

# Copernicus Netzwerk Büro Wald, Online-Seminar „Überblick zu Copernicus-Produkten für den Wald“

06/09/2022



## CLMS - HRL Forests Produkte Gestern, Heute, Morgen

Land Monitoring

André Stumpf, GAF AG

**GAFAG**  
an e-GEOE (AG) / 50% state-owned company



European Environment Agency





- Geoland (FP6, 2004-2007, 56 Partner) und Geoland2 (FP7 2008-2012, 12 partner) > Vorbereitende Forschungs- und Entwicklungsprojekte zur Bereitstellung EO-basierter Landbedeckungskarten für Europa
- GMES Initial Operations (GIO) Land Monitoring Services (EEA, 2012-2014): Produktion von 5 High-Resolution Layer für das Referenzjahr 2012 mit 20m Auflösung basierend auf ResourceSat-2, RapidEye
- HRL Forests updates für 2015 (EEA, 5 Lots) mit 20m Auflösung basierend auf SPOT-4/5, SPOT-5, ResourceSat-2 and Sentinel-2
- HRL Forests Updates für 2018 (EEA, 5 Lots) mit 10m Auflösung basierend auf Sentinel-2 Zeitreihen
- Projekte zur externen Validierung:

<https://land.copernicus.eu/user-corner/technical-library/comparative-validation>

<https://land.copernicus.eu/user-corner/technical-library/hrl-forest-2015-final-validation-report>



Land  
Monitoring

# HRL Forests - Überblick



**Global**

provides a series of bio-geophysical products on the status and evolution of the land surface at global scale at mid and low spatial resolution



**Pan-European**

provides information about land cover and land use and its changes, as well as bio-geophysical parameters at European scale at high resolution



**Local**

focuses on different hotspots, i.e. areas that are prone to specific environmental challenges and problems



**Imagery and reference data**

satellite imagery forms the input for the creation of our products; and in order to ensure the efficient use of satellite imagery, in-situ data is required



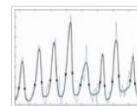
**CORINE Land Cover**



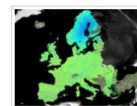
**CLC+**



**High Resolution Layers**



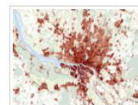
**Biophysical parameters**



**European Ground Motion Service**



**Related Pan-European products**



**Imperviousness**



**Forests**



**Grassland**



**Water & Wetness**



**Small Woody Features**

<https://land.copernicus.eu/pan-european/high-resolution-layers/forests>



# HRL Forests - Überblick



## Main status products

- Dominant Leaf Type 10m
- Tree Cover Density 10m
- Forest Type 10m
- 2 Change Produkte 20m

## Aggregierte Produkte auf 100m

- Tree Cover Density
- Forest Type
- Broadleaved Cover Density
- Coniferous Cover Density

Weiter Produkte zu Verlässlichkeit,  
Korrekturen, Referenzdaten,  
Produktionslayout, Nationale Proj.



# HRL Forests – Technische Spezifikationen

## Definition: Was wird / wird nicht als Baumbestand erfasst?

<b>Elements included in the tree covered area</b> <i>(if tree cover can be detected from the 10m imagery)</i>	<b>Elements excluded from tree covered area</b> <i>(if no tree cover can be detected from the 10m imagery)</i>
<ul style="list-style-type: none"><li>• Evergreen/deciduous broadleaved, sclerophyllous and coniferous trees of any use</li><li>• Forests (grown-up and under development)</li><li>• Orchards, olive groves, fruit and other tree plantations, agro-forestry areas</li><li>• Transitional woodland, forests in regeneration</li><li>• Groups of trees within urban areas (alleys, wooded parks and gardens)</li><li>• Forest management/use features inside forests (forest roads, firebreaks, thinnings, forest nurseries, etc.)</li><li>• Forest damage features inside forests (partially burnt areas, storm damages, insect-infested damages, etc.)</li></ul>	<ul style="list-style-type: none"><li>• Open areas within forests (roads, permanently open vegetated areas, clear cuts, fully burnt areas, other severe forest damage areas, etc.)</li><li>• Dwarf shrub-covered areas, such as moors and heathland</li><li>• Vineyards</li><li>• Dwarf pine / green alder in alpine areas</li><li>• Mediterranean shrublands (macchia, garrigue etc.)</li><li>• Shrubland</li></ul>

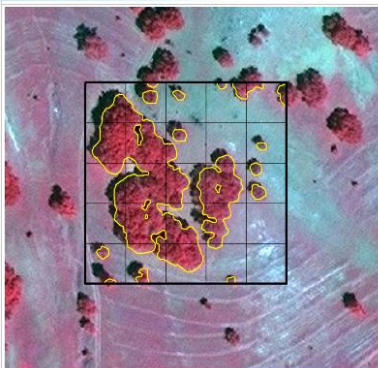
<https://land.copernicus.eu/user-corner/technical-library/hrl-forest>

<https://land.copernicus.eu/user-corner/technical-library/forest-2018-user-manual.pdf>



# HRL Forests – Technische Spezifikationen

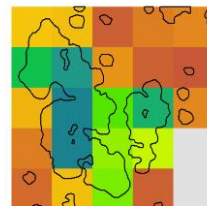
## Definition: Tree Cover Density ~ Kronenschlussgrad



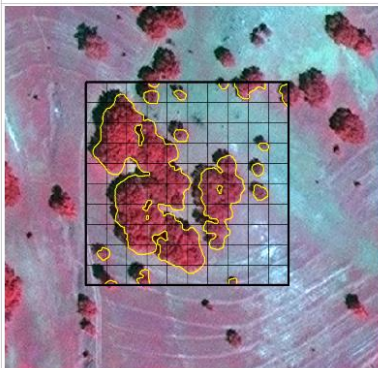
20m grid

30	29	8	14	16
69	81	19	6	3
26	87	64	74	16
14	87	49	46	0
9	29	91	6	0

20m TCD product



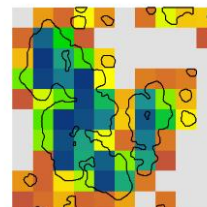
20m TCD product overlaid with Tree Cover Mask



