Statistical calibration of land cover changes in CLMS CLCplus Backbone time-series

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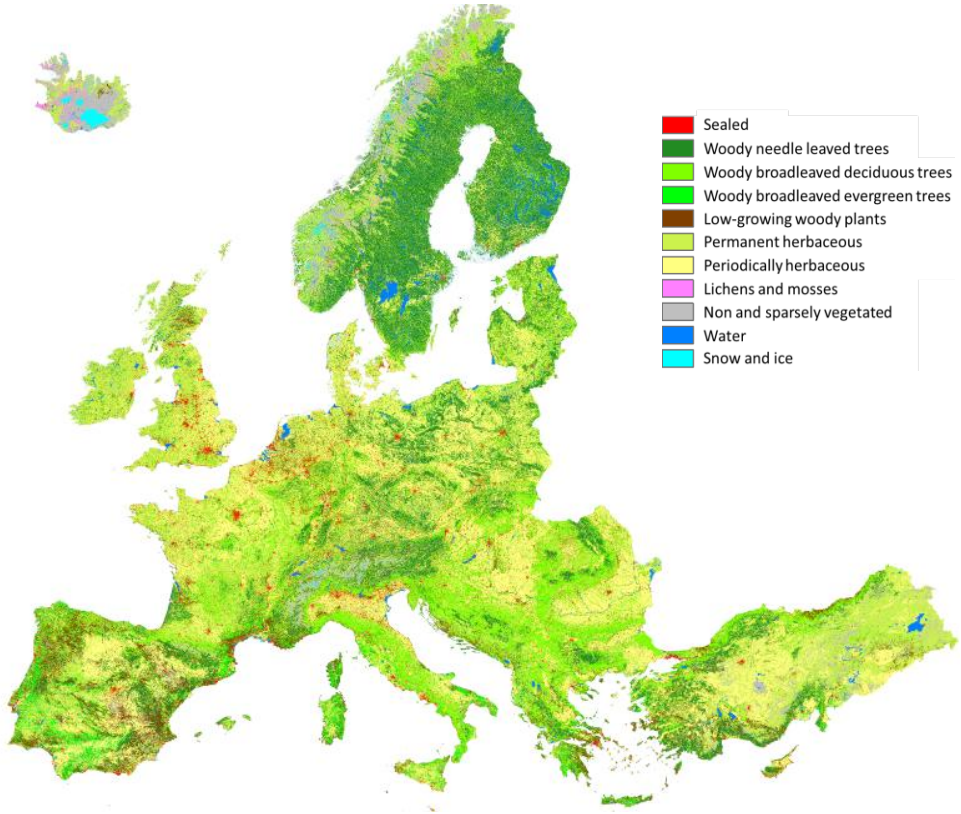
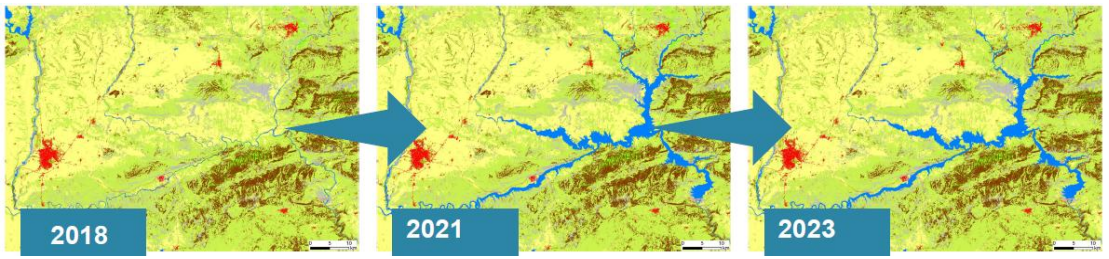
Project: CLCplus Backbone Raster 2023 & 2025 (EEA/DIS/R0/23/013)

Background – CLCplus Backbone Raster

- Land cover raster product with gapless 11-class nomenclature
- Produced for the area of the EEA38 + UK (and including the French DOMs)
- Spatial resolution: 10m (pixel-based, i.e. MMU = 1pixel = 100m²)
- Target overall accuracy ≥ 90% (and ≤15% omission and commission errors per class)
- Available for the reference years 2018, 2021, 2023
- Use cases: policy support (i.e. LULUCF, NRR), Environmental Monitoring, Climate Change Studies, or Research & Education
- Production ongoing for 2025, parallel consultancy task to explore feasibility of statistical calibration of changes



