

Wetlands Solutions *for the Future*

Learning from ALFAwetlands and
REWET Projects

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Land Cover Mapping in European Wetlands Using Satellite Remote Sensing

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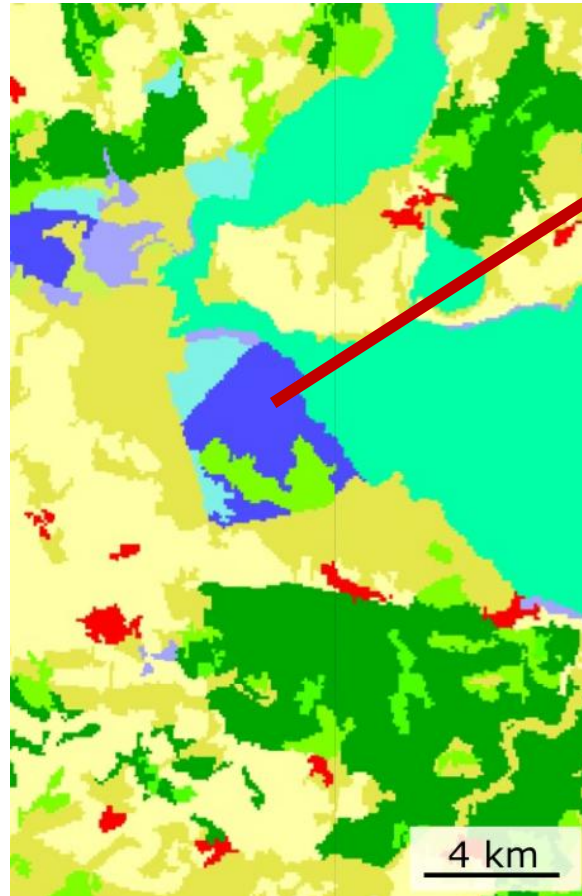


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The gap: Existing maps lack wetland thematic detail

CORINE Land Cover



Wetlands > Inland wetlands > Peat bogs

Existing maps show where wetlands are, but not their type or management.

What we need to distinguish:

- Bog
- Fen
- Treed peatland
- Drained peatland
- Rewetted peatland
- Mineral-soil wetland
- Restoration practices

Existing products **do not provide sufficient thematic resolution for wetland-specific monitoring**

The gap: Spatial resolution

WorldView-3 (0.3 m)



Sentinel-2 (10 m)



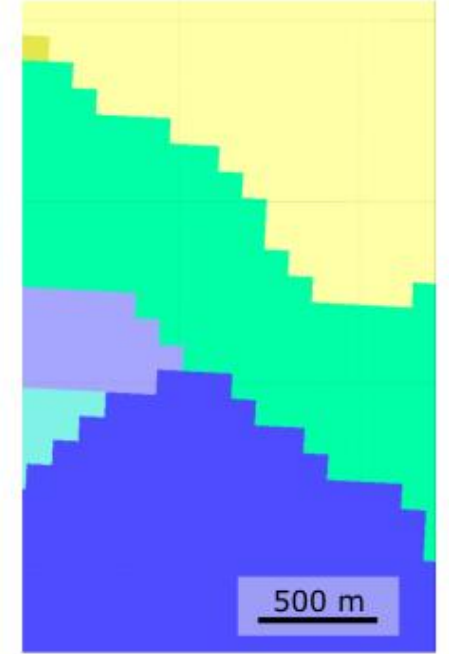
Landsat (30 m)



MODIS (500 m)



CORINE Land Cover (100 m)



Wetlands are highly heterogeneous



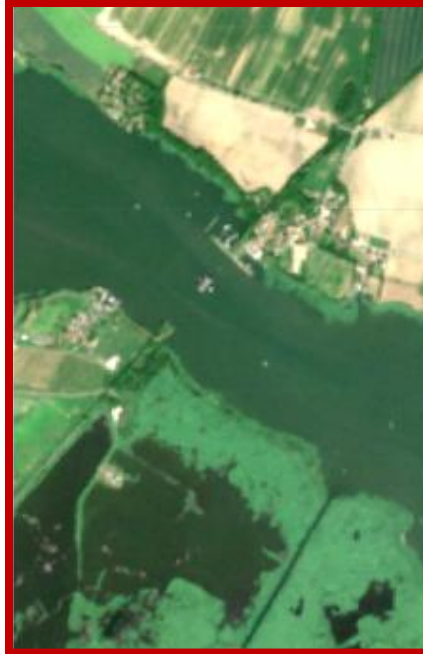
≤ 30-m resolution is needed to
distinguish wetland types

The gap: Spatial resolution

WorldView-3 (0.3 m)



Sentinel-2 (10 m)



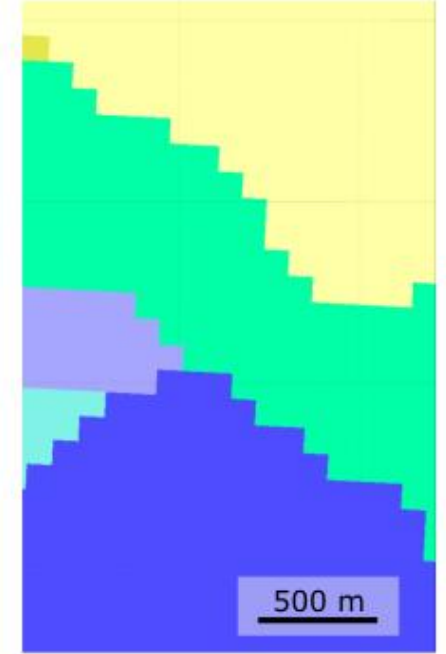
Landsat (30 m)



MODIS (500 m)



CORINE Land Cover (100 m)



Sentinel-1 & -2

Land Cover 2020

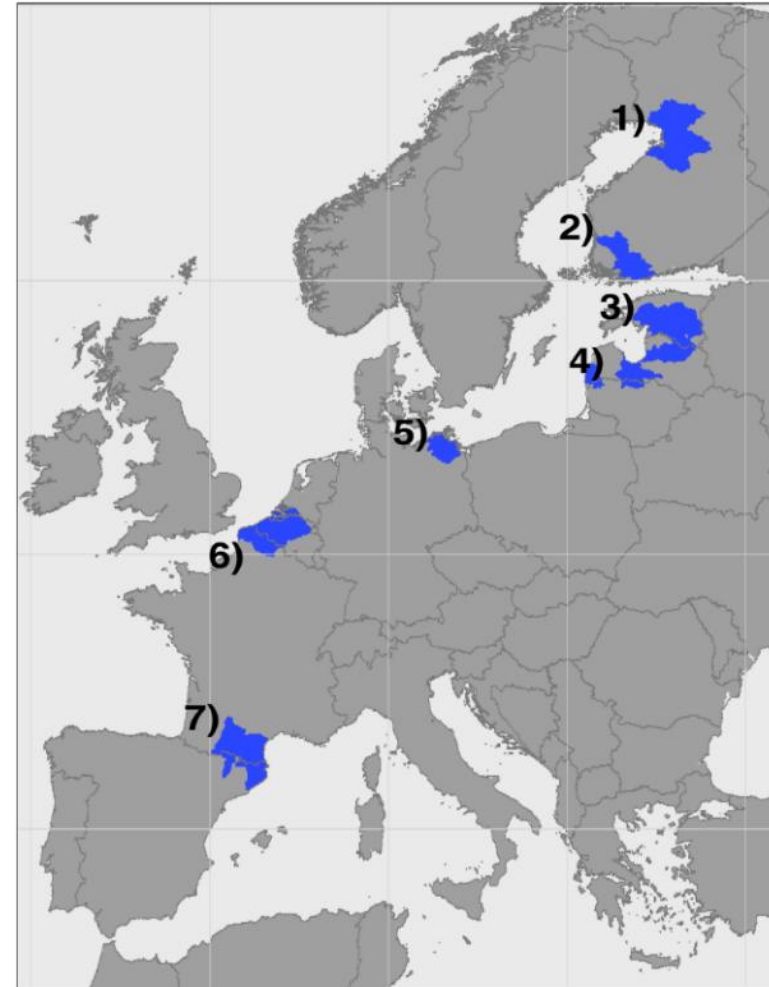
Land Cover
Change 1985-2023

Landsat -5, -7, -8 & -9

We developed a methodology for: **a)** present-day mapping (2020) from Sentinel-1 and -2 (10 m)
b) historical mapping (1985-2024) from Landsat (30 m)

Study area: Seven Living Labs

1. Northern Finland
2. Southern Finland
3. Estonia
4. Latvia
5. Germany
6. Belgium
7. Pyrenees



We tested a methodology across **7 European landscapes**: approach can transfer across Europe?