10m grid

0	20	19	40	18	0	12	42	30	25
9	67	51	5	9	6	0	0	0	3
27	67	79	58	33	8	0	0	0	0
12	16	65	76	41	8	14	11	14	0
3	44	14	66	71	25	94	56	27	0
0	54	65	36	37	21	64	57	38	0
0	50	66	79	42	10	18	13	6	0
0	7	66	79	61	19	79	2	0	0
19	7	35	42	16	70	13	0	0	0
1	13	28	8	10	22	0	12	0	0

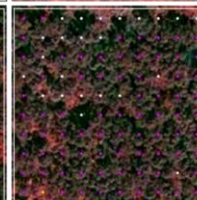
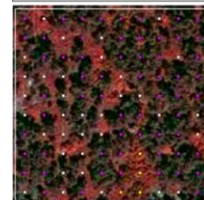
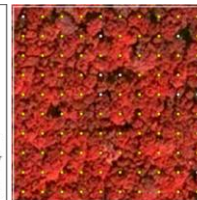
10m TCD product



10m TCD product overlaid with Tree Cover Mask

Selected examples for the collection of reference sampling points per 100m sample cell

- Broadleaved cover
- Coniferous cover
- Non-tree covered



100% Tree Cover Density

1% Tree Cover Density



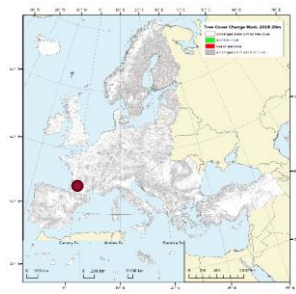
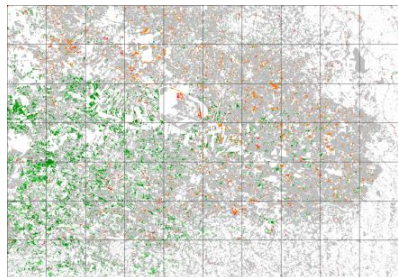
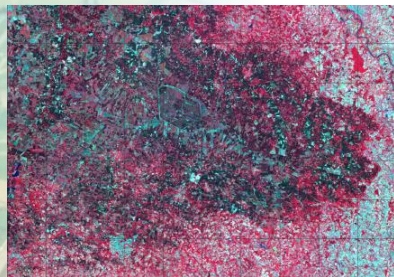


# HRL Forests – Technische Spezifikationen

## Definition: Tree Cover Change Mask und Dominant Leaf Type Change

- 20m räuml. Auflösung
- Räuml. Filter von 1 Pixel um Randeffekte und Unterschiede in Bildgeometrien zu kompensieren
- Minimum Mapping Unit = 1 ha für Veränderungen
- TCCM bildet Verlust / Zuwachs ab
- DLTC ergänzt zusätzlich den Blatttyp

Large area Pine forest rotation, Landes department, France



10 km

S-2 multi-temporal stack, false color DLTC 1518

Class Code	Class Name	Colour Palette
0	unchanged areas with no tree cover	
1	new tree cover	
2	loss of tree cover	
10	unchanged areas with tree cover	
254	unclassifiable in any of parent status layers	
255	outside area	

Class Code	Class Name	Colour Palette
0	unchanged areas with no tree cover	
1	new broadleaved cover	
2	new coniferous cover	
3	loss of broadleaved cover	
4	loss of coniferous cover	
10	unchanged areas with tree cover	
12	potential change among dominant leaf types	
254	unclassifiable in any of parent status layers	
255	outside area	



# H R L Forests – Technische Spezifikationen

Forest Type - basierend auf FAO Definition (min 10% TCD, MMU von 5ha, MMW 10m, tradit. Agroforstwirtschaft in Dehesas / Montados inkludiert)

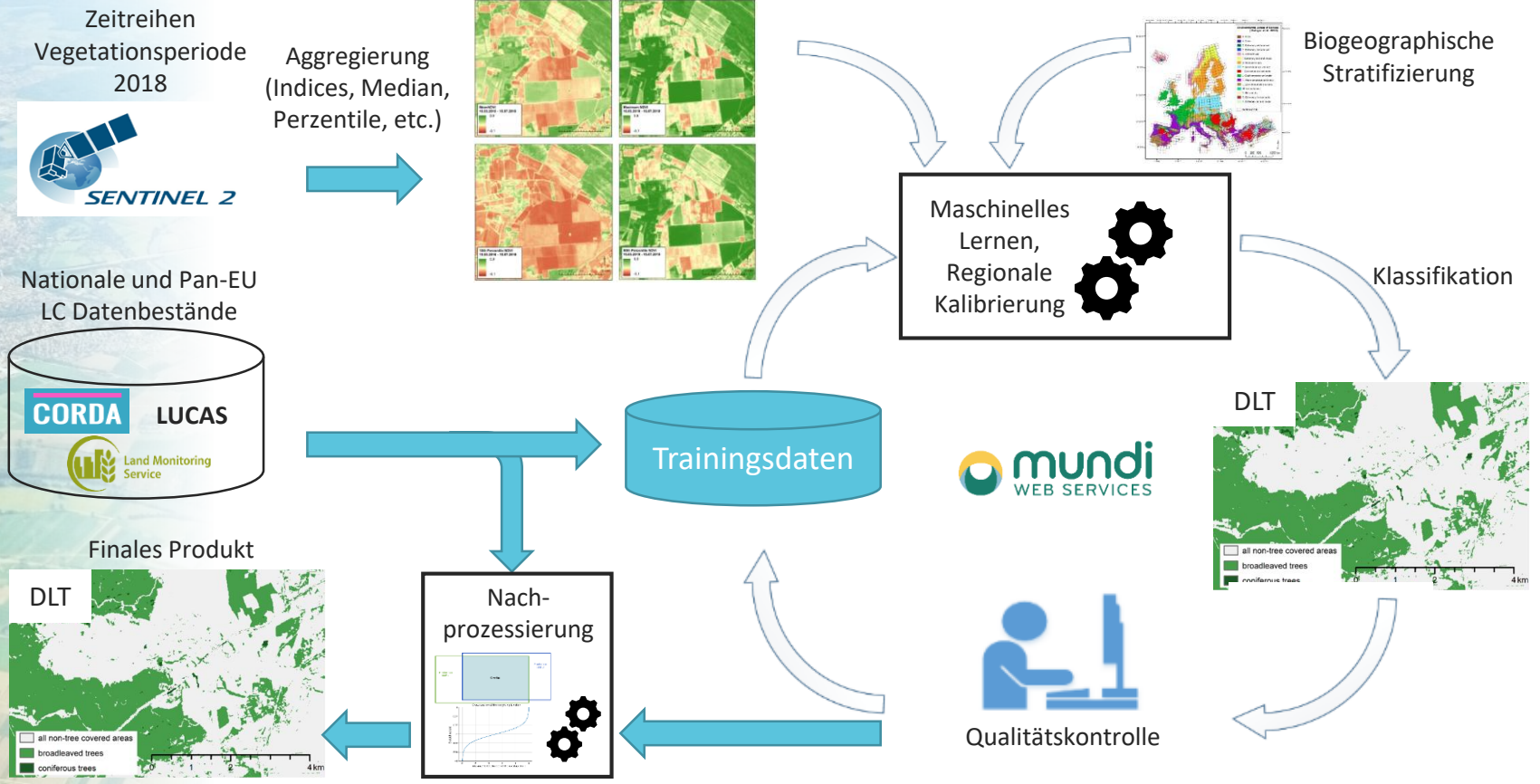
Included Features (FAO)	Excluded Features (FAO)
<ul style="list-style-type: none"><li>• forest nurseries and seed orchards that constitute an integral part of the forest</li><li>• forest roads, cleared tracts, firebreaks and other small open areas &lt; 0.5 ha and/or &lt; 20m width</li><li>• Forest in national parks, nature reserves and other protected areas such as those of specific scientific, historical, cultural or spiritual interest</li><li>• windbreaks and shelterbelts of trees with an area of more than 0.5 ha and width of more or equal than 20m</li><li>• plantations primarily used for forestry purposes, including cork oak stands</li><li>• traditional agroforestry system such as Dehesa / Montado</li></ul>	<ul style="list-style-type: none"><li>• land predominantly used for agricultural practices (fruit trees and olive groves)</li><li>• gardens and urban parks</li></ul>