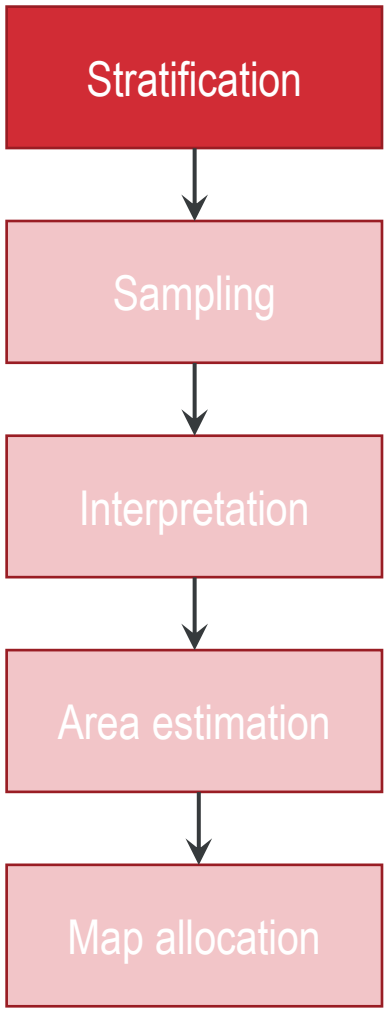


More information here: https://land.copernicus.eu/en/products/clc-backbone

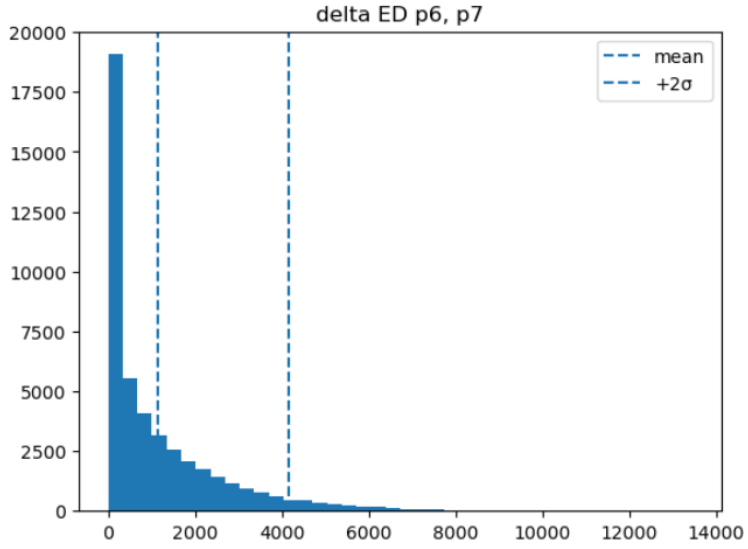
Background – Problem statement

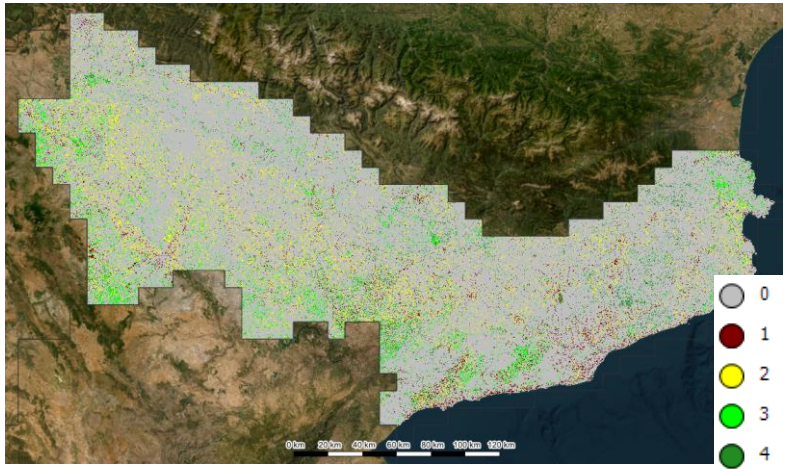
- Despite high accuracy (target OA ≥ 90%) the variance of annual classifications still leads to high amount of potential false positive changes
- Bi-annual updates therefore include an interannual calibration step to reduce false positive changes and improve consistency of the time-series > tends to omit many changes
- Increasing need to ensure reliable information on magnitude and location of changes to support policy uses cases such as LULUCF, NRR or Ecosystem accounting
- Established methods and recommendations for unbiased area estimates:
  - Olofsson et al. 2014. Good practices for estimating area and assessing accuracy of land change. Remote Sensing of Environment, 148:42–57
  - Olofsson et al. 2020. Mitigating the effects of omission errors on area and area change estimates. Remote Sensing of Environment, 236, 111492.
  - CEOS Land Product Validation Subgroup: Land Cover and Change Map Accuracy Assessment and Area Estimation Good Practices Protocol
- Rarely applied in context of operational map productions, challenges remain in particular regarding sampling and estimates for rare classes and propagation of estimates back to map products