Seven regions → different wetland types → different climates and management contexts:

(Boreal, Temperate, Alpine, Mediterranean wetlands)

Land cover mapping in ALFAwetlands (**WP1; T1.2** & T1.3).

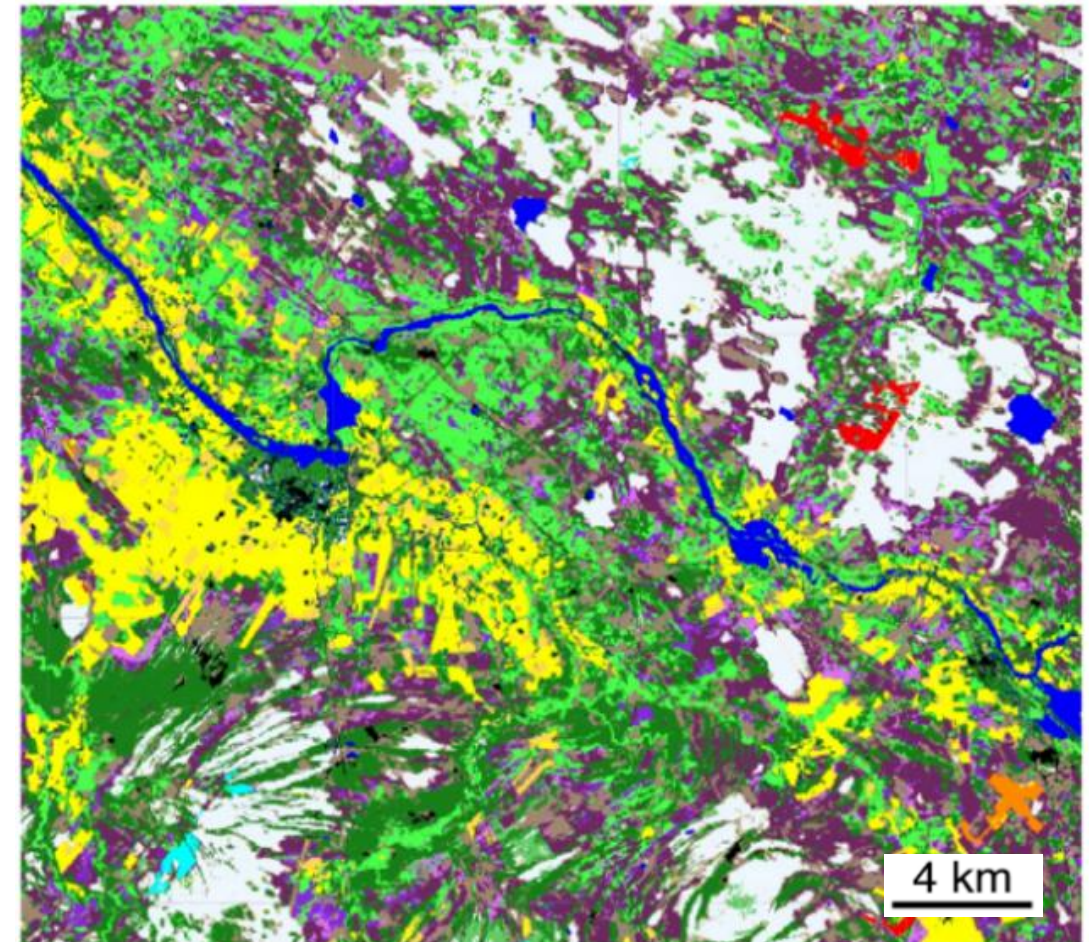
Two mapping products:

	Satellite data	Spatial resolution	Thematic classes
 Land Cover 2020	Sentinel-1 & -2	10 m	27
Land Cover Change 1985-2023	Landsat -5, -7, -8 & -9	30 m	8

Detailed present-day mapping & Long-term change detection

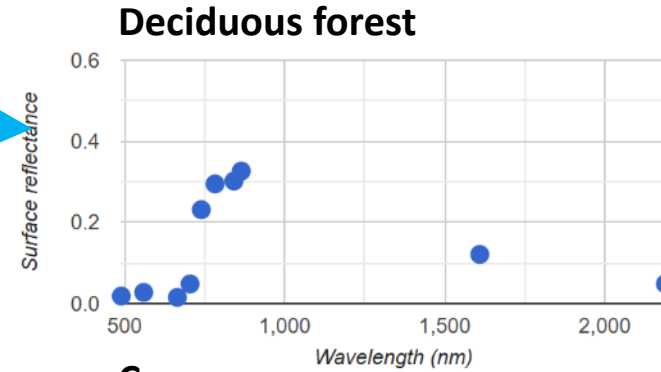
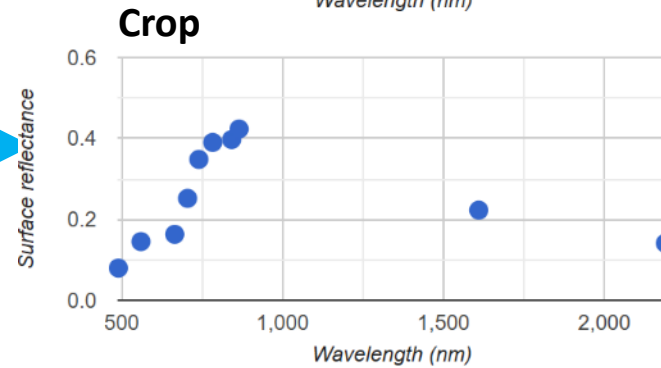
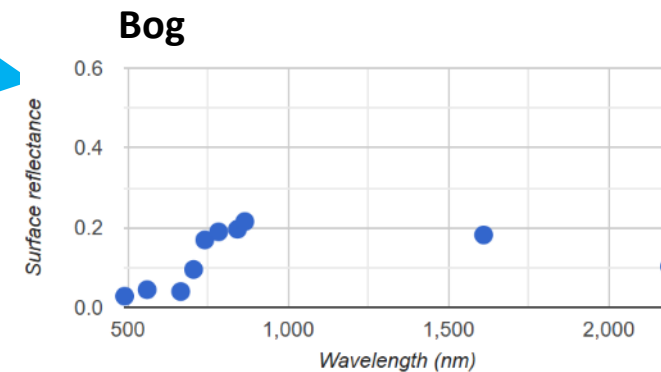
What exactly did we map? **27 classes** capturing wetland type, drainage, and land use

LULC class name (for detailed Sentinel LULC classification, 2020)	Soil type	Drainage status
fen	peat	undrained
bog	peat	undrained
treed bog	peat	undrained
deciduous swamp forest	peat	undrained
coniferous swamp forest	peat	undrained
mixed swamp forest	peat	undrained
coastal wetland / grassland	peat	undrained
drained pine bog	peat	drained
drained deciduous swamp forest	peat	drained
drained coniferous swamp forest	peat	drained
drained mixed swamp forest	peat	drained
forest clear-cut	peat	drained
agriculture: cropland	peat	drained
agriculture: grassland	peat	drained
peat extraction	peat	drained
coastal wetland / grassland	peat	drained
revegetated peat extraction site	peat	restored
rewetted for nature development	peat	restored
coastal wetland / grassland	mineral	NA
coniferous forest	mineral	NA
deciduous forest	mineral	NA
forest clear-cut	mineral	NA
Mediterranean shrubland/forest	mineral	NA
agriculture: cropland	mineral	NA
agriculture: grassland	mineral	NA
water	NA	NA
built-up	NA	NA

