

From Land Cover to Land Use: A Remote Sensing–Based Map of Forest Area in Europe

StatEO 2026

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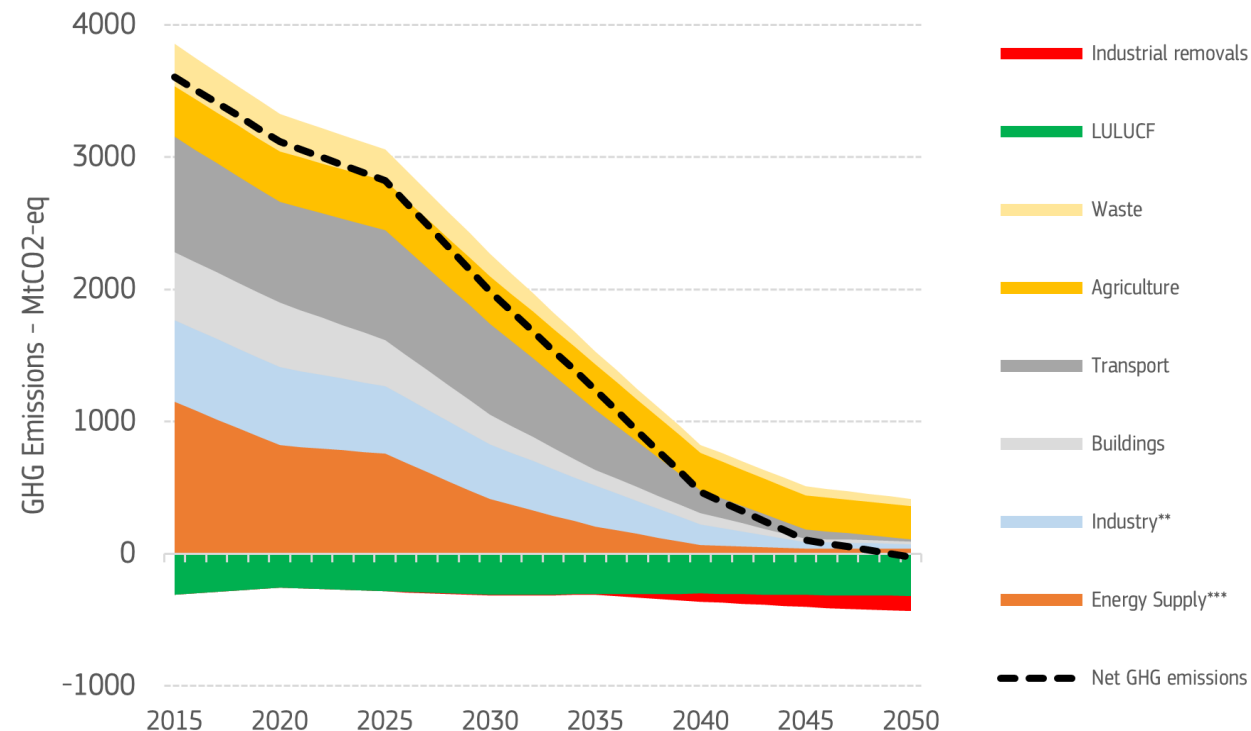
Forests in the EU climate targets

The role of the **forest CO2 sink** is expected to grow progressively over time.



Accurate, long-term **tracking of forest extent** is needed.

Greenhouse gas emissions in the period 2015-2050*



*Source: PRIMES, GAINS, GLOBIOM

**Excluding non-BECCS industrial removals

***Including Bioenergy with carbon capture and storage (BECCS)



Forest Extent Monitoring

Tools

Remote sensing

- Maps forest cover

National Forest Inventories (NFI)

- Classify land by use and management



Evolving Forests

- Forest disturbance regimes in Europe are intensifying and shifting.
- Harvest rates are increasing.
- Increasing unstocked forests.

Challenge

Remote sensing cannot capture **unstocked forests**.



Land Cover Vs Land Use

Misinterpreting forest change

- **Forest cover loss \neq forest loss.**
- Temporary disturbances can be mistaken for deforestation.
- This can lead to underestimation of forest area and overestimation of forest loss.



How to identify unstocked forests:

- Use **time series analysis** to assess past and present conditions.
- Detect changes in land use over time.



Objectives

Method

- Develop a framework to **map forest area**, capturing both stocked and temporarily unstocked forests .

