80	2	82	97.56	
non-Forest	17	28	45	62.22	
total	97	30	127		
PA	82.47	93.33	OA	85.04	
LS3 3 classes	Forest	non-Forest	total	UA	
Forest	70	6	76	93.33	
non-Forest	14	27	41	66.67	
total	84	33	117		
PA	83.33	81.82	OA	82.91	

Predicted value	Reference value				
	LS2 S1	Forest	non-Forest	total	UA
	Forest	70	6	76	92.11
	non-Forest	23	16	39	41.03
	total	93	22	115	
	PA	75.27	72.73	OA	74.78
	LS2 S2	Forest	non-Forest	total	UA
	Forest	71	5	76	93.42
	non-Forest	10	29	39	74.36
	total	81	34	115	
	PA	87.05	85.29	OA	86.96
	LS2 S3	Forest	non-Forest	total	UA
	Forest	72	4	76	94.74
	non-Forest	10	29	39	74.36
	total	82	33	115	
	PA	87.80	87.88	OA	87.83