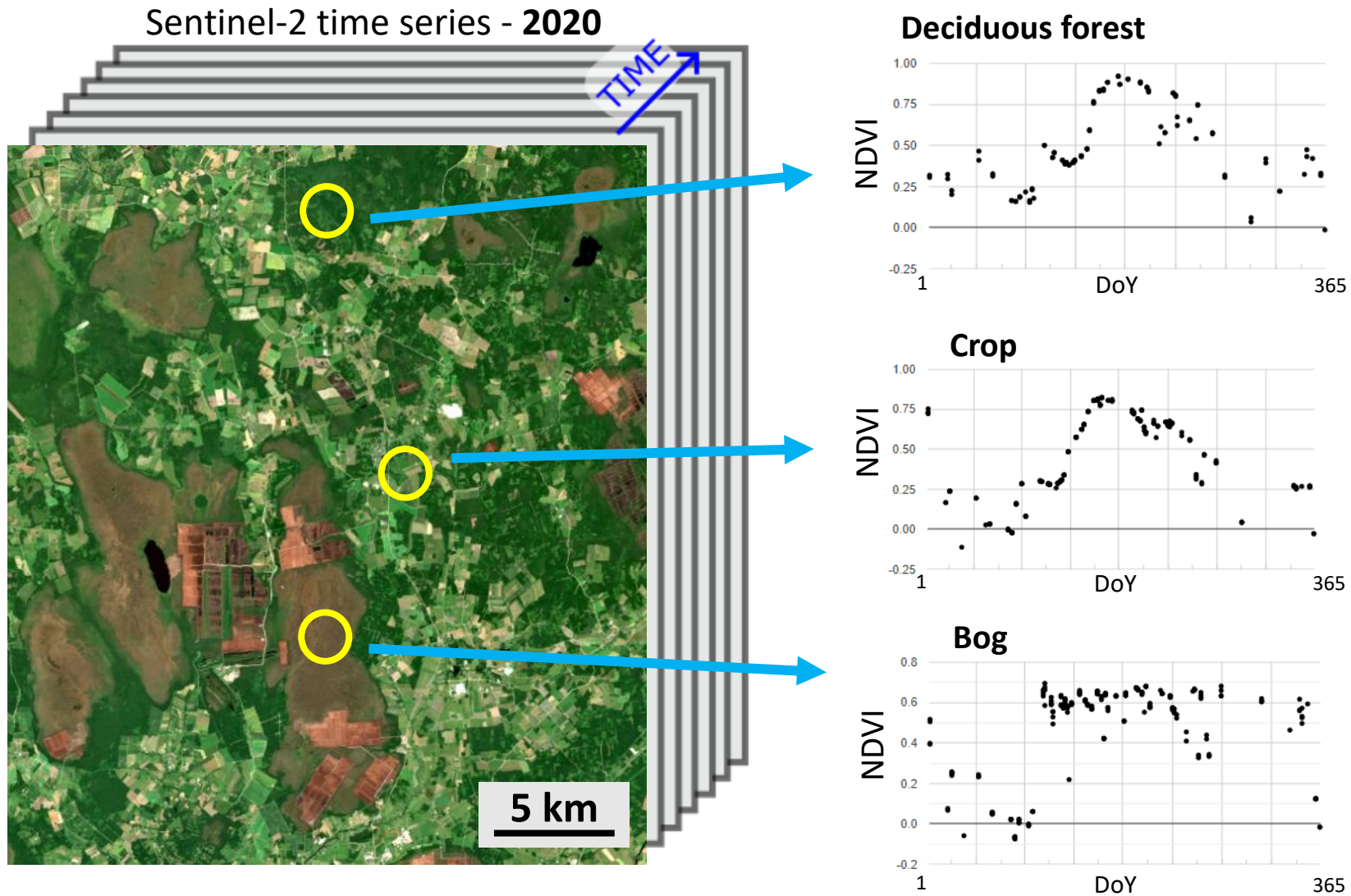


What do satellites see?: Different spectral signatures

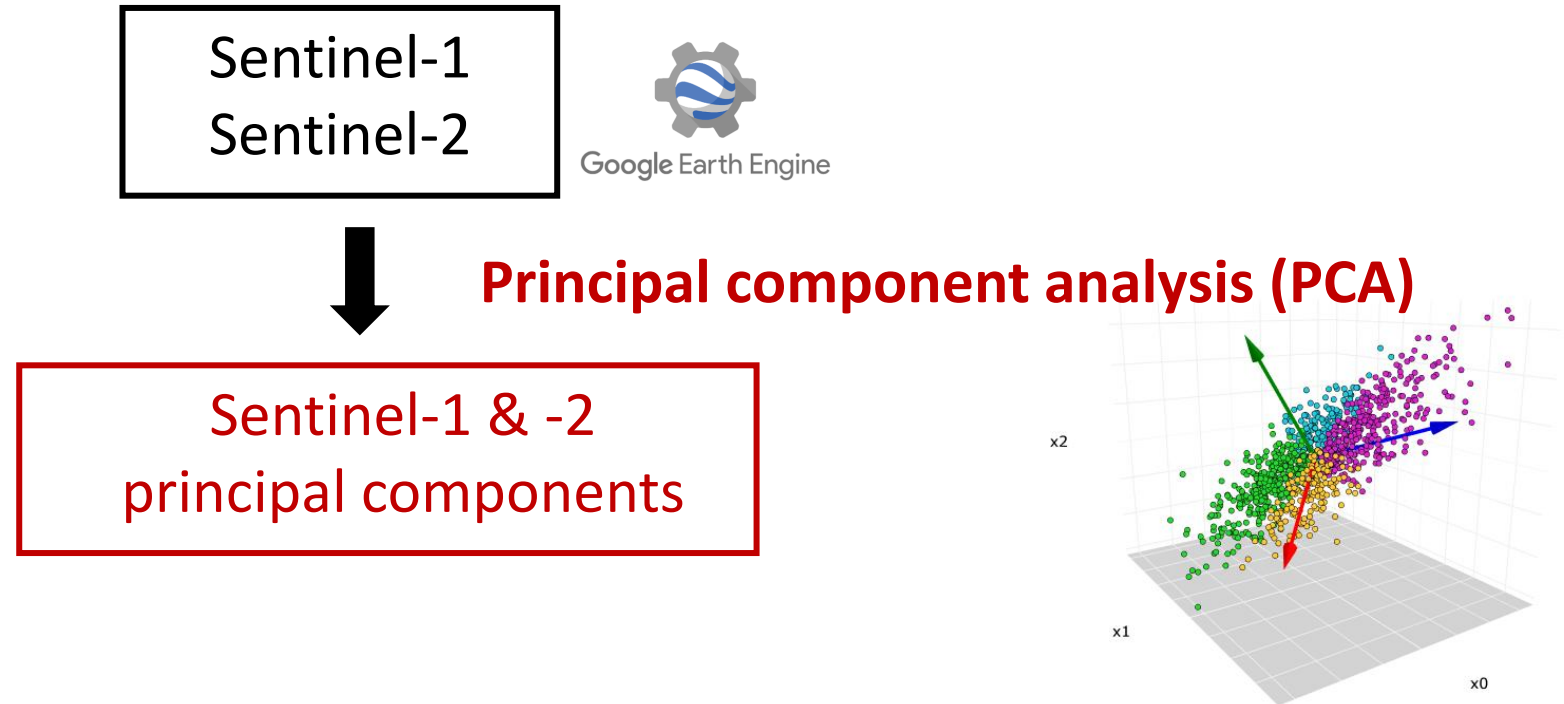
Sentinel-2 true colour composite - 18 July 2020



What do satellites see?: Different temporal signature (phenology)