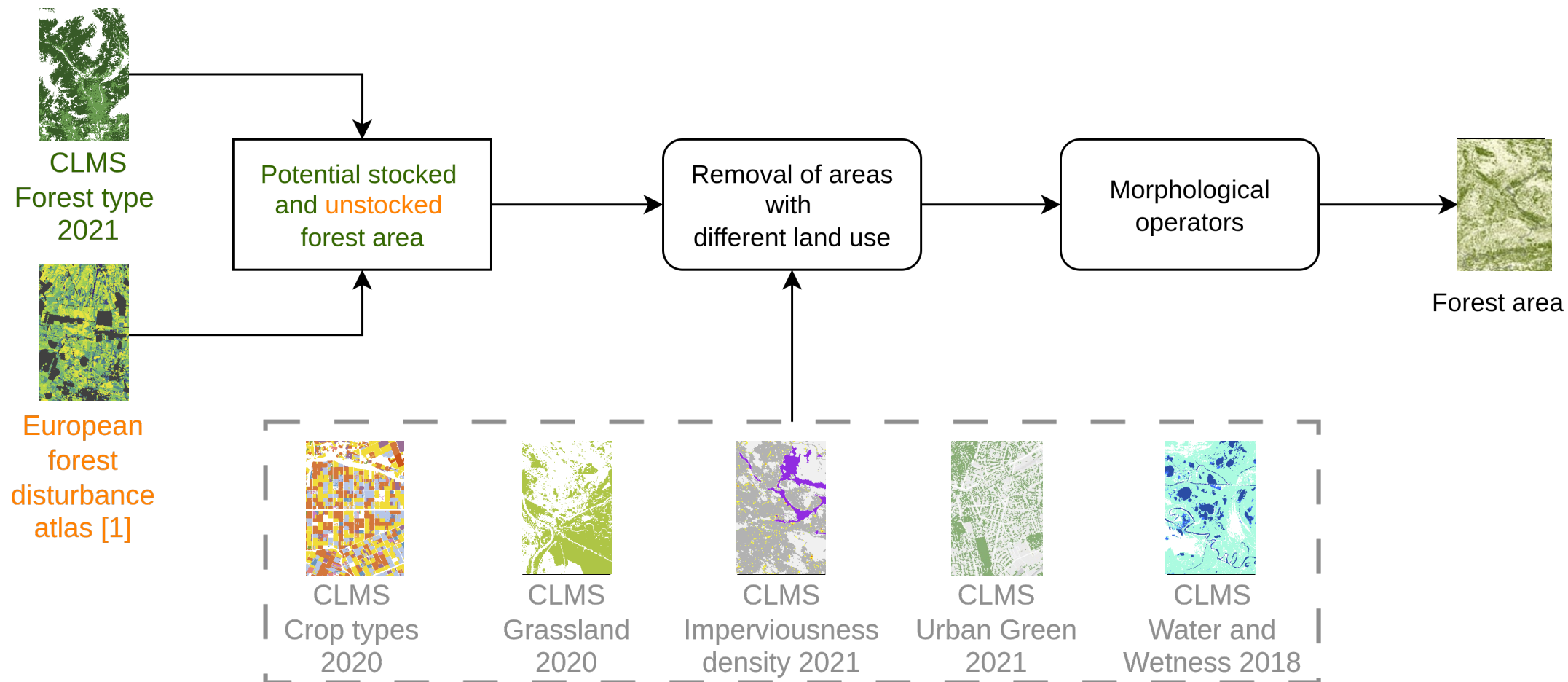
Data

- Rely primarily on Copernicus Land Monitoring Service (CLMS) High Resolution Layers.

Validation

- Validate the forest area product using National Forest Inventory (NFI) data from European countries.
- Quantify the contribution of each product to the final forest area map.

Method



6 [1] Viana-Soto, Alba, and Cornelius Senf. "The European Forest Disturbance Atlas: a forest disturbance monitoring system using the Landsat archive." *Earth System Science Data*, 2025.



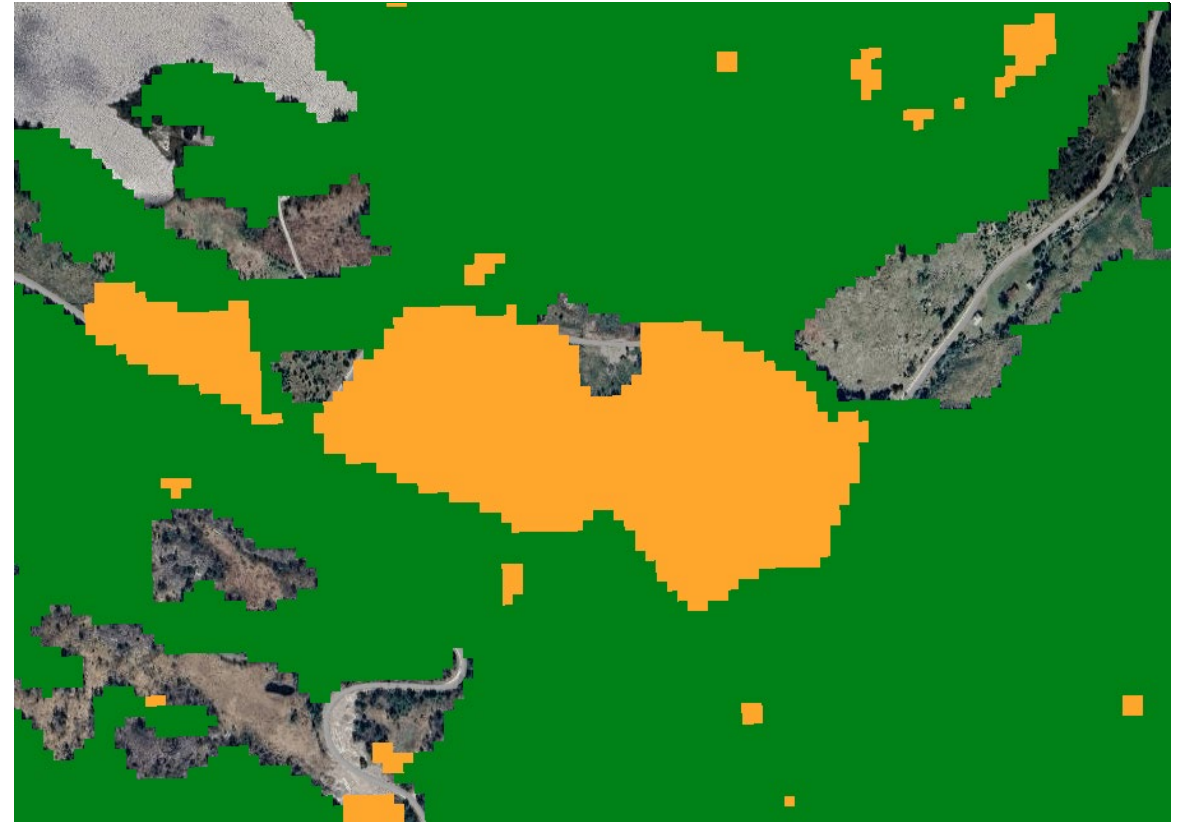
Potential Stocked and Unstocked Forest Area

