GeoVille

Information Systems and Data Processing GmbH

Towards an Operational EO-integrated LULUCF and Carbon Removal MRV Service at Pan-European level

Second Forum on EO for Carbon Market
Copenhagen, 10 October 2024

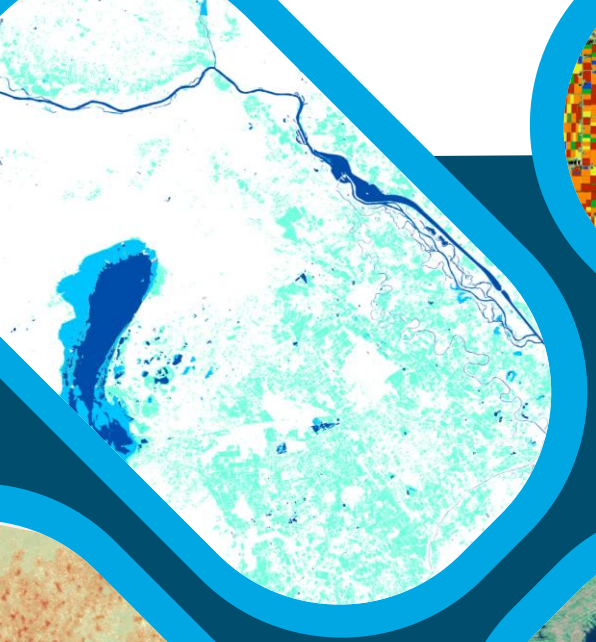
25+ Innovating with Experience

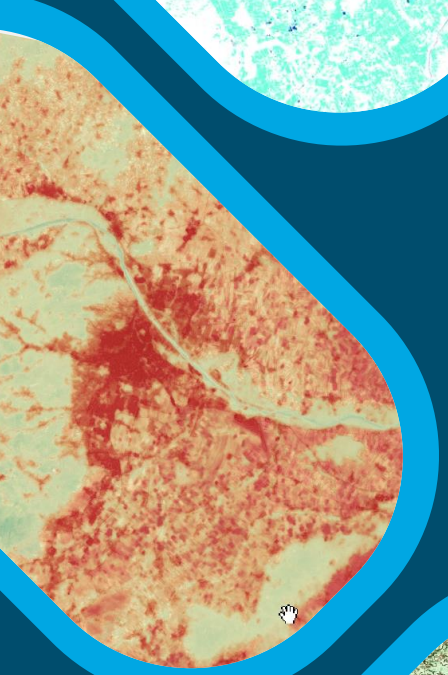
Delivering actionable Earth Observation services

European Environment Agency

Nathalie Morin et al.
morin@geoville.com / www.GeoVille.com

esa





Copernicus
Europe's eyes on Earth

Emergency Management

Land Monitoring

HIGHLY EXPERIENCED
COPERNICUS SERVICE PROVIDER

GeoVille is playing a key role in Copernicus services for land applications, related to both land cover data production and emergency management services, as well as value-added downstream applications in the spatial planning domain.