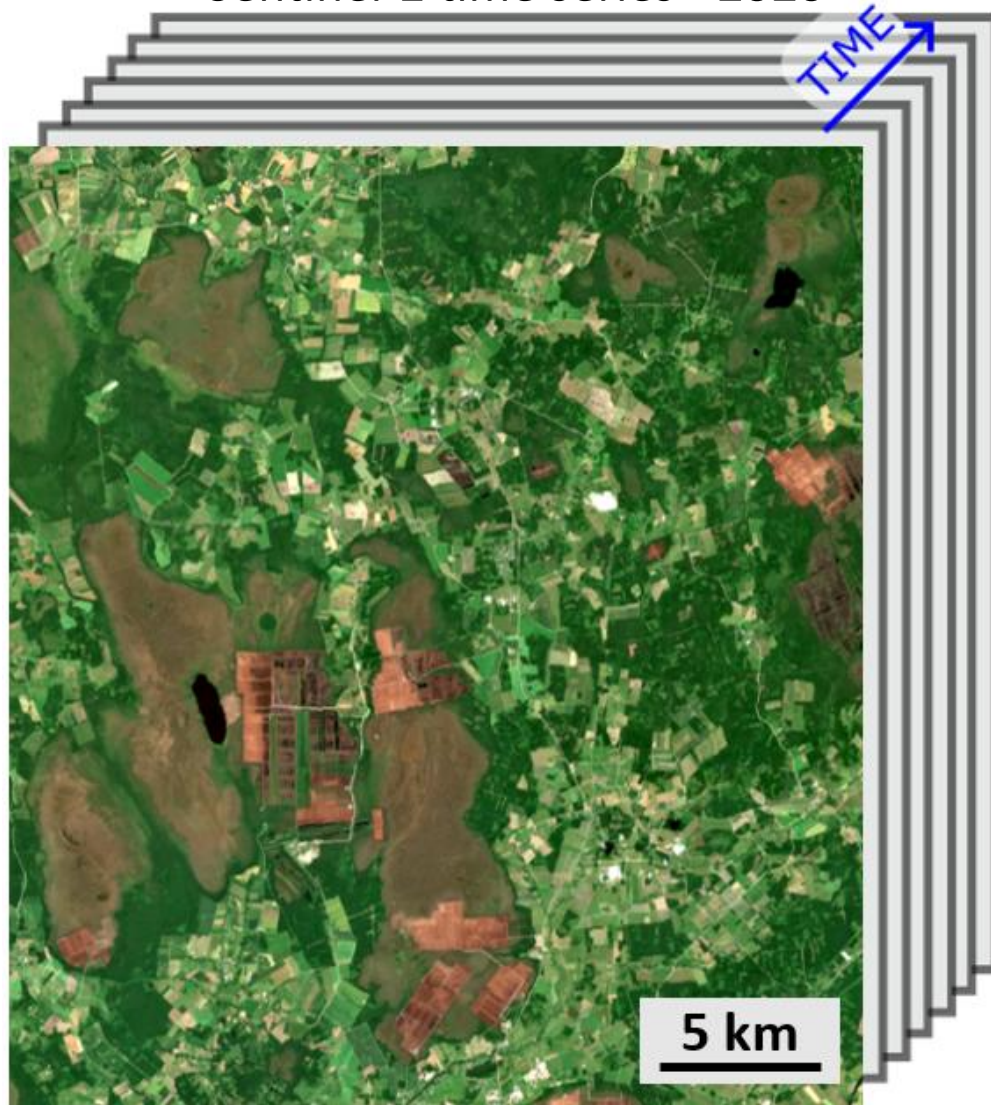


Overview of the methodology: 1) Dimensionality reduction



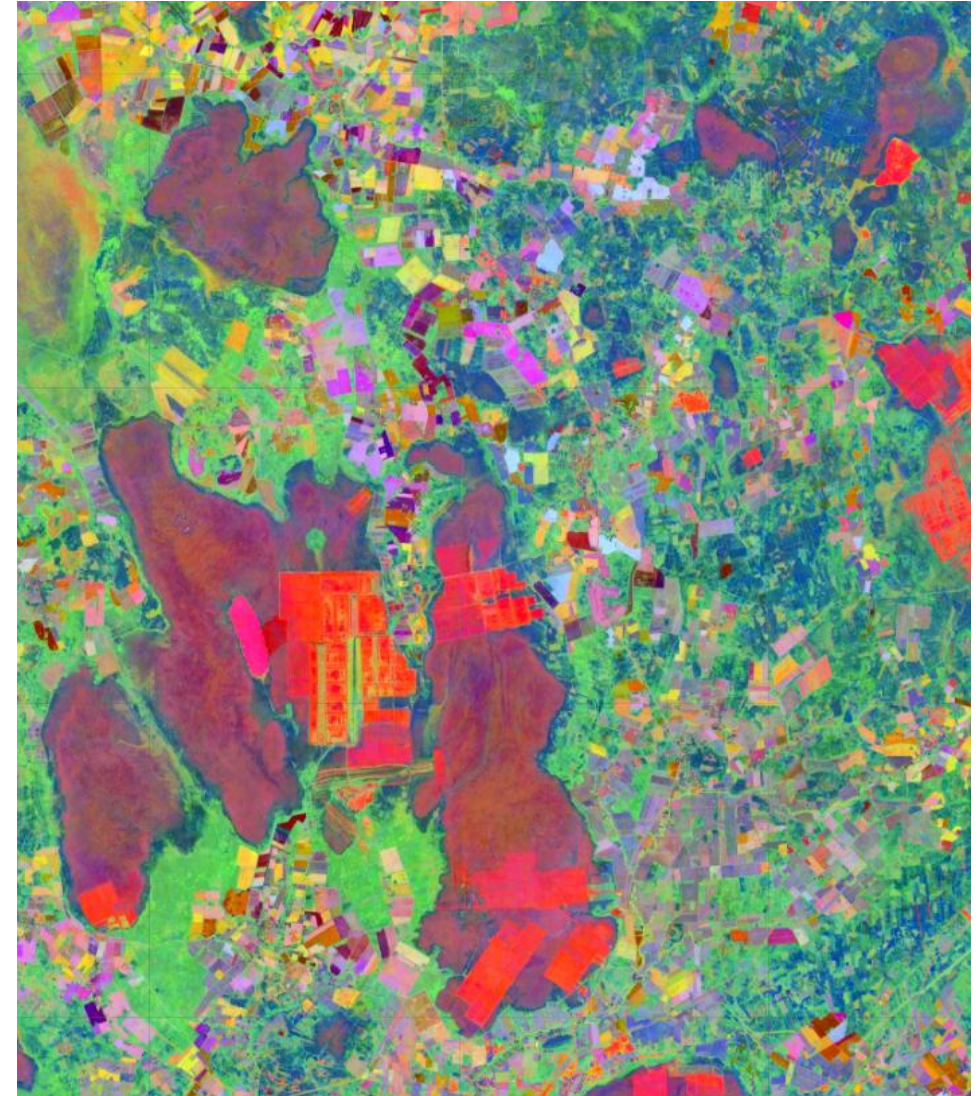
- Data accessed through Google Earth Engine
- PCA reduced the high-dimensional Sentinel time series into a set of meaningful variables
- PCs capture the main patterns in space and time.