Current forest cover

- Currently stocked forest as mapped by the CLMS forest type product.

Potential forest area

- Areas not classified as forest cover but **identified as disturbed in the 30 years** preceding the reference year.
- Either unstocked forest (i.e., without land-use change) or areas that have experienced land-use change.



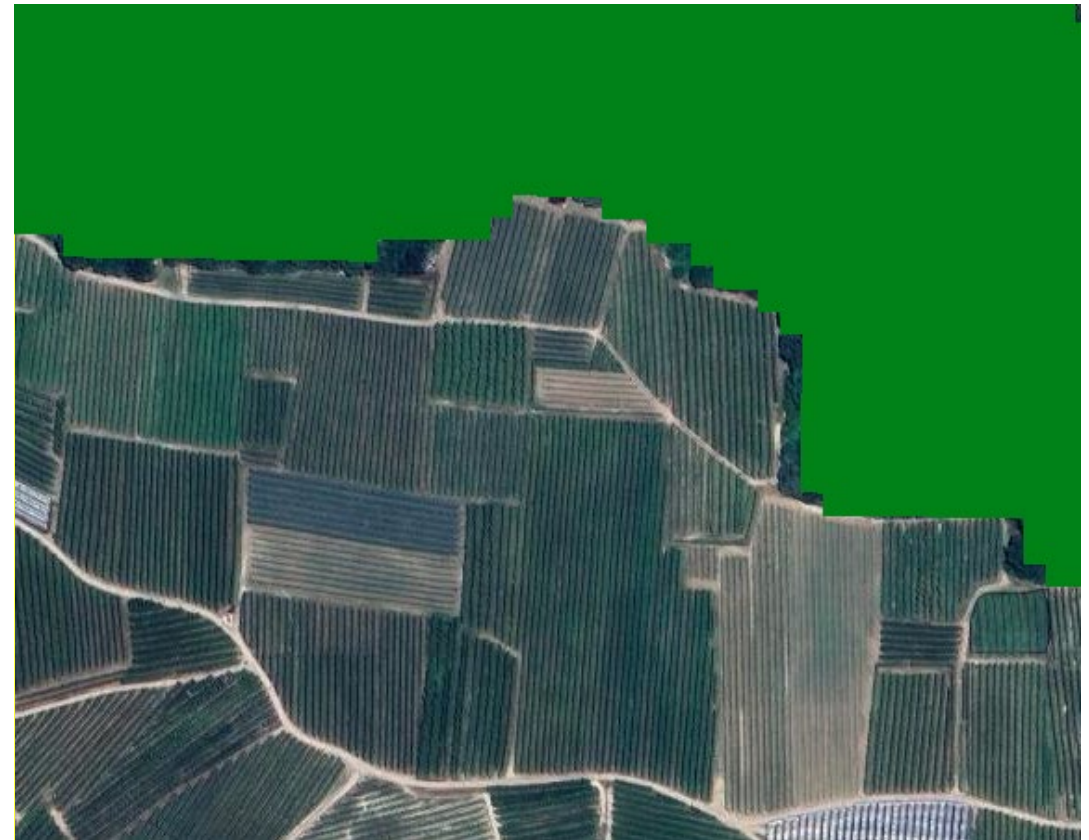
Land Use Change

Objective

- Distinguish true forest areas from areas affected by land-use change.

Approach

- Exclude areas classified under **different land-use or land-cover** by CLMS products.
- Apply the procedure **across the entire study area** to ensure coherence between the final product and the CLMS portfolio.



Validation

Questions


- *Where did this result come from?*
- *Which steps helped or hindered performance?*

Provenance

- Record the **full sequence of decisions** applied to each pixel as a binary string, then convert it to an integer (provenance ID).
- To ensure the confidentiality of plot coordinates, the provenance map was shared with NFI managers, who sampled it and returned aggregated results in terms of TP, TN, FP, and FN by provenance ID.

Example of a pixel classified as disturbed potential forest area but then removed due to land use change to urban area.