Proposed approach



- General prevalence of changes relatively low in Europe > even in areas with high land cover dynamics typically < 5%
- Strong prevalence of changes between arable crops vs. herbaceous and tree cover loss / gain
- 5 strata to minimize change omission and focus on certain change types
  - 0: no change
  - 1: sealing / de-sealing
  - 2: from/ to arable crops vs. herbaceous
  - 3: any other change
  - 4: tree cover loss / gain
- Strata combine map changes and additional areas with high probability changes (21-23)





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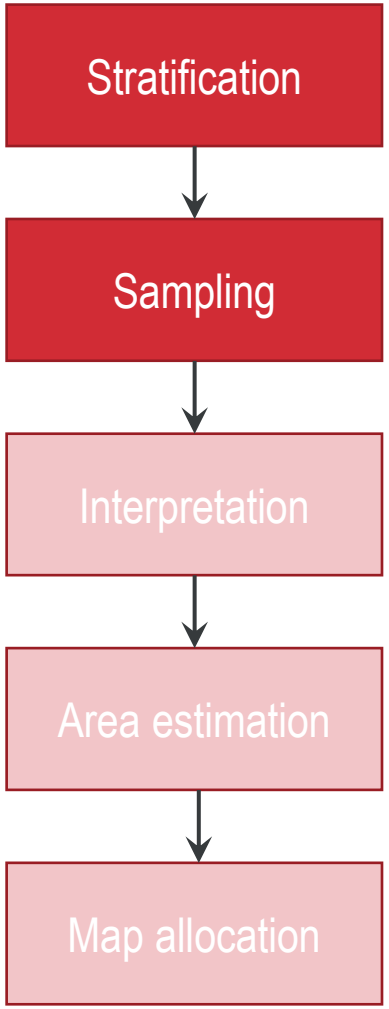
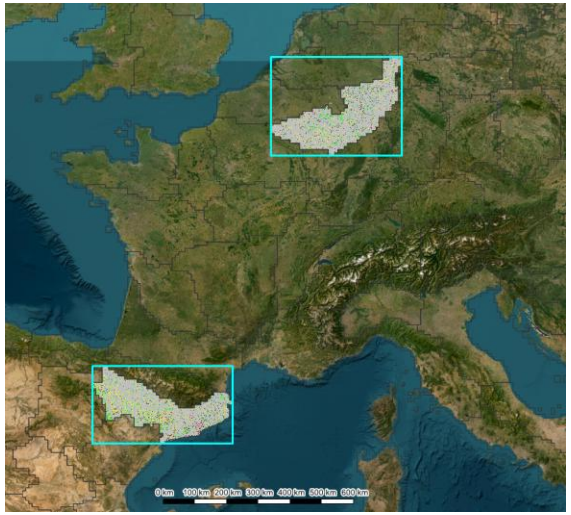
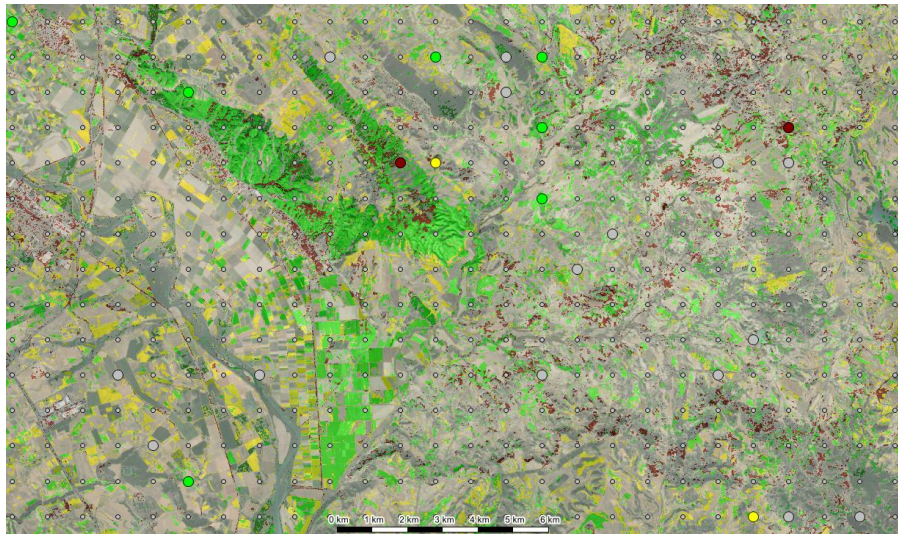