GeoVille

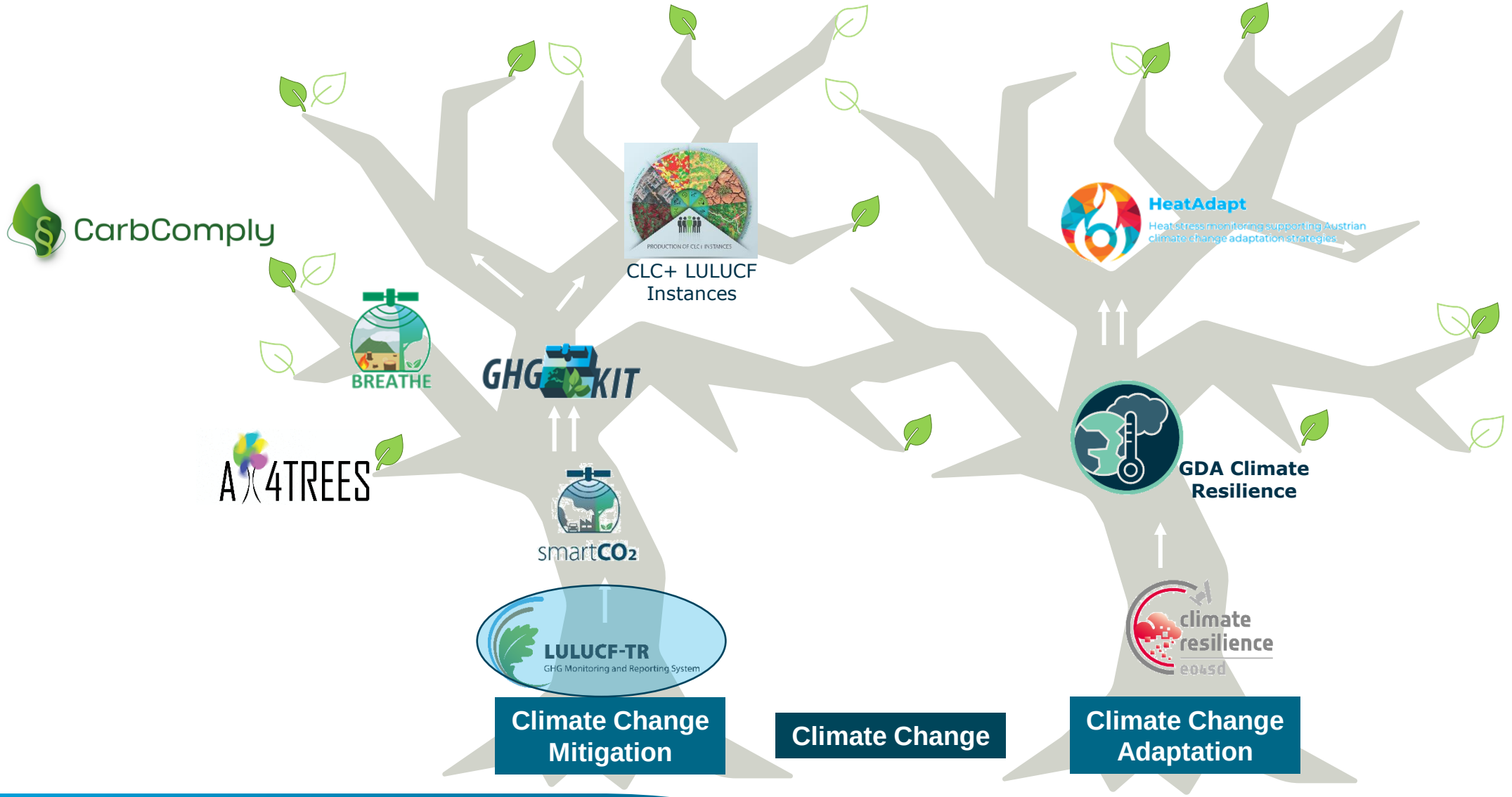
“The monitoring and reporting of greenhouse gas emissions must be robust, transparent, consistent and accurate for the EU emissions trading system (EU ETS) to operate effectively.”

Source: European Commission Directorate-General for Climate Action
https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets/monitoring-reporting-and-verification-eu-ets-emissions_en