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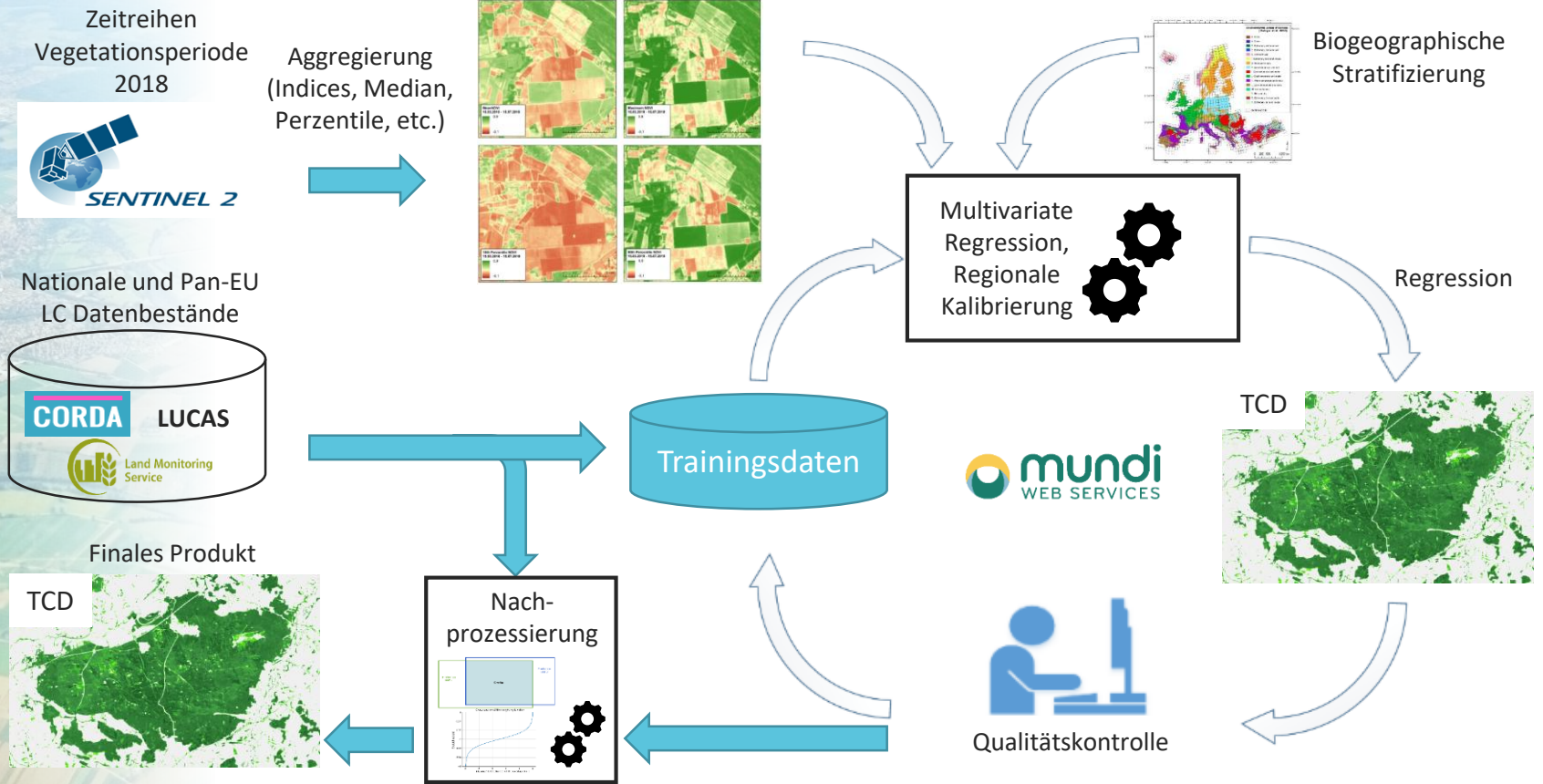
# Methodik DLT Klassifikation (2018)





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# Methodik TCD Abschätzung (2018)