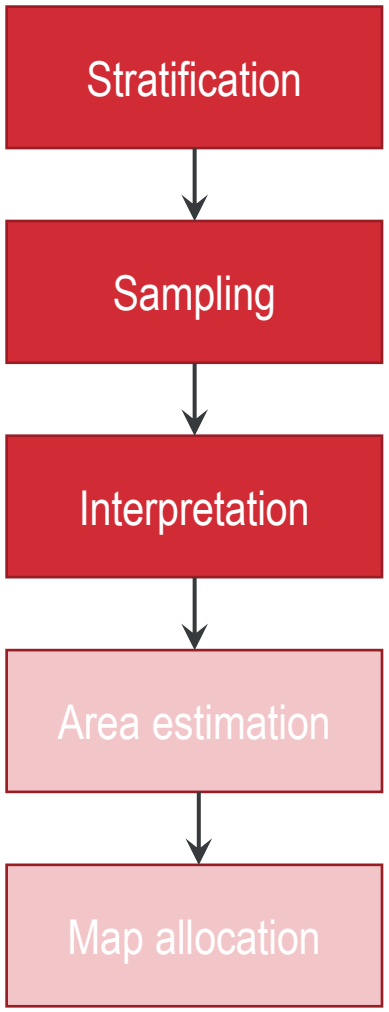
- Two test areas with land cover and change diversity
- Stratified random sampling with minimal allocation
- Regular 1x1 km point grid
  - Total of 1500 samples per AOI (production unit)
  - At least 50 per strata
  - Remainder of the samples are allocated proportional to strata size