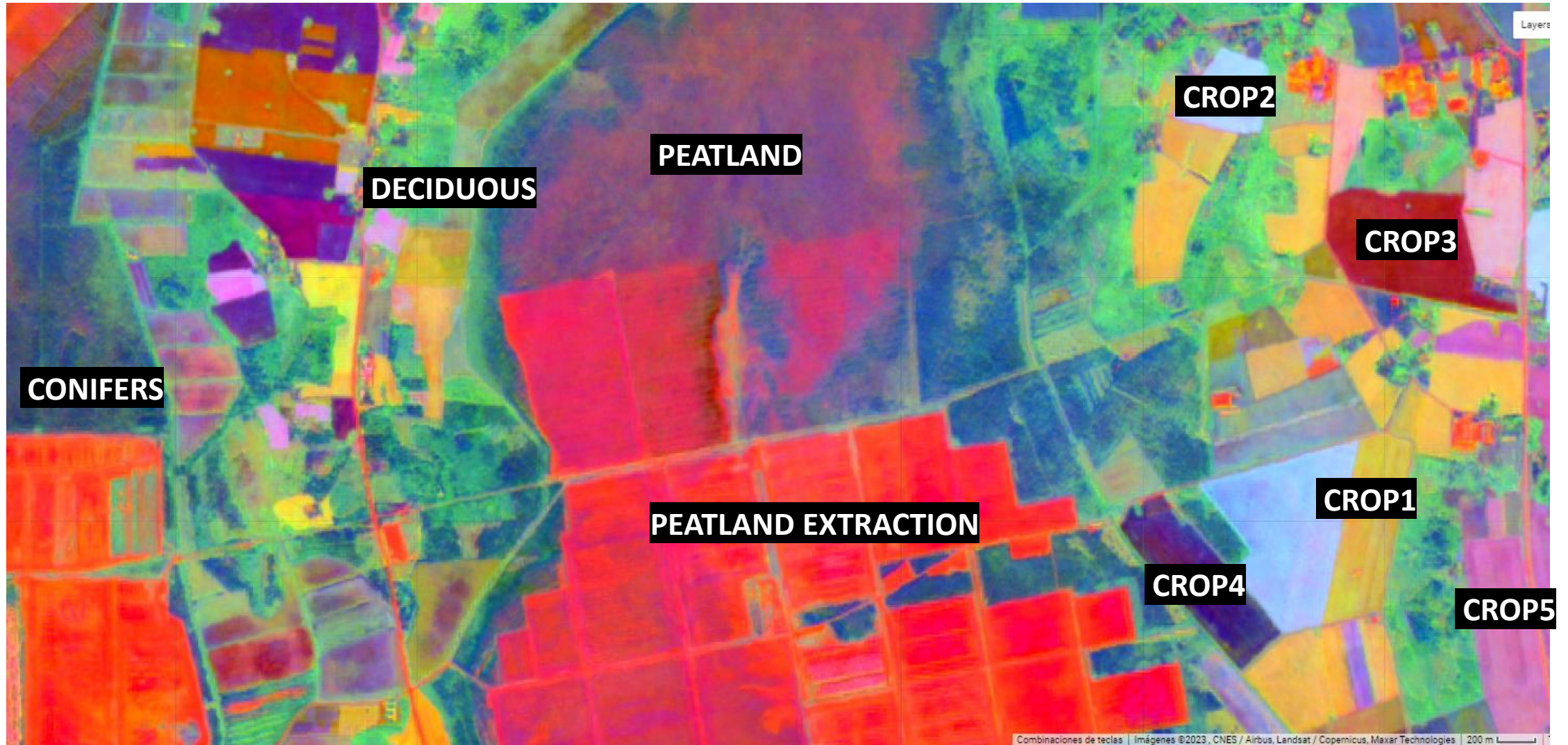
Sentinel-2 time series - 2020



PCA
➔

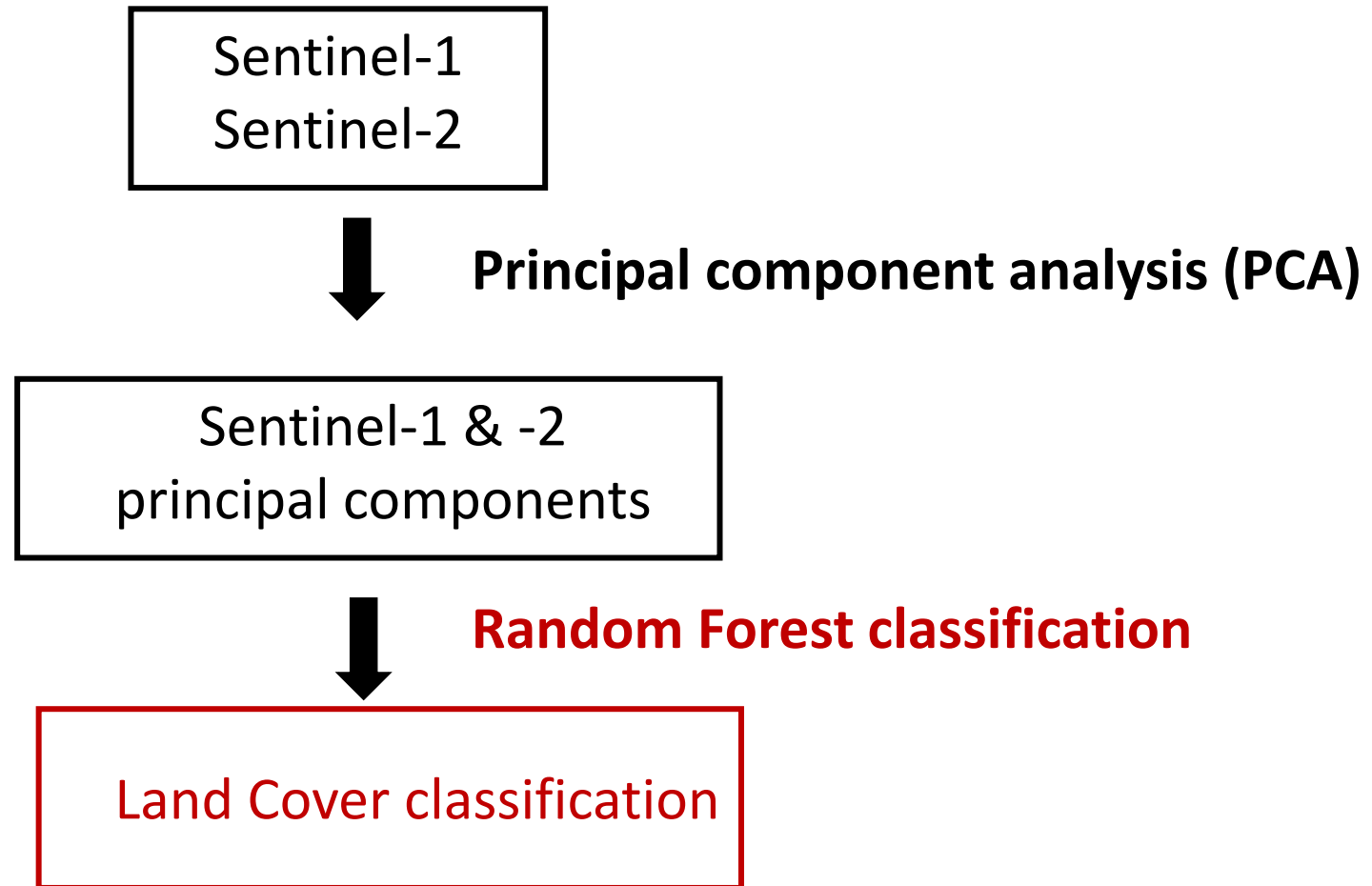
Principal components #1, 2, and 3 - 2020





Principal components show spatial and temporal patterns that help identify land-cover types

Overview of the methodology: 2) Supervised classification



Validation: Satellite imagery alone is not enough

Region name	OA1 (%)
Northern Finland	70.0
Southern Finland	60.1
Estonia	54.4
Latvia	51.5
Germany	46.2
Belgium	67.0
Pyrenees	84.8