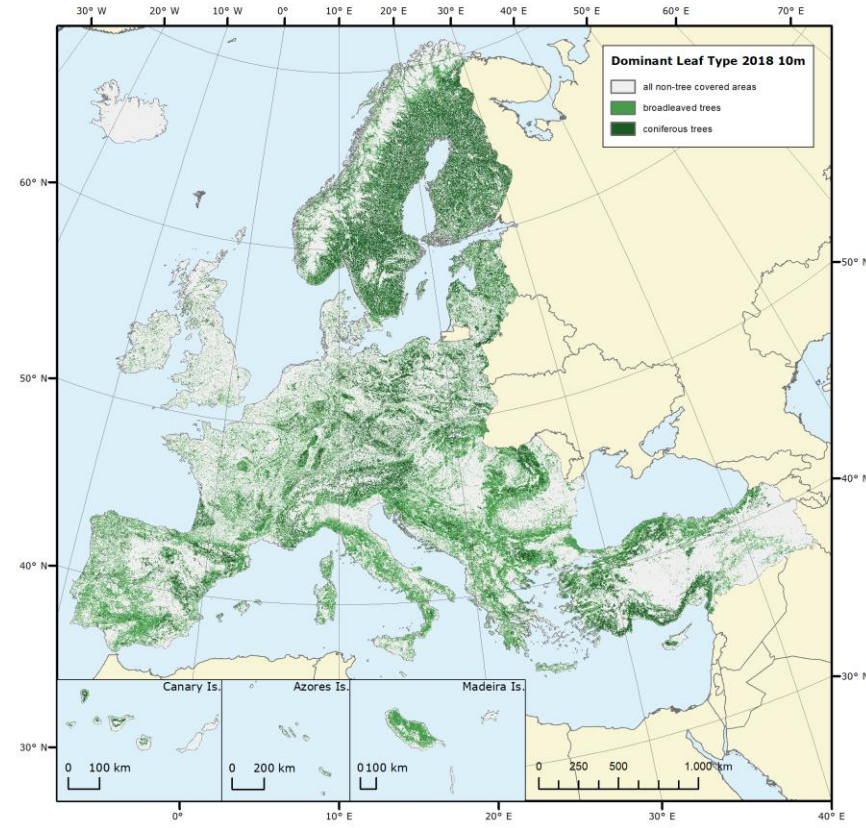


# HRL Forests – Stärken und Limitierungen

- DLT 2018 Klassengenauigkeit insgesamt > 90% mit hoher räumlicher Konsistenz
- Überdurchschnittlich hohe Genauigkeit nördlich der Alpen
- Tendenz zur Überschätzung von Laubbaumbeständen im Mittelmeerraum
- Lokale Fehler durch Geometrieversätze, topographische Übernormalisierung und Fehler in den Wolkenmasken der S-2 Eingangsdaten
- Erfassung von Einzelbäumen und sehr dünnen Beständen auf sehr hellem Untergrund (e.g. Olivenhaine) nicht immer möglich

Table 17: Area-weighted confusion matrix of the pan-European DLT 2018 status layer

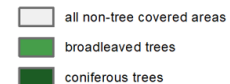
DLT 2018 Status Layer (weighted)		REFERENCE				User Accuracy	CI at 95%
		No Tree Cover	Broadleaved	Coniferous	Total		
MAP DATA	No Tree Cover	<b>6134.66</b>	61.39	29.90	6225.95	<b>98.53%</b>	0.17%
	Broadleaved	128.39	<b>1820.52</b>	69.27	2018.18	<b>90.21%</b>	0.43%
	Coniferous	26.63	22.08	<b>1402.15</b>	1450.86	<b>96.64%</b>	0.26%
	Total	6289.86	1903.99	1501.31	<b>9694.98</b>		
	Producer Accuracy	<b>97.54%</b>	<b>95.62%</b>	<b>93.39%</b>		<b>96.52%</b>	<b>Overall Accuracy</b>
	CI at 95%	0.22%	0.30%	0.36%		0.37%	CI at 95%
						0.913	Kappa



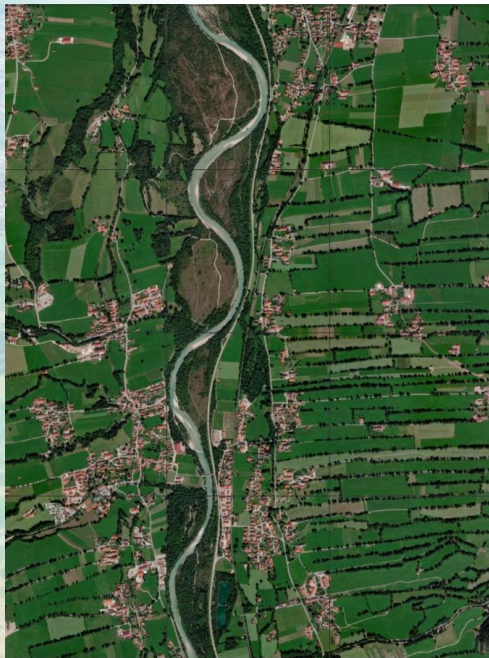


# HRL Forests – Stärken und Limitierungen

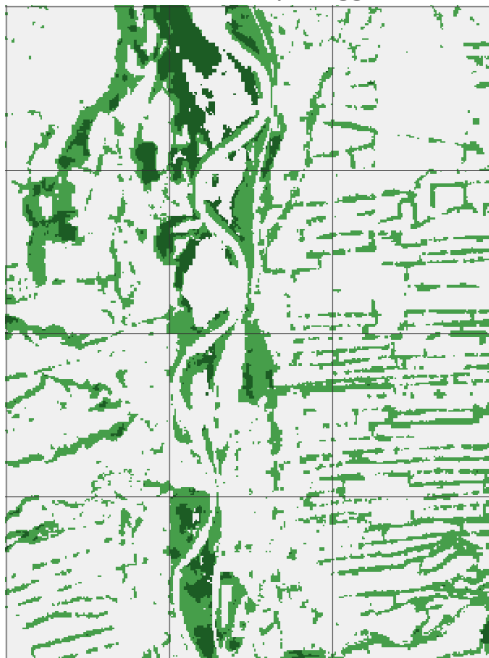
- Insgesamt gut Konsistenz der verschiedenen Referenzjahre
- Unterschiede in 2018 vor allem durch verbesserte Auflösung, Datengrundlage und Methodik



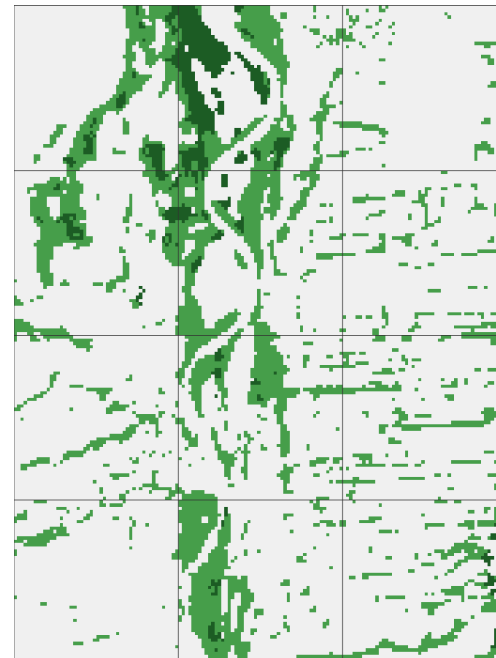
Tree Lines and Forests nearby Lenggries, Germany