strata		
0	1101	84.08%
1	83	2.6%
2	123	5.87%
3	109	4.7%
4	84	2.75%

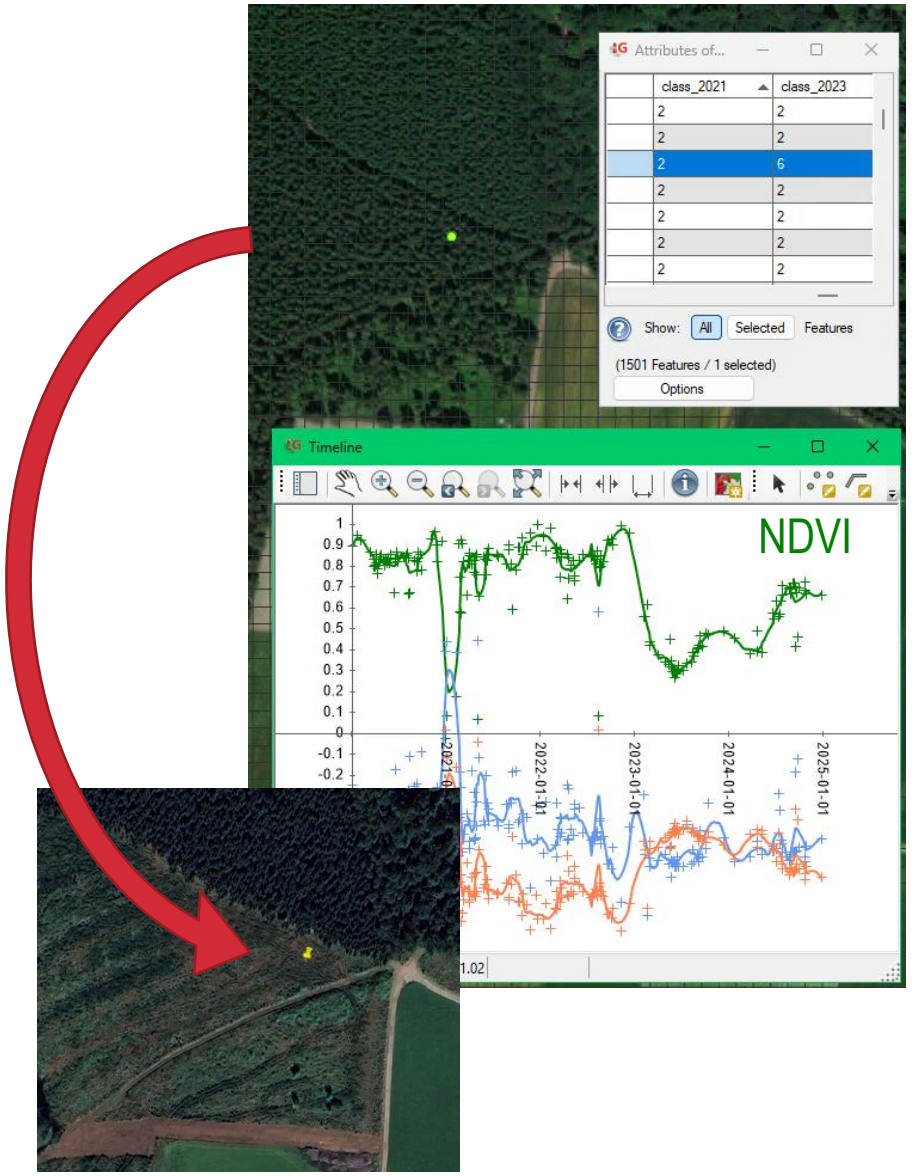




Proposed approach



- Interpretation of the samples by experts, considering the 11-class nomenclature of the CLCplus Backbone
- Separate assignment of the land cover class for the reference years 2021 and 2023
  - Identification of land cover changes in the sense of the CLCplus BB nomenclature as well as unchanged pixels – with focus on those two reference years
- Ancillary data for the interpretation:
  - VHR imagery
  - NDVI, NDSI and NDWI profiles for the respective reference year
  - Sentinel-2 imagery



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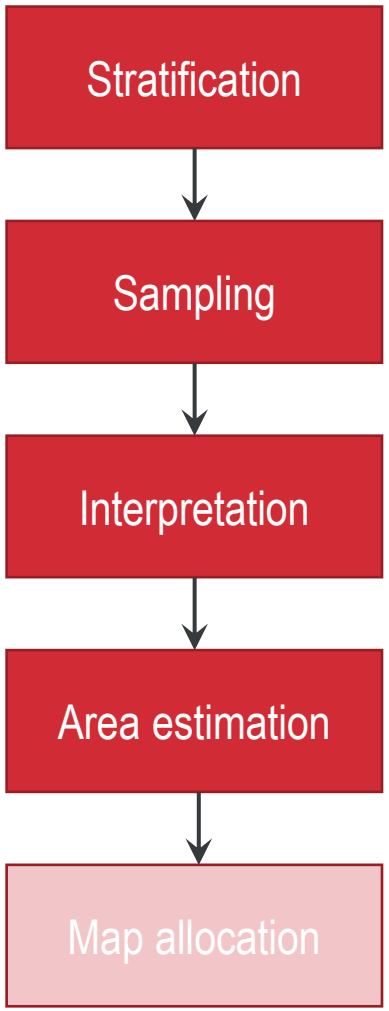
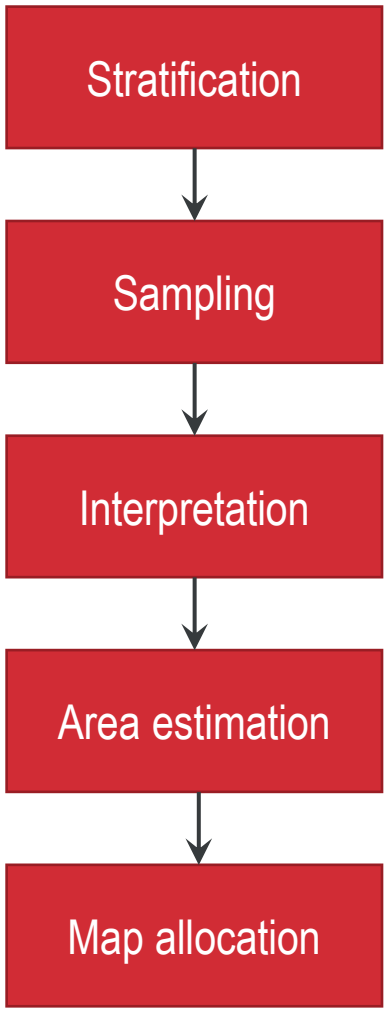