European Environment Agency

GeoVille

esa



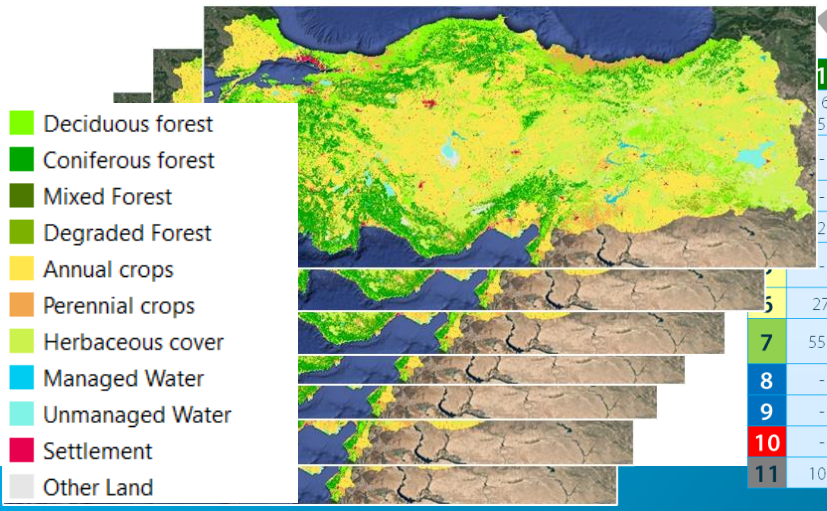
Strategic Innovation Path

GeoVille

LULUCF GHG Monitoring and Reporting System of Türkiye

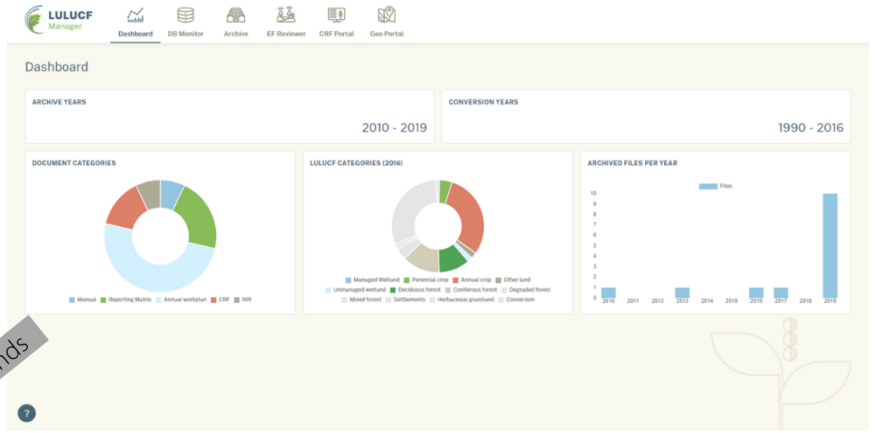
LULUCF-TR
GHG Monitoring and Reporting System

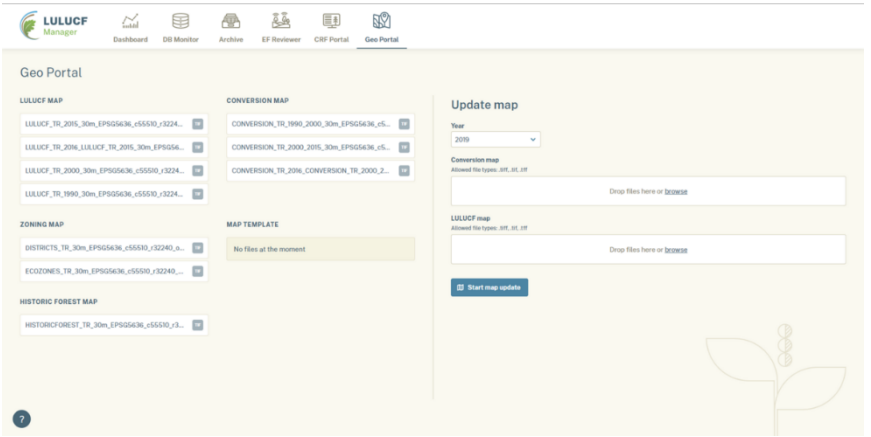
FROM LANDSAT 1990-2015 SATELLITE OBSERVATIONS TO STANDARDIZED REPORTING



	Forest	Cropland	Grassland	Wetlands	Settlements	Other lands
Forest	6.675	-	-	113	145	14	99	17	39	24	19
Cropland	-	10.373.940	-	549	323	76	231	67	37	81	77
Grassland	-	-	728.208	1	1	-	2	0	0	0	0
Wetlands	28	1.006	19	3.256.445	122	50	142	29	28	12	61
Settlements	-	-	-	-	23.727.158	664	-	923	348	982	483
Other lands	27	23								87	30
7	551	2.136	146	569	572	226	24.227.393	284	78	113	274
8	-	-	-	-	30	-	11	287.798	-	1	6
9	-	-	-	-	505	-	311	-	1.348.149	47	260
10	-	-	-	-	-	-	-	1	1	815.398	7
11	107	329	1	124	436	45	219	66	542	38	1.702.887