ESRI World Imagery (2021)



DLT\_2018\_010m



DLT\_2015\_020m



# HRL Forests – Stärken und Limitierungen

- TCD 2018 insgesamt > 90% Genauigkeit mit hoher räumlicher Konsistenz (Validierung nach 30% Grenzwert)
- Tendenz zur Unterschätzung höherer Dichten durch Dürre 2018
- Höhere Streuung für sehr niedriger und sehr hoher Dichten (typ. für Fernerkundungsprodukte)

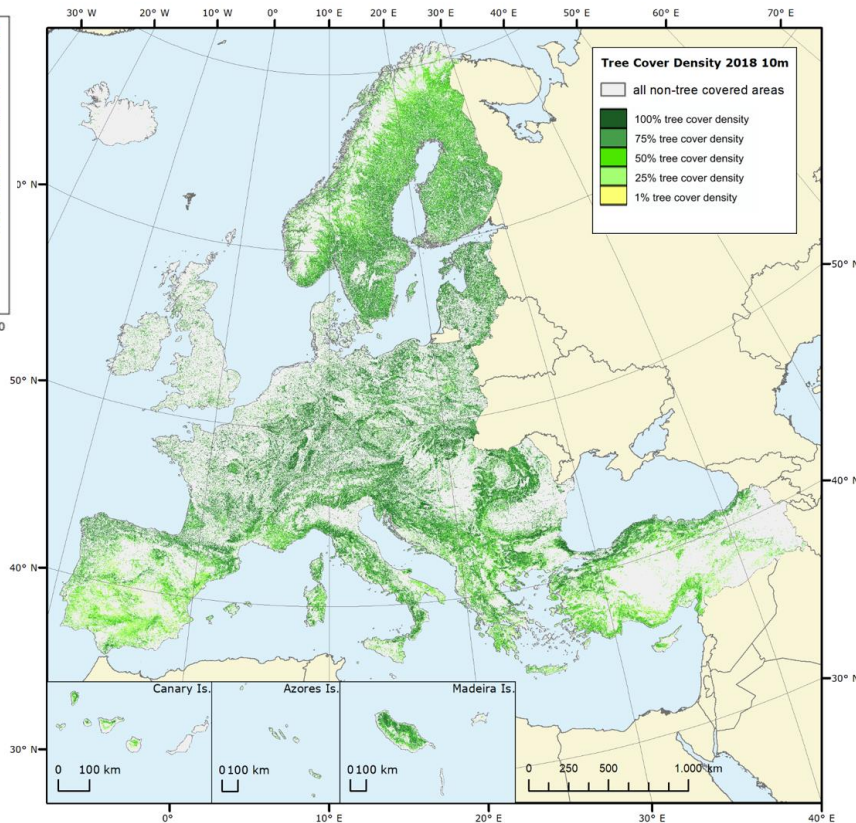
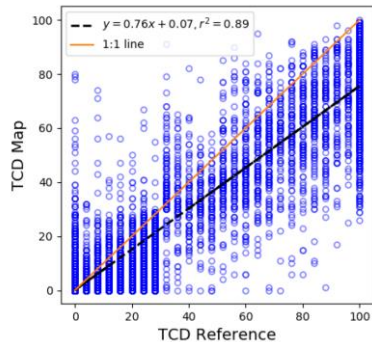


TABLE 25: CONFUSION MATRIX OF THE TCD 2018 STATUS LAYER (100% DELIVERY) WITH A 30% DENSITY THRESHOLD APPLIED

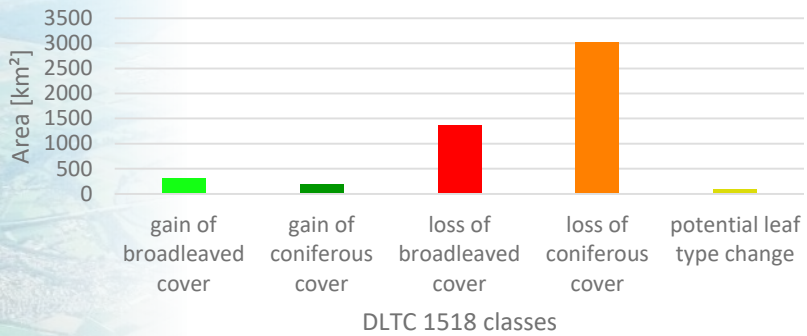
TCD 2018 Status Layer (weighted)		REFERENCE DATA		Total	User Accuracy	CI at 95%
		No Tree Cover (0-29% TCD)	Tree Cover (30-100% TCD)			
MAP DATA	No Tree Cover (0-29% TCD)	6128,88	260,41	6389,28	95.92%	0.28%
	Tree Cover (30-100% TCD)	86,07	3219,63	3305,70	97.40%	0.23%
Total		6214,94	3480,04	9694,98		
Producer Accuracy		98.62%	92.52%		96.43%	Overall Accuracy
CI at 95%		0.17%	0.28%		0.37%	CI at 95%
					0.913	Kappa



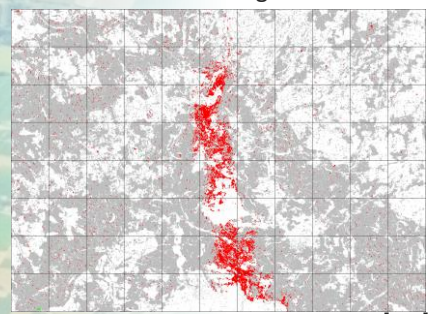
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# HRL Forests – Stärken und Limitierungen