- (Preliminary) bias corrected area estimates
  - Strong underestimation of changes in the maps (expected due to conservative calibration)
  - High conversion rate between periodically herbaceous and permanent herbaceous can be confirmed
  - Uncertainties considerable for many change types > might require fallback on estimates derived for larger areas

	Bias corrected		Map	
Type of change	**Area (ha)**	**% of total area**	**Area (ha)**	**% of total area**
no change	4194150.9	91.43%	43696.9	95.25%
other change	17826.4	0.39%	70.1	0.15%
sealing	4969.9	0.11%	33.9	0.07%
tree cover gain	9944.6	0.22%	100.5	0.22%
tree cover loss	44595.6	0.97%	136.3	0.30%
perm. herb. gain	16261.1	0.35%	24.3	0.05%
period. herb. gain	23597.6	0.51%	9.9	0.02%
period. - perm. herb. conversion	156330.2	3.41%	1684.0	3.67%
perm. herb loss	65296.3	1.42%	83.4	0.18%
period. herb.loss	54416.6	1.19%	34.6	0.08%
TOTAL	**4587389**	**100.00%**	**4587389**	**100.00%**

Proposed approach



- Map allocation of estimated change area to pixel with highest probability of change
  - Available population are all pixel of a certain class at t_1 (e.g. all tree cover pixel in 2021)
  - Ranked according to their likelihood of being affected by changes
  - Change only allowed for N most likely pixels until change area fits estimate
- Work in progress
  - Comparison of different metrics to quantify change probability > cosine dissimilarity with all bands seems to perform best

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================================================================================================
SUMMARY  –  F2 optimal thresholds  (ground truth: tree-involved change)
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                              label    AP   AUC  opt_n_std  threshold  precision  recall  F_score
      Cosine dissim – all 11 bands 0.205 0.834      1.814     0.4145      0.127   0.459    0.301
                RMS – all 11 bands 0.122 0.818      1.454  1742.5631      0.097   0.460    0.263
           RMS – tree bands (2,3,4) 0.139 0.867      2.755  2871.9243      0.215   0.326    0.296
Cosine dissim – tree bands (2,3,4) 0.011 0.463     -0.720     0.0041      0.013   0.896    0.063
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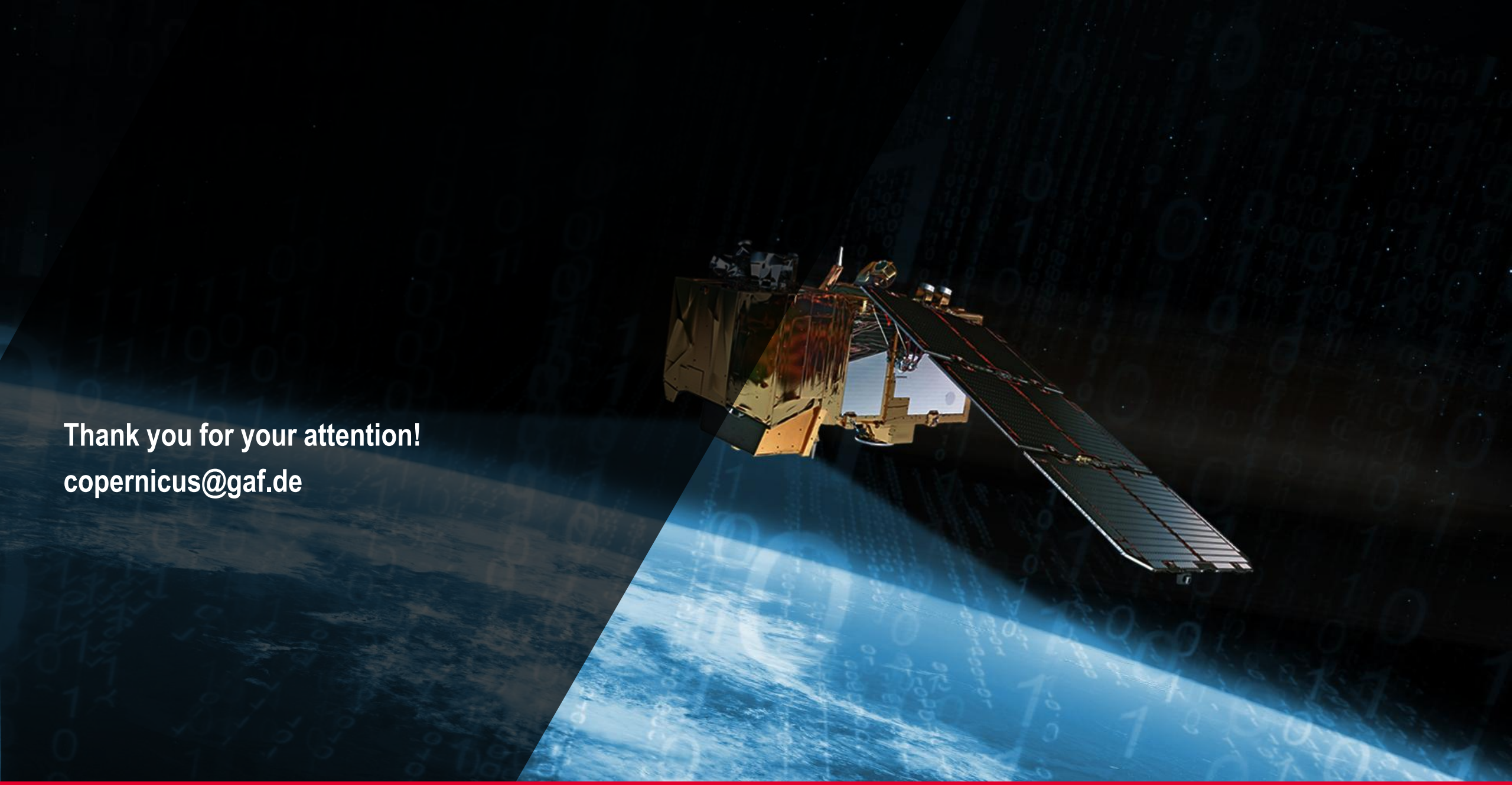
  - Iteration of analyses at second test site