	Operation Description	Decision
1	CLMS Forest Type	NO
2	Is it a disturbed area?	YES
3	Is it an agricultural area?	NO
4	Is it a grassland?	NO
5	Is it a built up area?	YES
6	Is it a green area?	NO
7	Is it a water body?	NO
8	Is it below minimum mapping unit?	NO
9	Is this a hole within a forest patch?	NO

 Not forest area

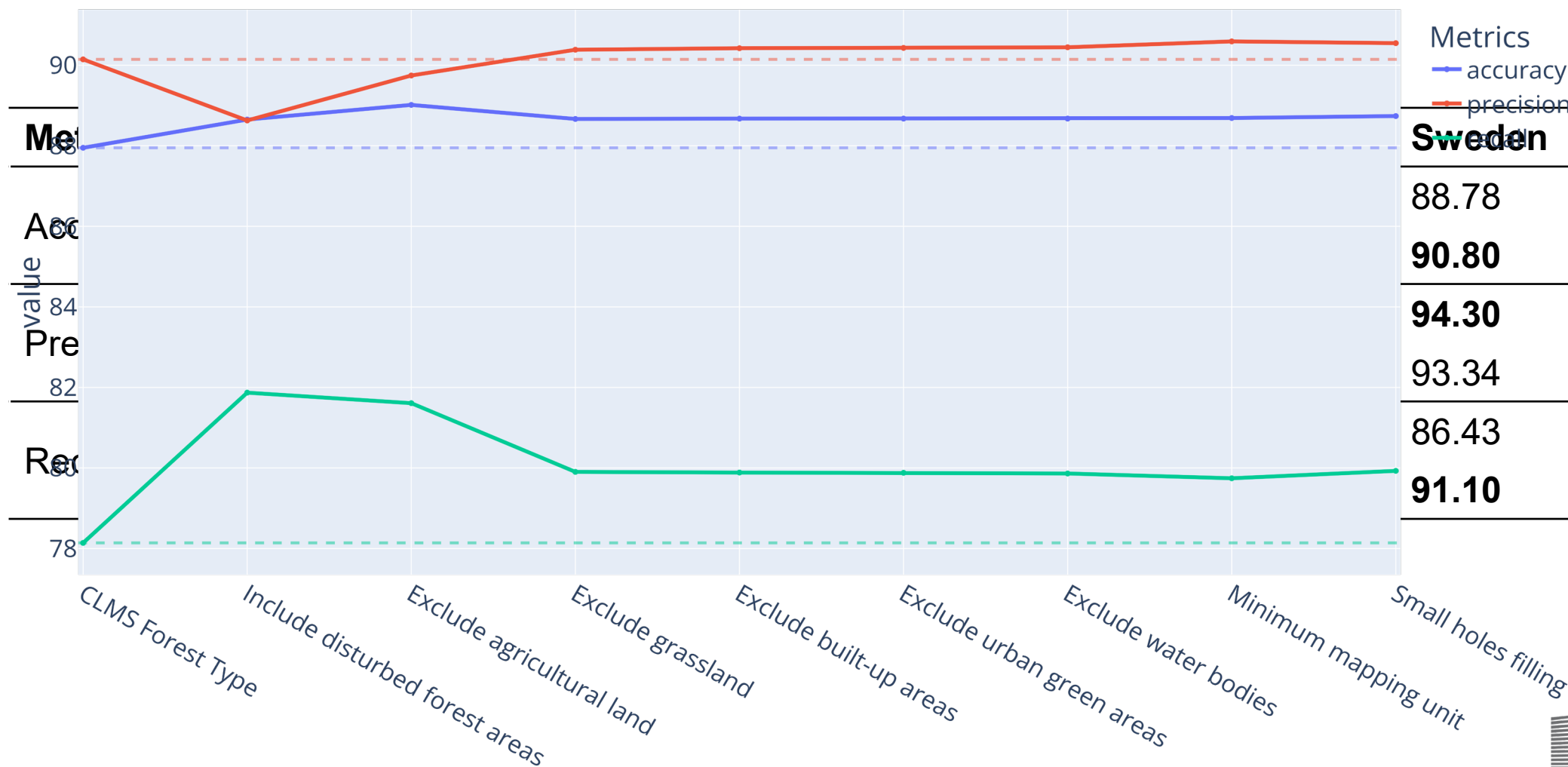
 Forest area



Results

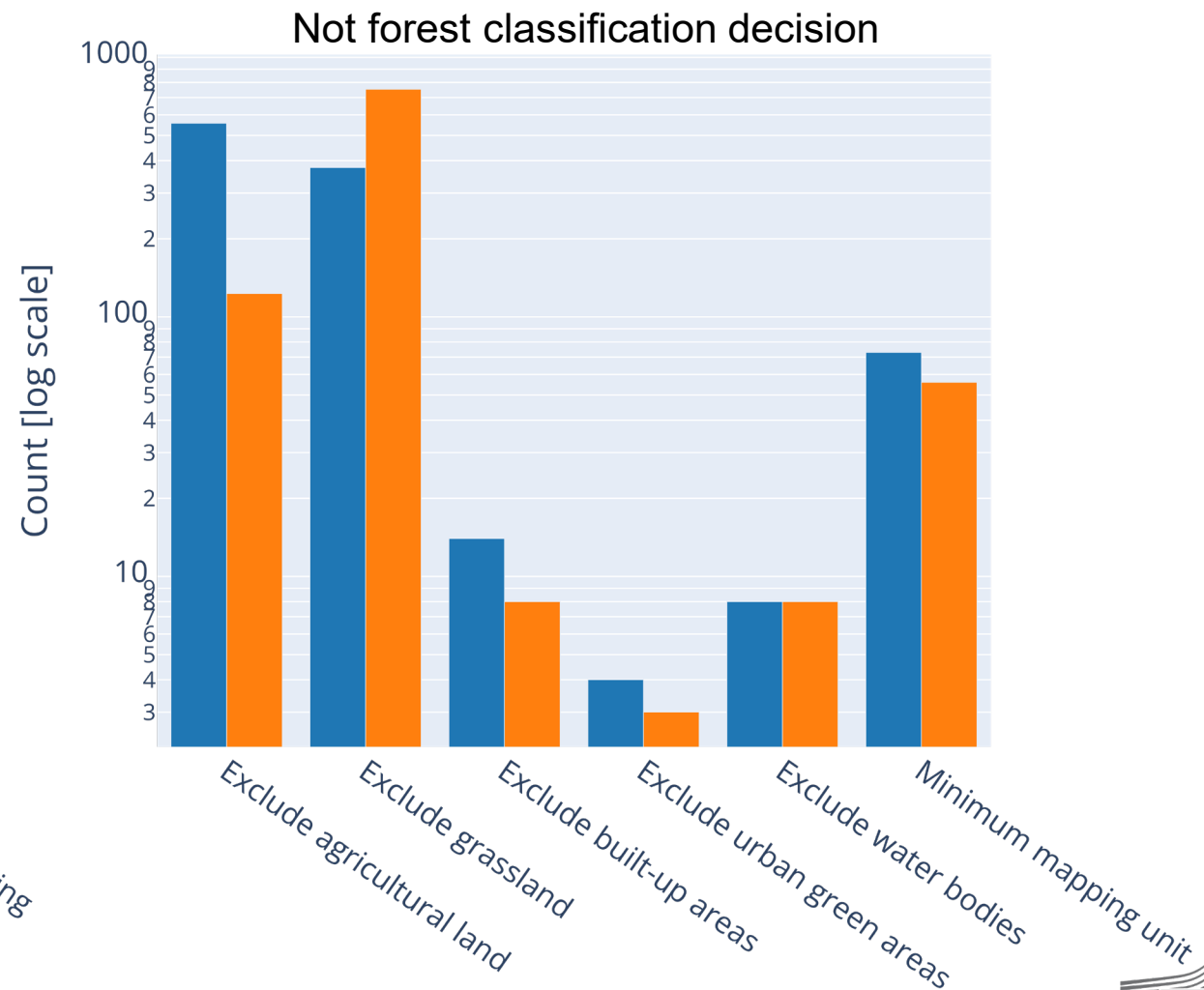
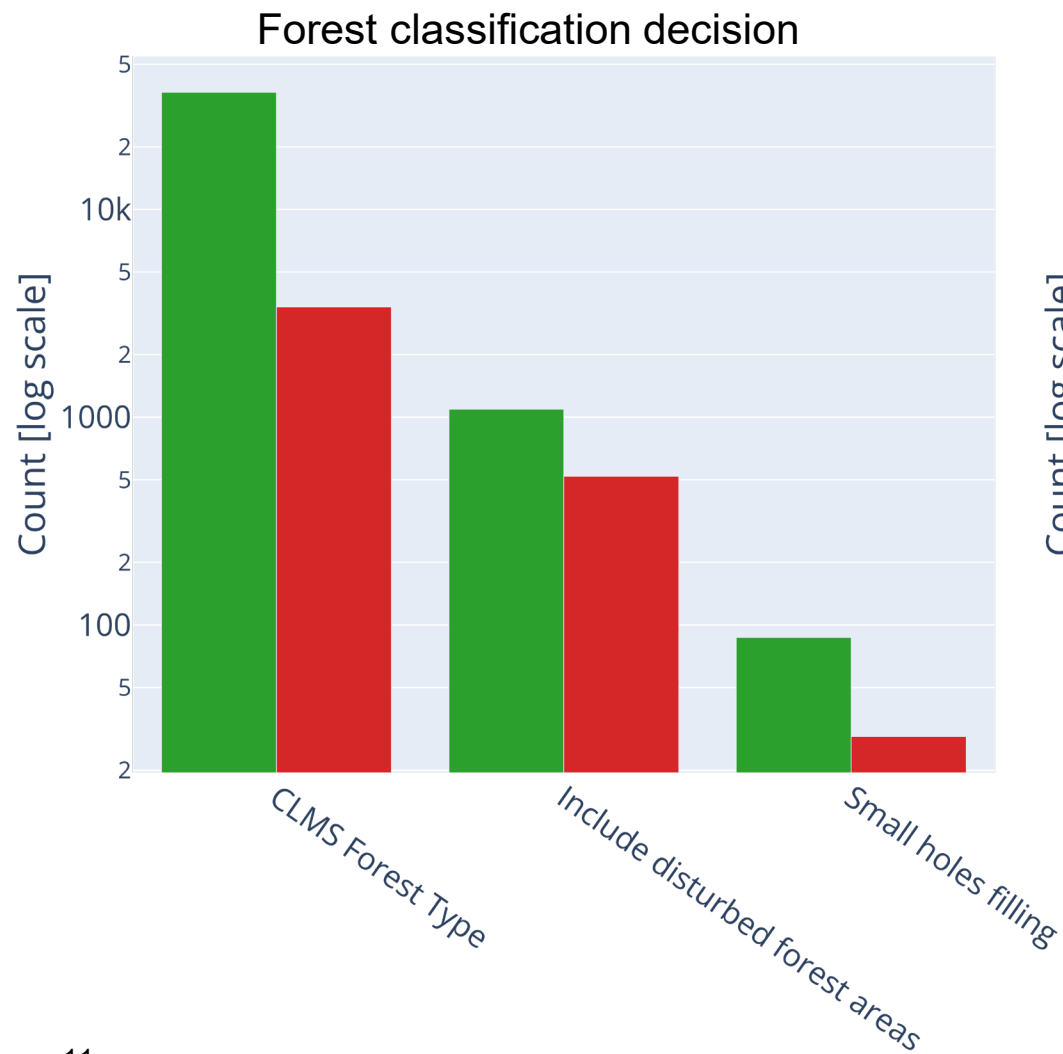
Precision = TP / (TP+FP)