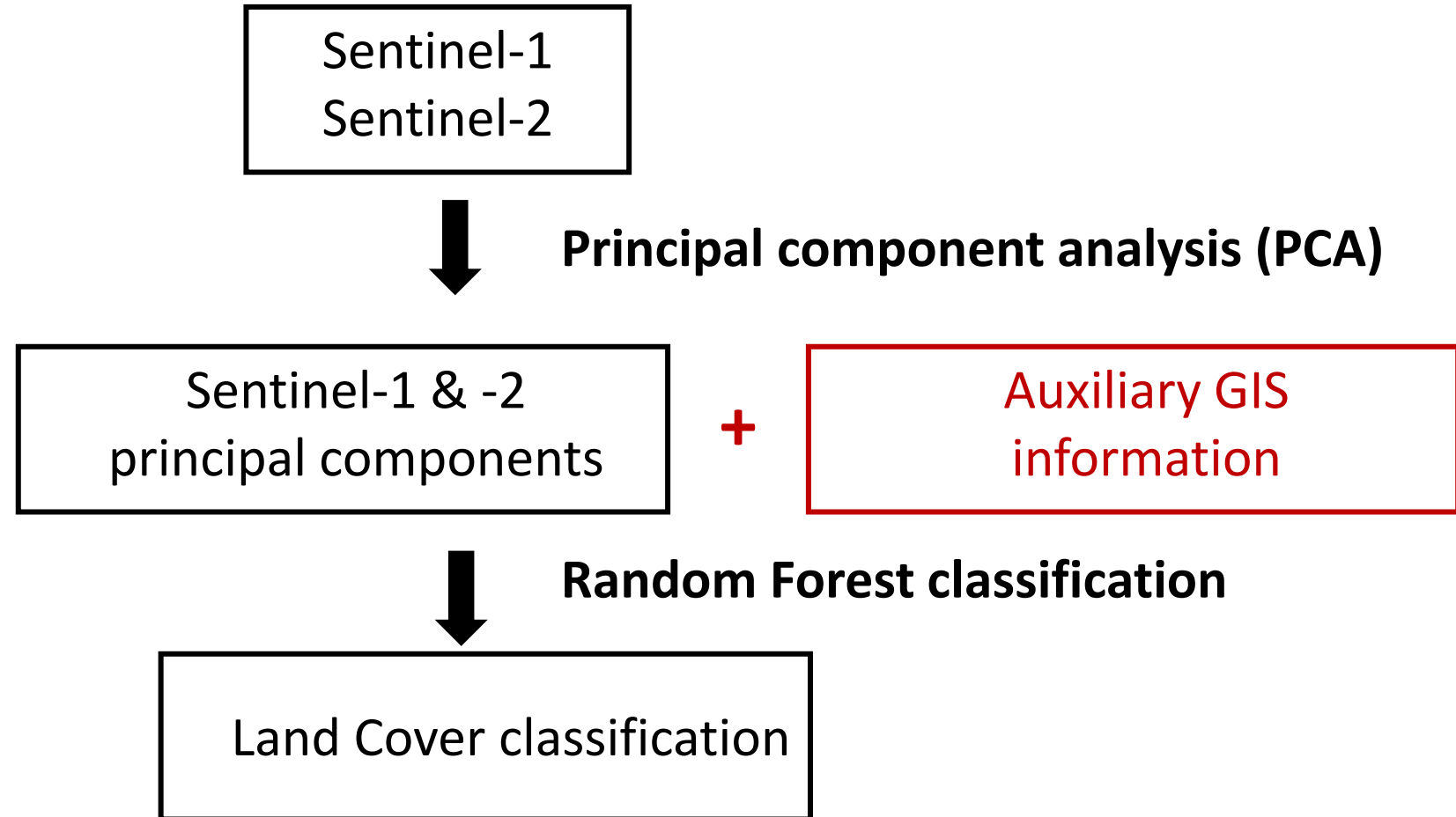
OA1 = Only considers spectral data

Mean overall accuracy was 62% across Living Labs.

Overall accuracy (OA) = percentage of validation samples correctly classified.

Spectral and temporal information alone is not sufficient
for accurate maps across regions.

Overview of the methodology: 3) Adding auxiliary data



Added auxiliary data as input variables of the Random Forest

Auxiliary GIS information

COMMON DATASETS

All 7 Living Labs

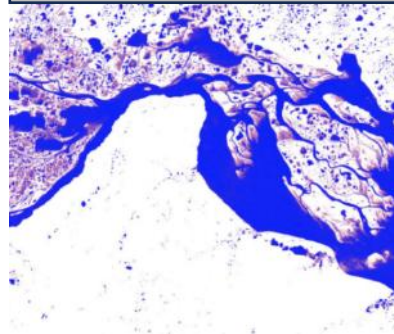
- Surface water
- Forest cover
- Canopy height
- Topography

SITE-SPECIFIC DATA

- Peat/soil maps
- Drainage status
- Forest types
- Local LULC (Restored peatland)
- Management data

Environmental and spatial context that improves the accuracy of the Random Forest

JRC Surface Water



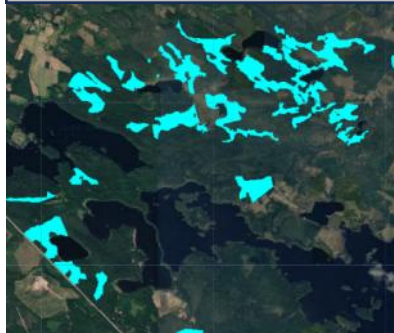
Hansen Forest loss



Lang Canopy Height



Restored peat - S.FIN



Peat soils - EST



Forested peat - DEU



Validation: Overall accuracy across different input-data combinations

Region name	OA1 (%)	OA2 (%)	OA3 (%)	OA4 (%)	OA5 (%)	OA6 (%)
Northern Finland	70.0	73.1	70.2	74.5	90.4	93.1
Southern Finland	60.1	66.2	62.8	64.3	90.2	92.7
Estonia	54.4	58.8	56.9	62.6	83.3	85.8
Latvia	51.5	54.7	52.3	58.3	64.7	70.6
Germany	46.2	53.5	45.3	47.3	58.7	62.5
Belgium	67.0	69.4	69.0	69.8	73.2	75.7
Pyrenees	84.8	90.0	86.4	94.6	NA*	96.0

OA1 = Only considers spectral data

OA2 = Only considers spectral data + topography

OA3 = Only considers spectral data + canopy height model

OA4 = Only considers spectral data + global land cover maps

OA5 = Only considers spectral data + local auxiliary data

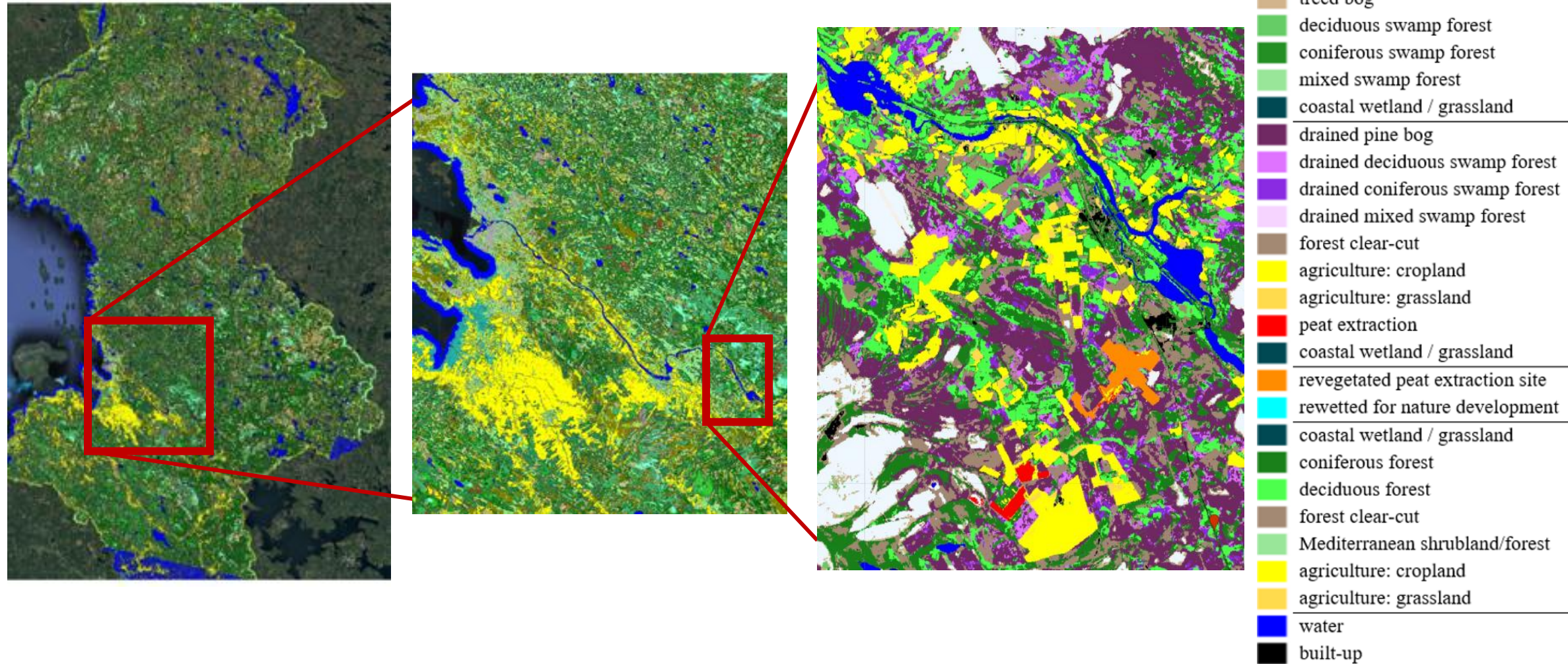
OA6 = Considers spectral and all auxiliary data

*No local auxiliary data was used.