26 annual transition matrices





EUROPEAID

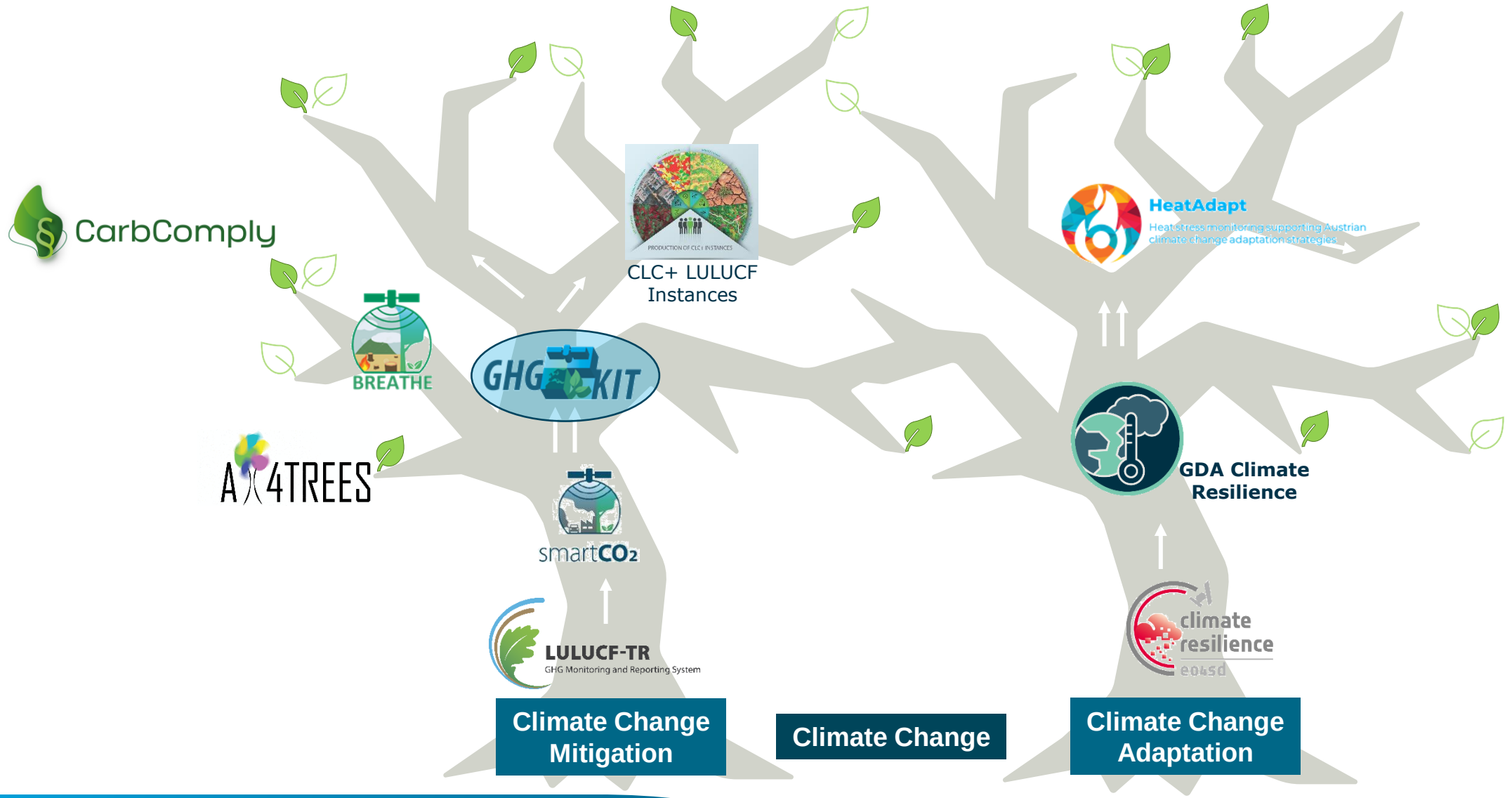
CFCU

AESA CONSORTIUM

T.C. ÇEVRE VE ŞEHİRCİLİK BAKANLIĞI

REPUBLIC OF TÜRKİYE
MINISTRY OF TREASURY
AND FINANCE

GeoVille



Strategic Innovation Path

GeoVille

Austrian Flagship project – GHG-KIT
Prototyping an EO-enabled kit supporting greenhouse gas reporting

Overall Aim

Prototype EO-integrated GHG Monitoring Reporting and Verification (MRV) system supporting the Austrian inventory report

- Verification Element: GHG flux estimates (inverse modelling - top-down)
- LULUCF Inventory Reporter (bottom-up)

FFG Forschung wirkt.