Recall = TP / (TP+FN)






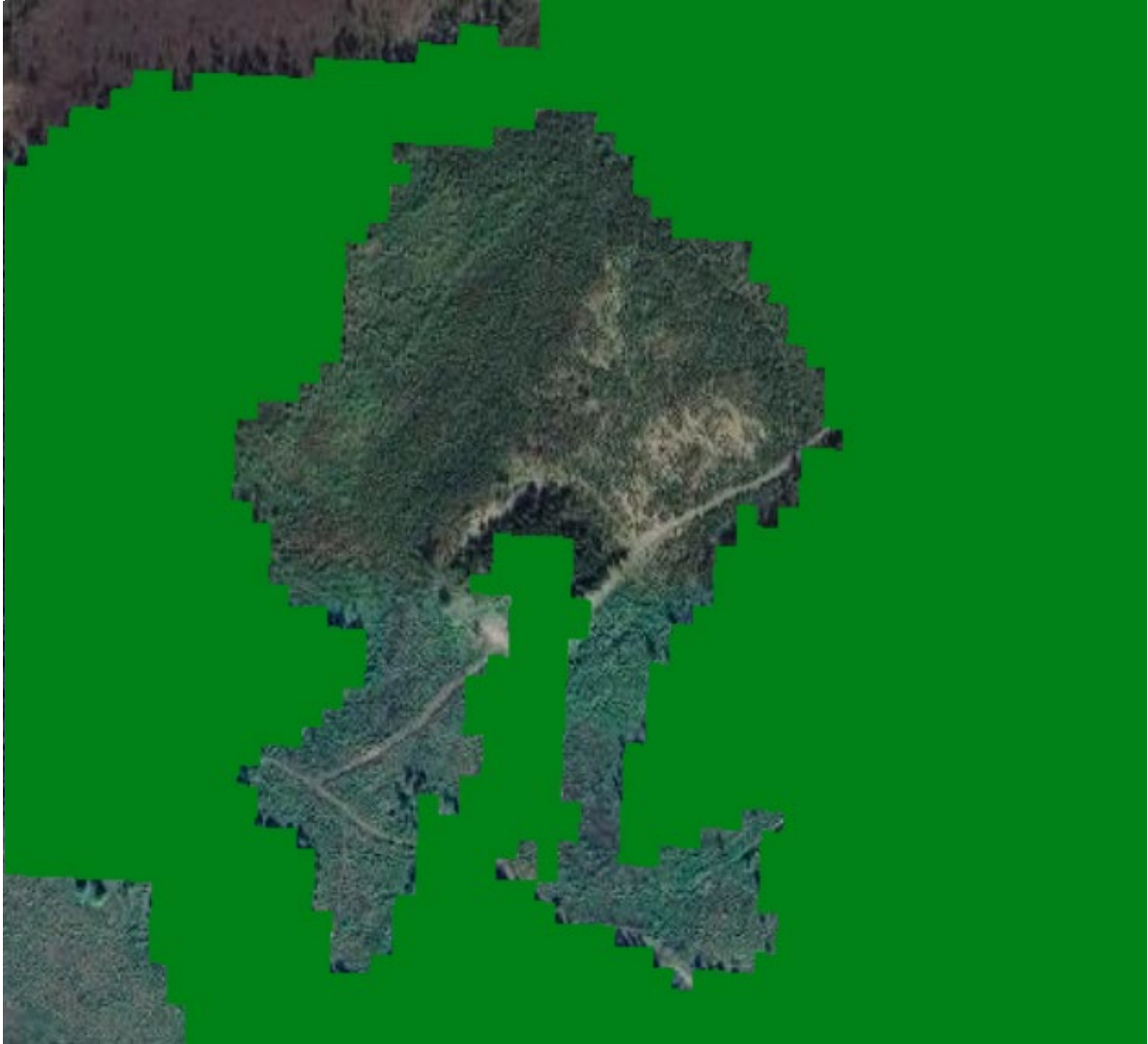
Results: Products Contribution

■ TP ■ FP ■ TN ■ FN



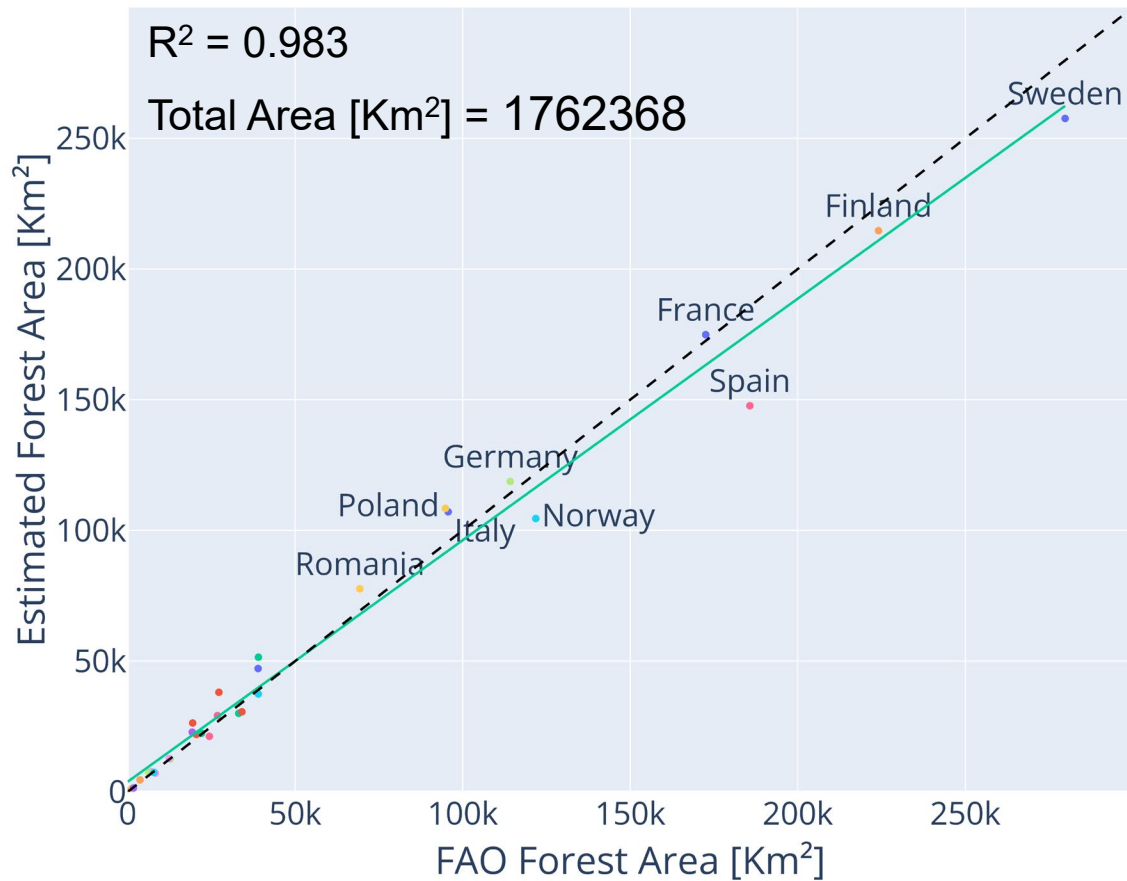
Results: Grassland Error Example

-  Forest cover
-  Disturbed areas
-  Grassland

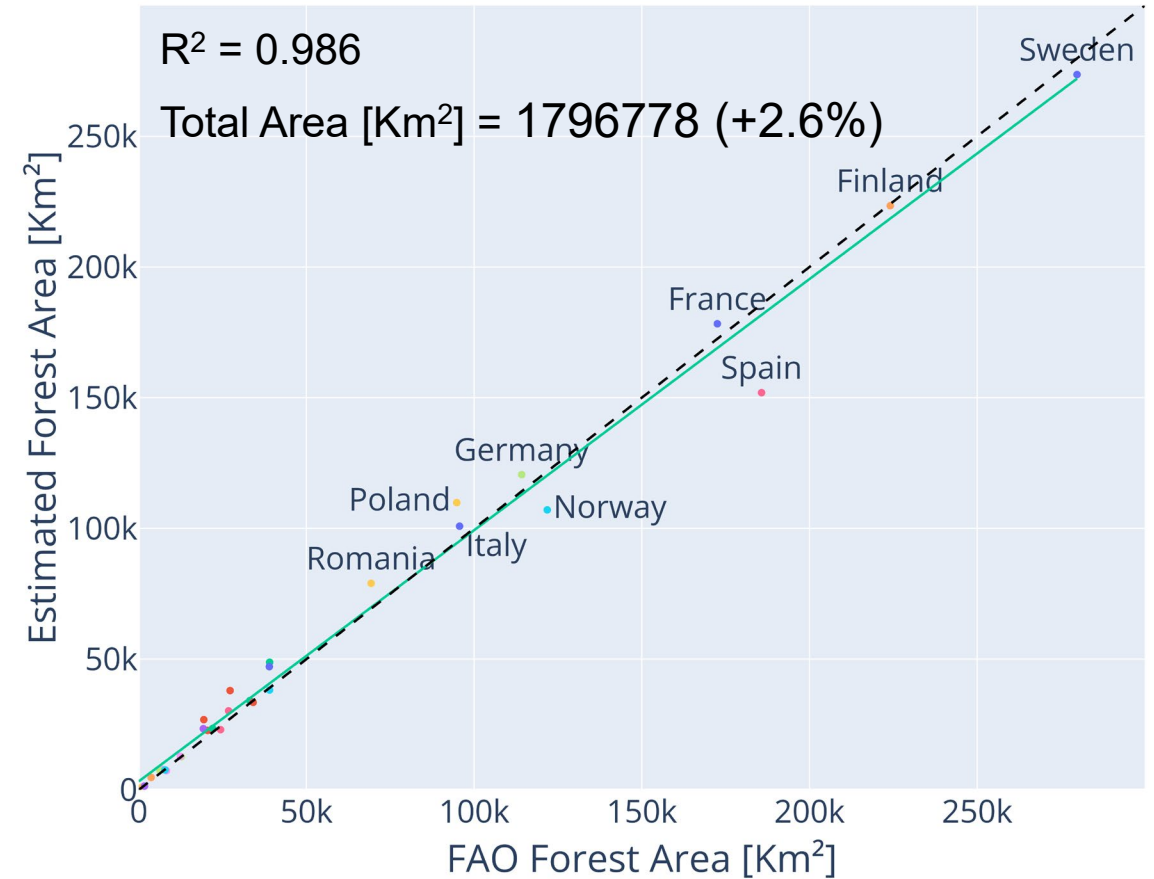


Results: Area Estimates

CLMS Forest Type



Proposed Forest Area Product



Conclusion