Adding environmental context substantially improves overall accuracy

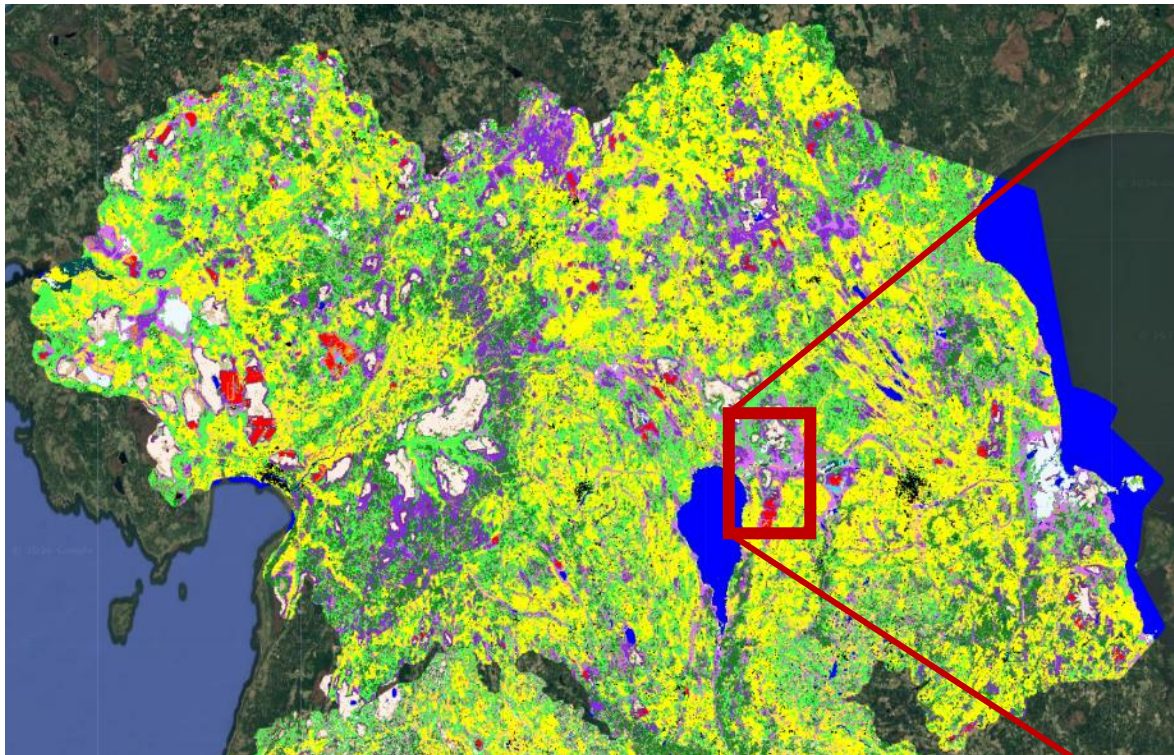
Results of the land cover classification – Northern Finland

Overall Accuracy: 93.1%



Results of the land cover classification – Estonia

Overall Accuracy: 85.8%



- | | |
|--|----------------------------------|
| | fen |
| | bog |
| | treed bog |
| | deciduous swamp forest |
| | coniferous swamp forest |
| | mixed swamp forest |
| | coastal wetland / grassland |
| | drained pine bog |
| | drained deciduous swamp forest |
| | drained coniferous swamp forest |
| | drained mixed swamp forest |
| | forest clear-cut |
| | agriculture: cropland |
| | agriculture: grassland |
| | peat extraction |
| | coastal wetland / grassland |
| | revegetated peat extraction site |
| | rewetted for nature development |
| | coastal wetland / grassland |
| | coniferous forest |
| | deciduous forest |
| | forest clear-cut |
| | Mediterranean shrubland/forest |
| | agriculture: cropland |
| | agriculture: grassland |
| | water |
| | built-up |

Land cover mapping in ALFAwetlands (**WP1**; T1.2 & **T1.3**).

Two mapping products:

	Satellite data	Spatial resolution	Thematic classes
Land Cover 2020	Sentinel-1 & -2	10 m	27
 Land Cover Change 1985-2023	Landsat -5, -7, -8 & -9	30 m	8

Detailed present-day mapping & Long-term change detection

Thematic classes aggregated into broader categories

LULC class name (for detailed Sentinel LULC classification, 2020)	Soil type	Drainage status	LULC class name (for generalised Landsat LULC classification, 1985–2023)	
fen	peat	undrained	open peatland	
bog	peat	undrained	open peatland	
treed bog	peat	undrained	open peatland	
deciduous swamp forest	peat	undrained	forest	
coniferous swamp forest	peat	undrained	forest	
mixed swamp forest	peat	undrained	forest	
coastal wetland / grassland	peat	undrained	open peatland	
drained pine bog	peat	drained	forest	
drained deciduous swamp forest	peat	drained	forest	
drained coniferous swamp forest	peat	drained	forest	
drained mixed swamp forest	peat	drained	forest	
forest clear-cut	peat	drained	clear-cut	
agriculture: cropland	peat	drained	agriculture	
agriculture: grassland	peat	drained	agriculture	
peat extraction	peat	drained	peat extraction	
coastal wetland / grassland	peat	drained	agriculture	
revegetated peat extraction site	peat	restored	low vegetation	
rewetted for nature development	peat	restored	low vegetation	
coastal wetland / grassland	mineral	NA	agriculture	
coniferous forest	mineral	NA	forest	
deciduous forest	mineral	NA	forest	
forest clear-cut	mineral	NA	clear-cut	
Mediterranean shrubland/forest	mineral	NA	low vegetation	
agriculture: cropland	mineral	NA	agriculture	
agriculture: grassland	mineral	NA	agriculture	
water	NA	NA	water	
built-up	NA	NA	built-up	

Land cover classes

- 0. open peatland
- 1. forest
- 2. low vegetation
- 3. agriculture
- 4. clear-cut
- 5. peat extraction
- 6. water
- 7. built-up

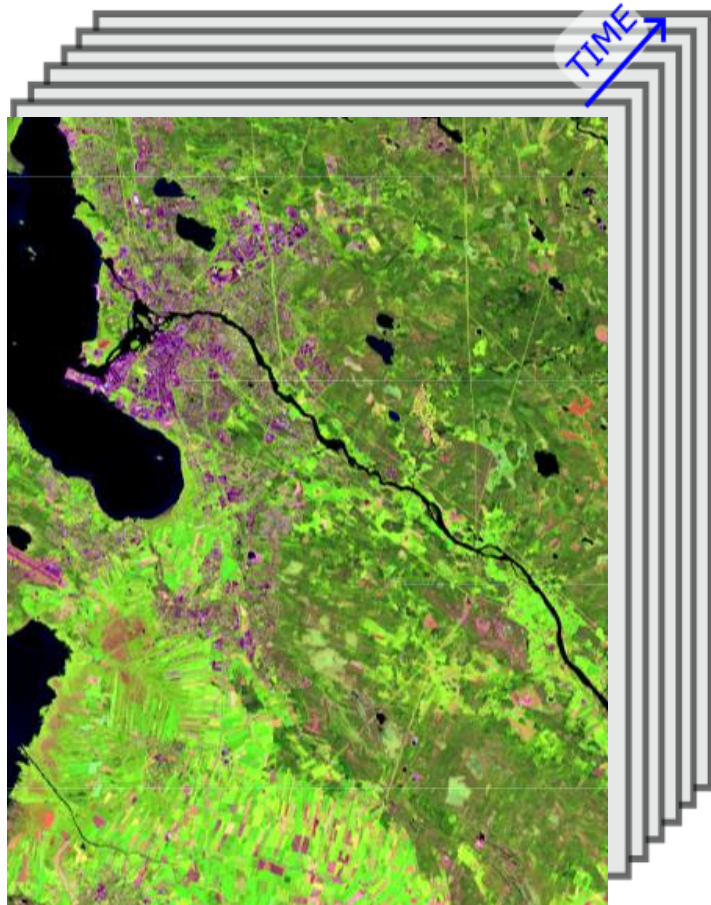
- Detailed long-term mapping was not possible as auxiliary data were not available from 1985.



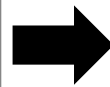
- We aggregated the classes into 8 broader categories for the Landsat analysis.