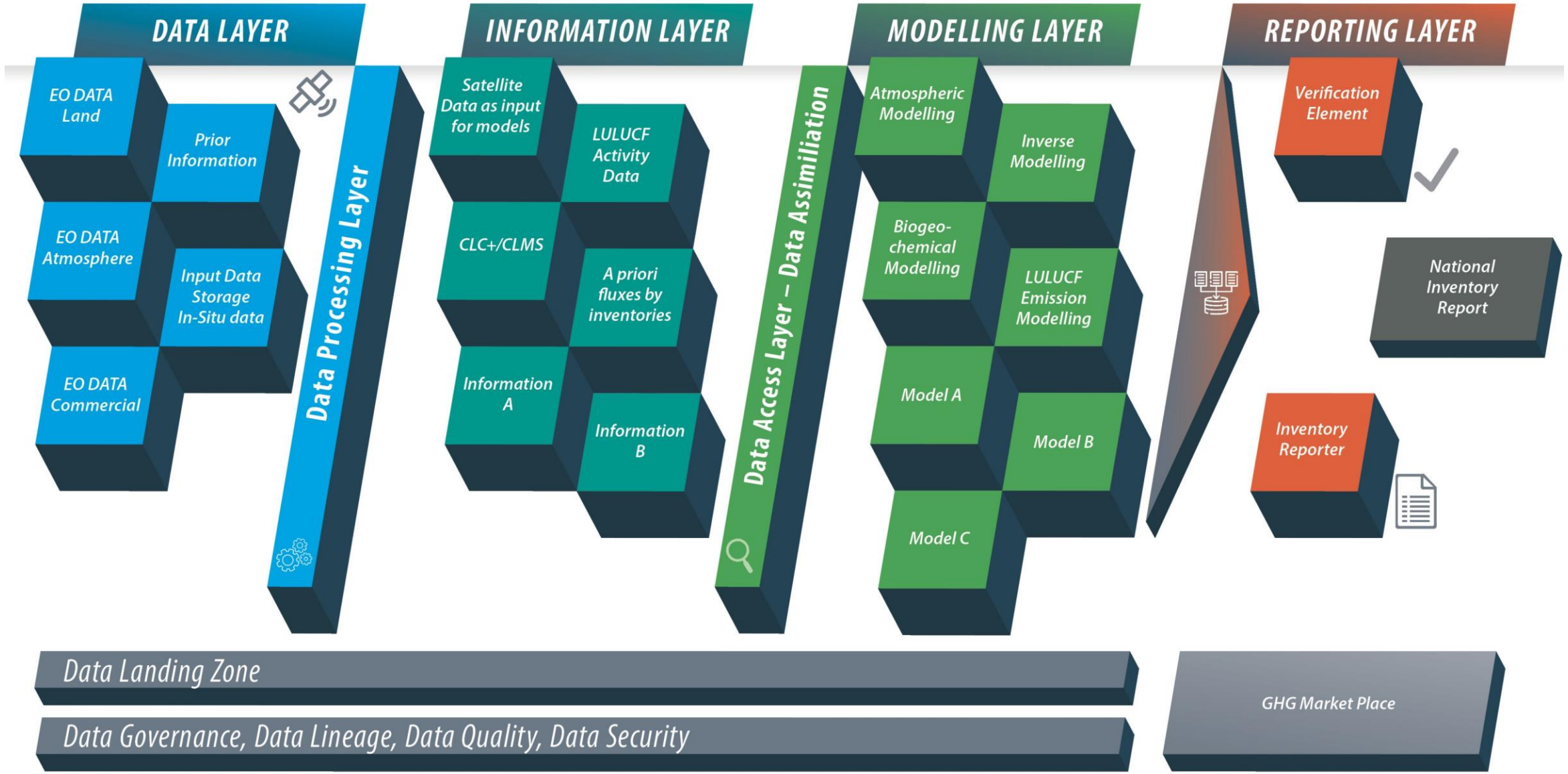
https://ghg-kit.at/

Keep it traceable!