- Developed a framework to **map forest area** (both stocked and unstocked) by integrating temporal information through a historic disturbance product.
- The estimated forest area shows a **+2.6% increase** compared to existing forest cover products, improving recall while keeping stable precision.

Limitations

- Results are dependent on the **quality of input datasets**.
- Land cover products (e.g., grassland) can introduce systematic errors.
- The disturbance Atlas 30 m resolution often misses small disturbed areas.

Future Developments

- The framework is modular and can be easily updated as new datasets become available.
- Integrating **higher-resolution disturbance data** (e.g., Sentinel-2).



Thank you

Google
Earth Engine
App

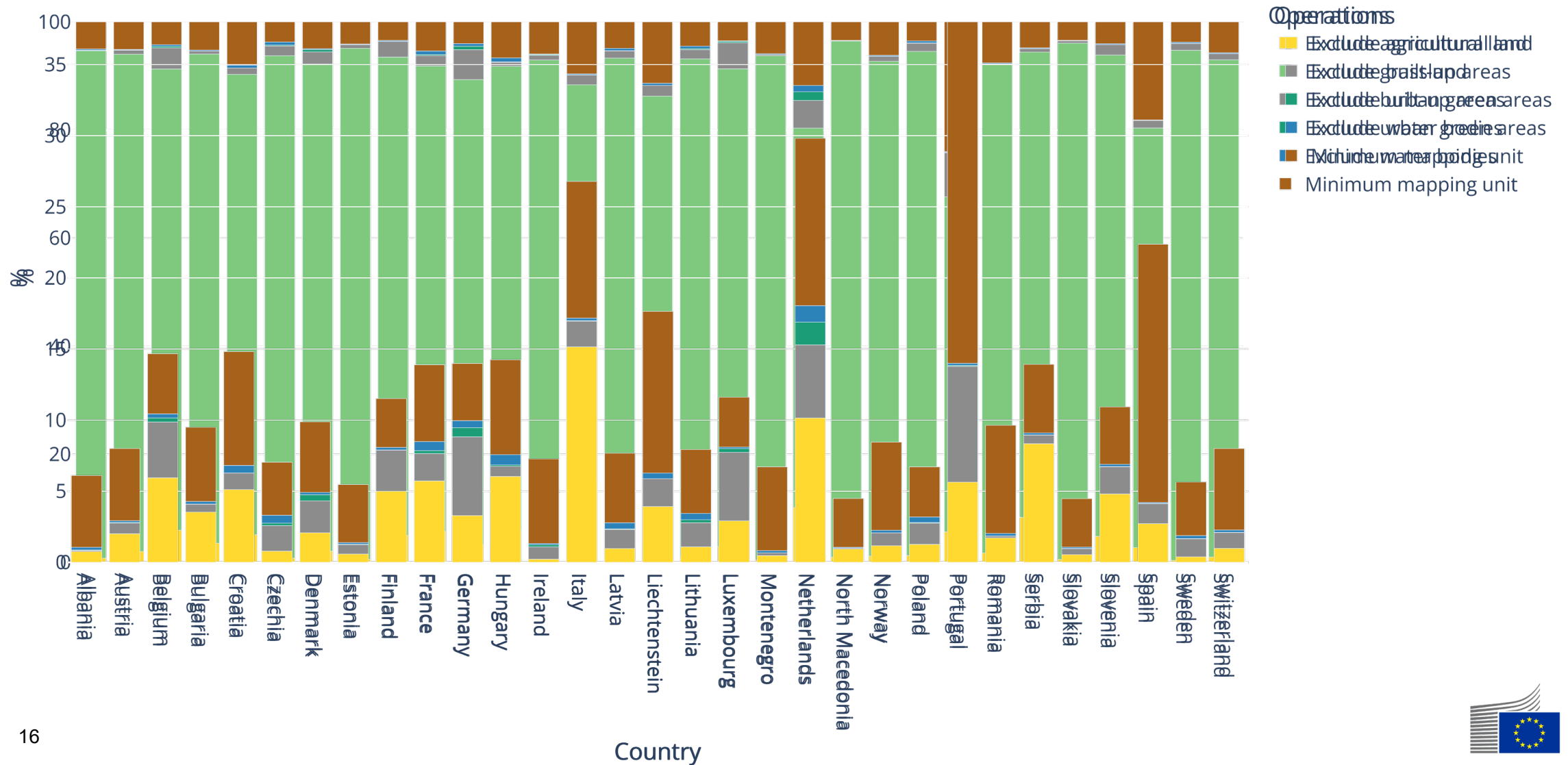


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Results: Disturbance to land use change



Percentage of unsotcked forest