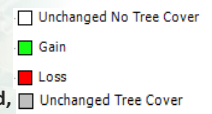
- Tree Cover Change Mask 2015-2018



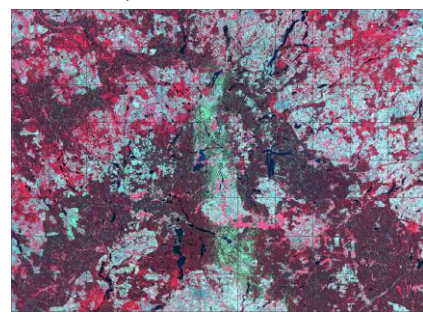
Large area clear cuts Pomerania, Poland



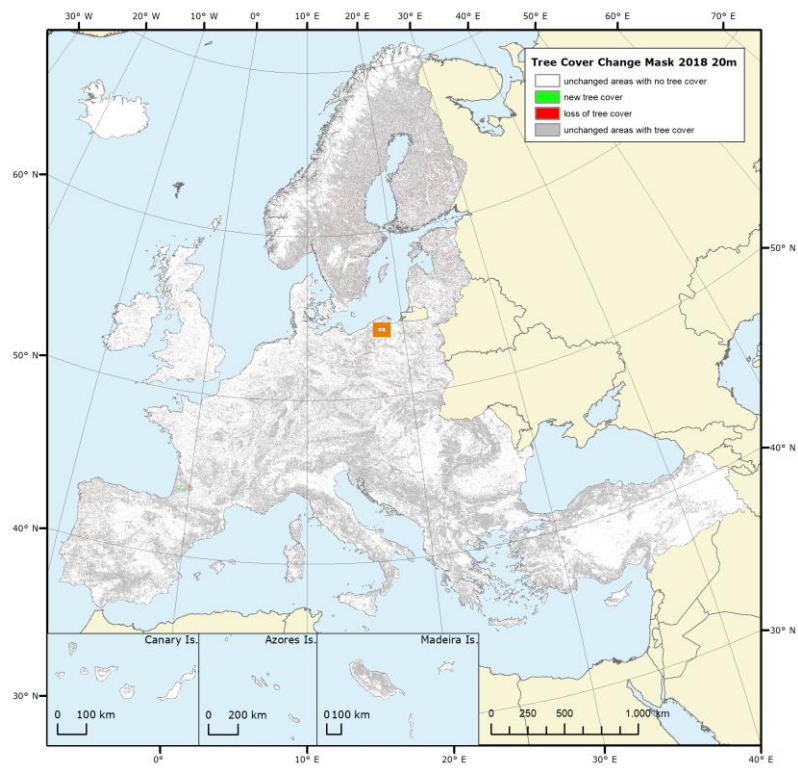
TCCM 1518



10 km



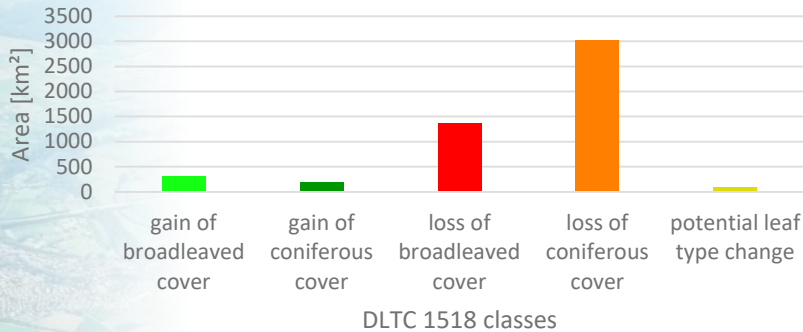
S-2 multi-temporal stack, false color



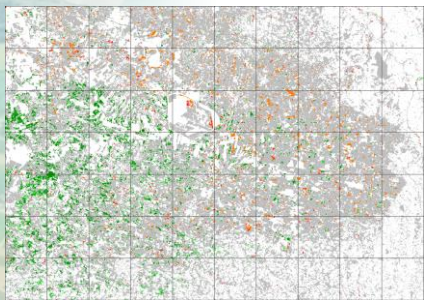


# HRL Forests – Stärken und Limitierungen

- Dominant Leaf Type Change 2015-2018



Large area Pine forest rotation, Landes department, France

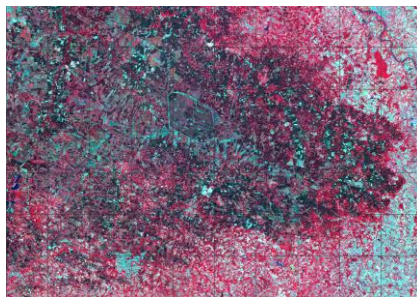


DLTC 1518

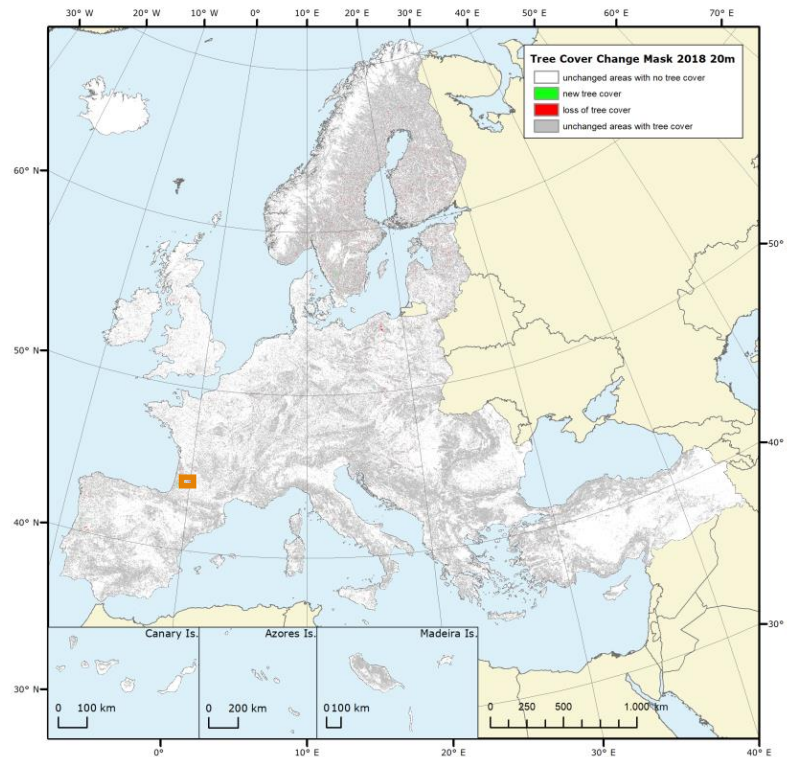
- Unchanged No Tree Cover
- Unchanged Tree Cover