Thank you for your attention!

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Transition matrix – current draft

t1 \ t2	1	2	3	4	5	6	7	8	9	10	11
1	**no change**	tree cover gain	tree cover gain	tree cover gain	*other changes*	perm. herb gain	period. herb gain	*other changes*	*other changes*	*other changes*	*other changes*
2	sealing	**no change**	*other changes*	*other changes*	tree cover loss	tree cover loss	tree cover loss	tree cover loss	tree cover loss	tree cover loss	tree cover loss
3	sealing	*other changes*	**no change**	*other changes*	tree cover loss	tree cover loss	tree cover loss	tree cover loss	tree cover loss	tree cover loss	tree cover loss
4	sealing	*other changes*	*other changes*	**no change**	tree cover loss	tree cover loss	tree cover loss	tree cover loss	tree cover loss	tree cover loss	tree cover loss
5	sealing	tree cover gain	tree cover gain	tree cover gain	**no change**	perm. herb gain	period. herb. gain	*other changes*	*other changes*	*other changes*	*other changes*
6	sealing	tree cover gain	tree cover gain	tree cover gain	perm. herb loss	**no change**	period. - perm. herb. conversion	perm. herb. loss	perm. herb loss	perm. herb loss	perm. herb loss
7	sealing	tree cover gain	tree cover gain	tree cover gain	period. herb. loss	period. - perm. herb. conversion	**no change**	period. herb. loss	period. herb. loss	period. herb. loss	period. herb. loss
8	sealing	tree cover gain	tree cover gain	tree cover gain	*other changes*	perm. herb. gain	period. herb gain	**no change**	*other changes*	*other changes*	*other changes*
9	sealing	tree cover gain	tree cover gain	tree cover gain	*other changes*	perm. herb gain	period. herb gain	*other changes*	**no change**	*other changes*	*other changes*
10	sealing	tree cover gain	tree cover gain	tree cover gain	*other changes*	perm. herb gain	period. herb gain	*other changes*	*other changes*	**no change**	*other changes*
11	sealing	tree cover gain	tree cover gain	tree cover gain	*other changes*	perm. herb gain	period. herb gain	*other changes*	*other changes*	*other changes*	**no change**

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