Results of land cover change classification

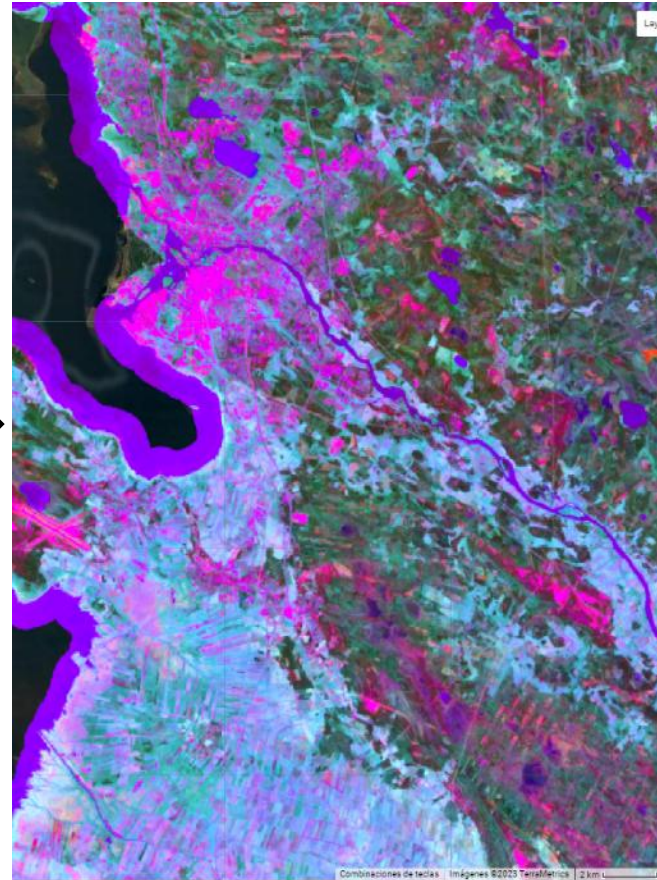
Landsat-5, -7, -8, & -9 time series



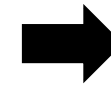
PCA



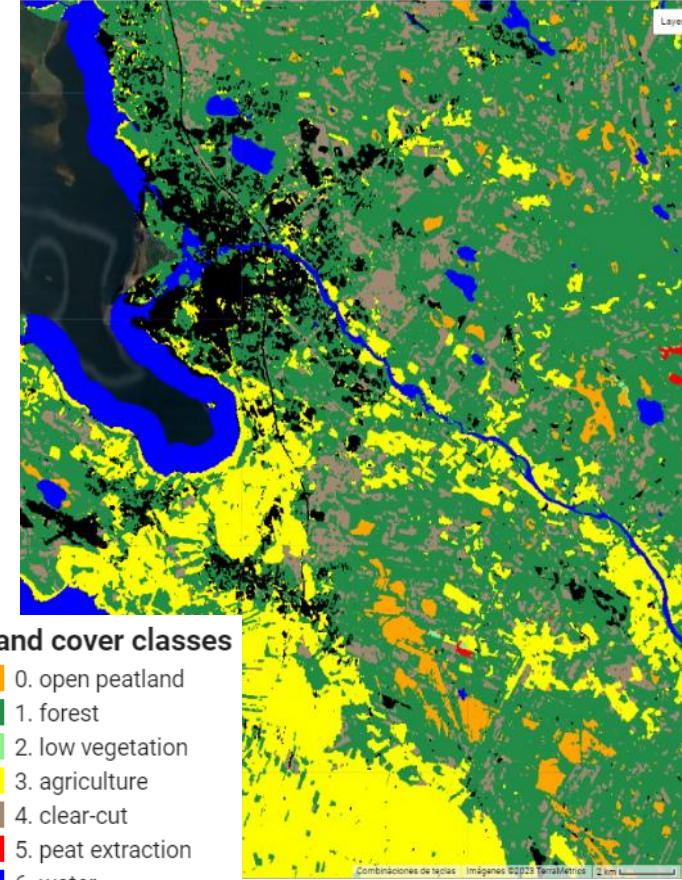
PCA image (5-year interval)



Random
Forest



5-year LULC (1985-2023)

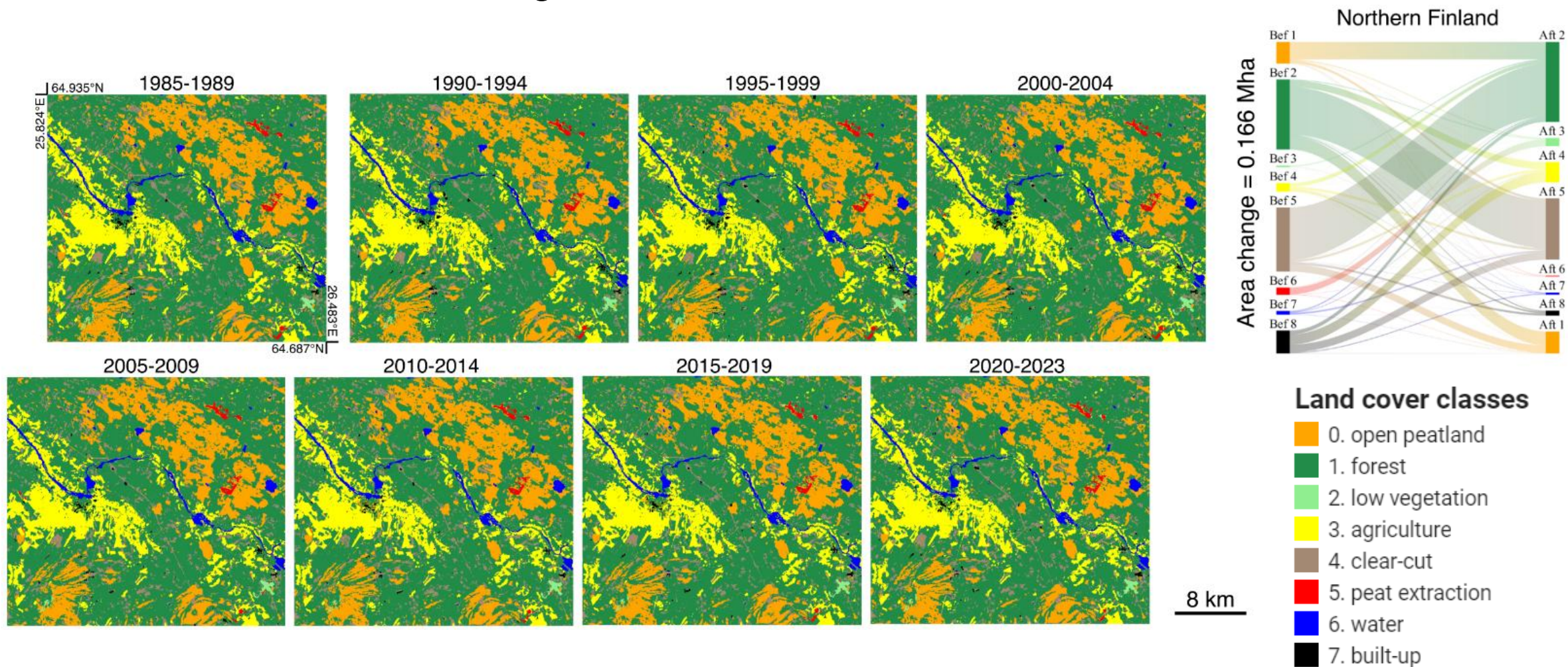


Land cover classes

- 0. open peatland
- 1. forest
- 2. low vegetation
- 3. agriculture
- 4. clear-cut
- 5. peat extraction
- 6. water
- 7. built-up

Land surface phenology aggregated over 5-year intervals

Results of land cover change classification



Spatial view of four decades of land-cover change at **30-m resolution**

Key Takeaways

- **The final classification provides detailed, consistent land-cover maps** across the study regions.
- **Spectral information alone is not sufficient** for robust land-cover classification across diverse regions.
- **Auxiliary environmental information substantially improved accuracy.** It provided ecological and spatial context for the Random Forest.
- **Landsat enables reconstruction of land-cover patterns over four decades,** at 30 m, from 1985 to 2023, but only for **broad thematic classes.**

THANK YOU

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