- new broadleaved cover
- new coniferous cover
- loss of broadleaved cover
- loss of coniferous cover

10 km



S-2 multi-temporal stack, false color





# HRL Forests – Stärken und Limitierungen

- Change 2015-2018 mit generell sehr guter Genauigkeit mit Bezug auf vergleichbare Change Produkte
- Generell niedrigere Rate an Kommissionsfehlern
- Tendenz zur Unterschätzung von Bestandsverlusten für Nadelbäume und Überschätzung von Bestandsverlusten für Laubbäume
- Tendenz zur Unterschätzung von graduellen Zuwächsen von Laubbäumen
- Bildet auch durch MMU von 1ha eher die Untergrenze der tatsächlichen Bestandsverluste 2015-2018 ab

Table 20: Area-weighted confusion matrix of the TCCM 1518 change layer; Class names: 0=unchanged areas with no tree cover, 1=new tree cover, 2=loss of tree cover, 10=unchanged areas with tree cover

TCCM 1518 (weighted)		REFERENCE				Total	User's Accuracy	CI at 95%
		0	1	2	10			
MAP DATA	0	7159.27	0.98	13.85	81.96	7256.06	98.67%	0.16%
	1	0.1	11.32	0.12	0.2	11.74	96.45%	0.06%
	2	4.0	0.0	54.83	3.63	62.46	87.79%	0.44%
	10	106.97	1.54	0.0	4256.24	4364.75	97.51%	0.22%
Total		7270.34	13.84	68.8	4342.03	11695		
Producer's Accuracy		98.47%	81.79%	79.70%	98.02%		98.18%	Overall Accuracy
CI at 95%		0.17%	0.55%	0.59%	0.19%		0.26%	Confidence Interval
							0.96	Kappa

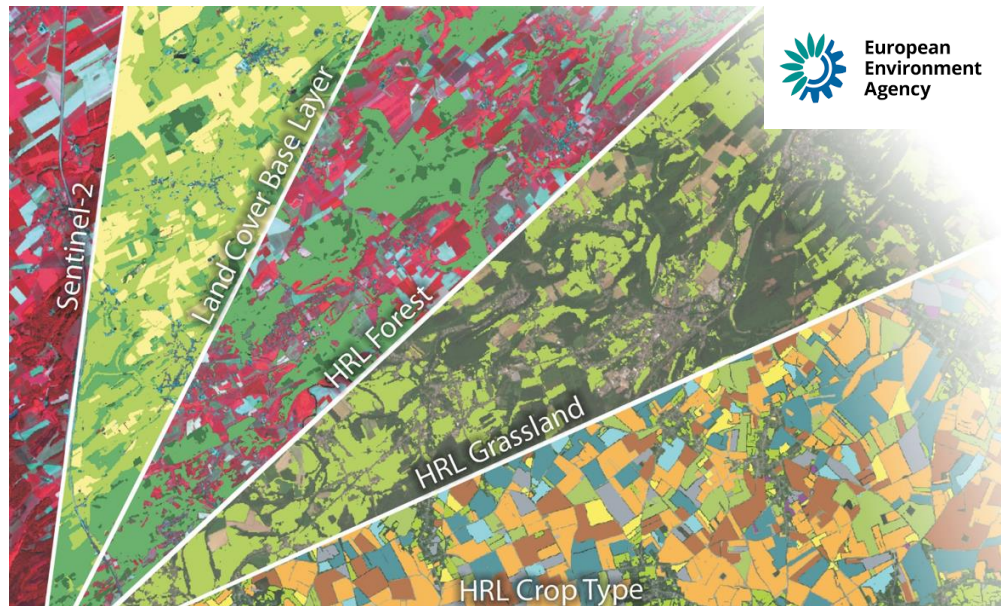
Table 21: Area-weighted confusion matrix of the DLTC 1518 change layer; Class names: 0=unchanged areas with no tree cover, 1=new broadleaved cover, 2=new coniferous cover, 3=loss of broadleaved cover, 4=loss of coniferous cover, 10=unchanged areas with tree cover

DLTC 1518 (weighted)		REFERENCE						Total	User's Accuracy	CI at 95%
		0	1	2	3	4	10			
MAP DATA	0	7159.27	0.98	0.0	1.54	12.31	81.96	7256.06	98.67%	0.16%
	1	0.08	6.37	0.16	0.12	0.0	0.18	6.91	92.24%	0.09%
	2	0.02	0.02	4.77	0.0	0.0	0.02	4.83	98.77%	0.03%
	3	2.86	0.0	0.0	15.36	1.75	1.77	21.74	70.64%	0.65%
	4	1.14	0.0	0.0	0.32	37.4	1.85	40.71	91.86%	0.34%
	10	106.97	1.54	0.0	0.0	0.0	4256.24	4364.75	97.51%	0.22%
Total		7270.34	8.91	4.93	17.34	51.46	4342.02	11695		
Producer's Accuracy		98.47%	71.5%	96.78%	88.62%	72.67%	98.02%		98.16%	Overall Accuracy
CI at 95%		0.17%	0.67%	0.06%	0.42%	0.66%	0.19%		0.27%	CI at 95%
									0.96	Kappa





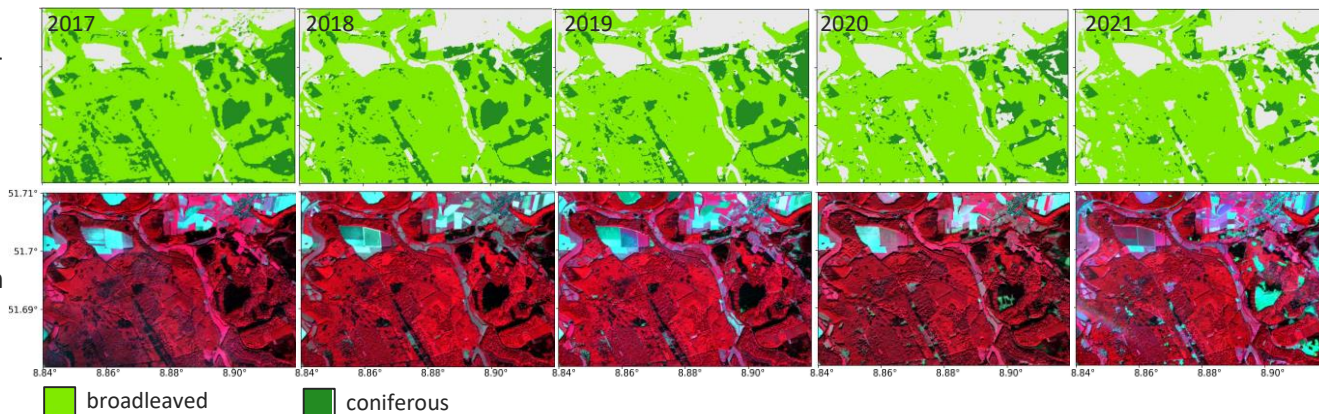
- High Resolution Layer – Vegetated Land Cover Characteristics (HRL VLCC)
- Vergabe durch EEA (EEA/DIS/RO/21/013) an ein an ein industrielles Konsortium (GAF (Lead), GeoVille, VITO)
- Kontinuität und Erweiterung der bestehenden HRL Forest und Grassland Produkte
- Einführung des neuen HRL Crop Type
- Jährliche Updates für den Zeitraum 2017/18 - 2023
- Unterstützung zahlreicher EU Regularien wie LULUCF, CAP, Climate Change Mitigation, Urban Agenda, European Biodiversity Strategy, Energy Union ...





- Verbesserte Methodik: Klassifikation direkt auf Zeitreihen mit Tiefen Neuronalen Netzen (basierend auf TempCNN), TCD Abschätzung mit CatBoost
- Erhöhter Automatisierungsgrad, gezielte Selektion und Revision von Trainingsdaten mit Veränderungen weiterhin essentiell
- Kalibrierung der Zeitreihe für verbesserte zeitliche Konsistenz und Veränderungskartierung
- Prozessierung auf WEkEO mit Elementen einer modularen Prozesskette die bereits im Rahmen von CLC+ Backbone genutzt wurde

Beispiel für erweiterte DLT Zeitreihe (Testgebiet nahe Paderborn). Verlust von Nadelbaumbeständen ist in der Kartierung und der Sentinel-2 Zeitreihe (NIR, G, B Falschfarben) deutlich zu erkennen.

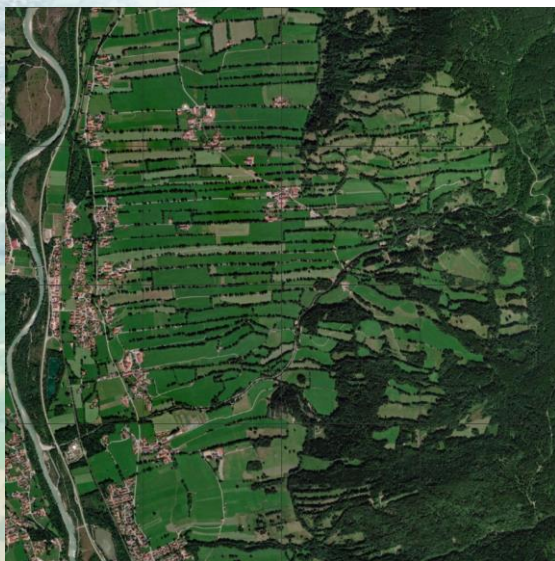




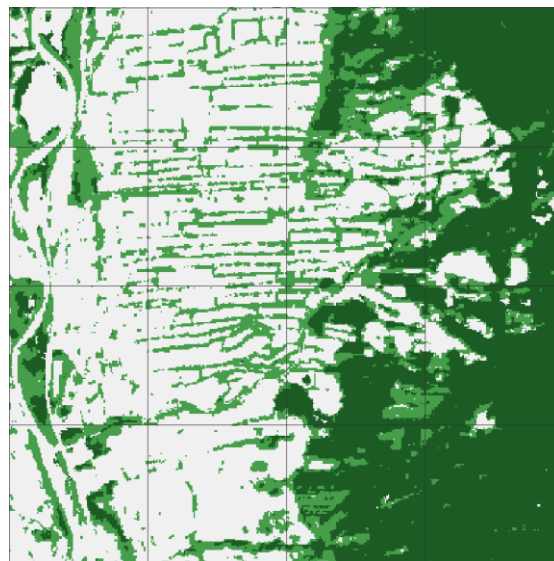
# HRL Forests – Fortsetzung / Status

- Offizielles Kick-Off Ende für Phase 1 (2017-2021) im Juni 2022
- Initiale Test- und Aufbauphase von 6 Monaten für fünf Testgebiete
- Start der Produktion für Phase 1 (2017-2021) Ende des Jahres
- Erste Flächendeckende Ergebnisse für EU27 in Q4/2023 erwartet

- 1 - Sealed
- 2 - Coniferous
- 3 - Broadleaved deciduous
- 4 - Broadleaved evergreen
- 5 - Shrubs
- 6 - Perm. Herb
- 7 - Periodically Herb
- 8 - Lichens and mosses
- 9 - Sparsely vegetated
- 10 - Water
- 11 - Perm. Snow and Ice

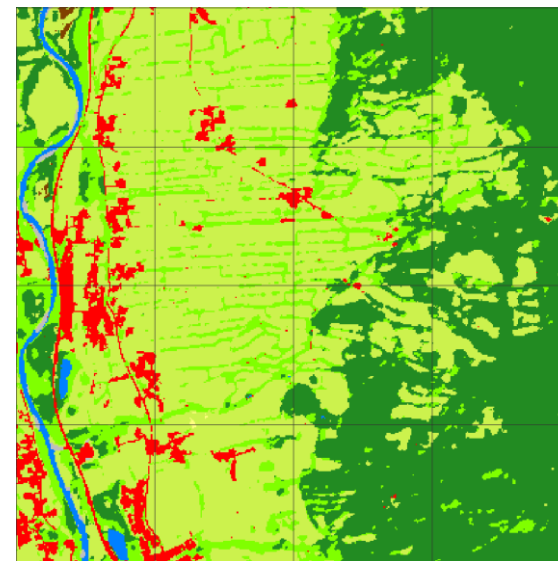


ESRI World Imagery (2021)



all non-tree covered areas HRL DLT 2018 10m

- broadleaved trees
- coniferous trees



CLC+ Raster 2018 10m



Land Monitoring

# Fragen? Anregungen? Nutzungsbeispiele?

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Cop. Netzwerk Büro Wald, 2022-09-06