GeoVille

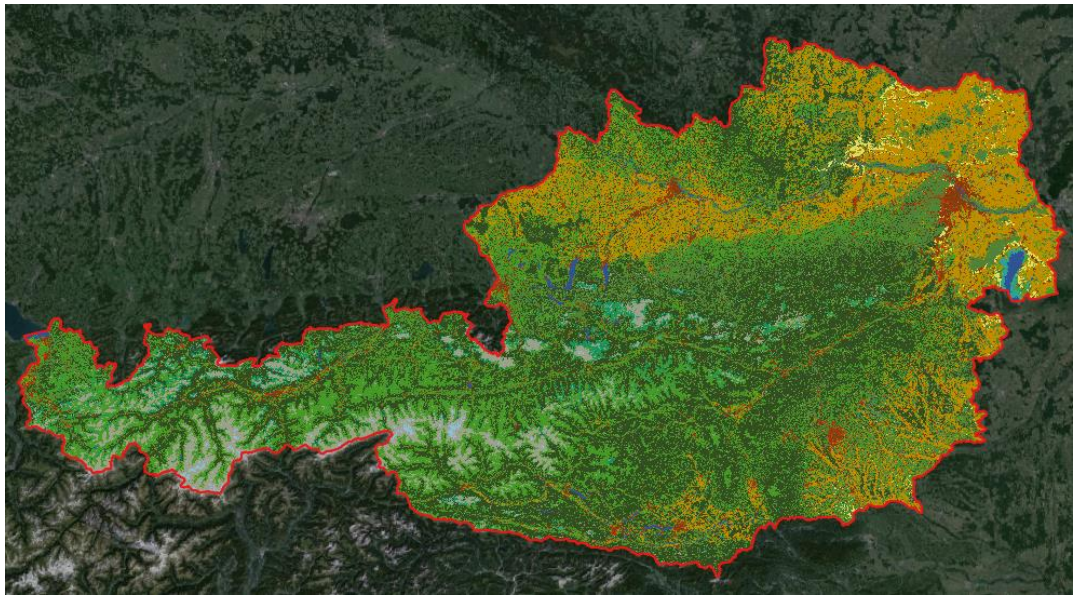
GHG KIT

Keep it traceable. Prototyping an independent tool-kit system for GHG verification in Austria

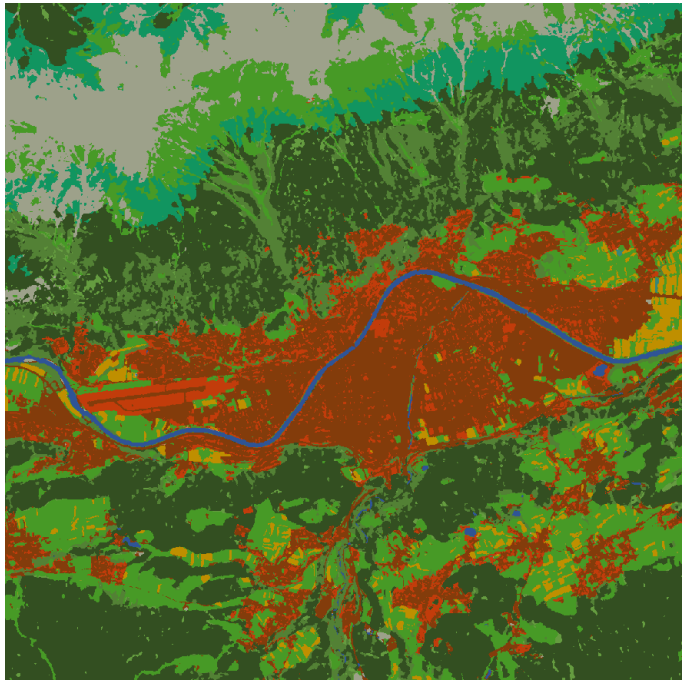


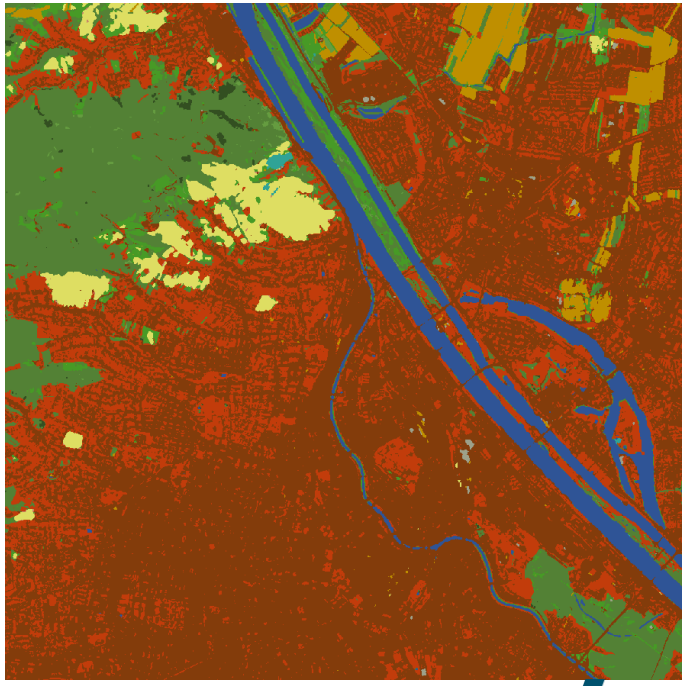
LULUCF Activity Data 2015-2023

- 9 LULUCF annual status maps
- 8 LULUCF transition maps
- QA/QC Uncertainty assessment
- Area statistics LU/LUC matrices
- Comparison with NIR numbers



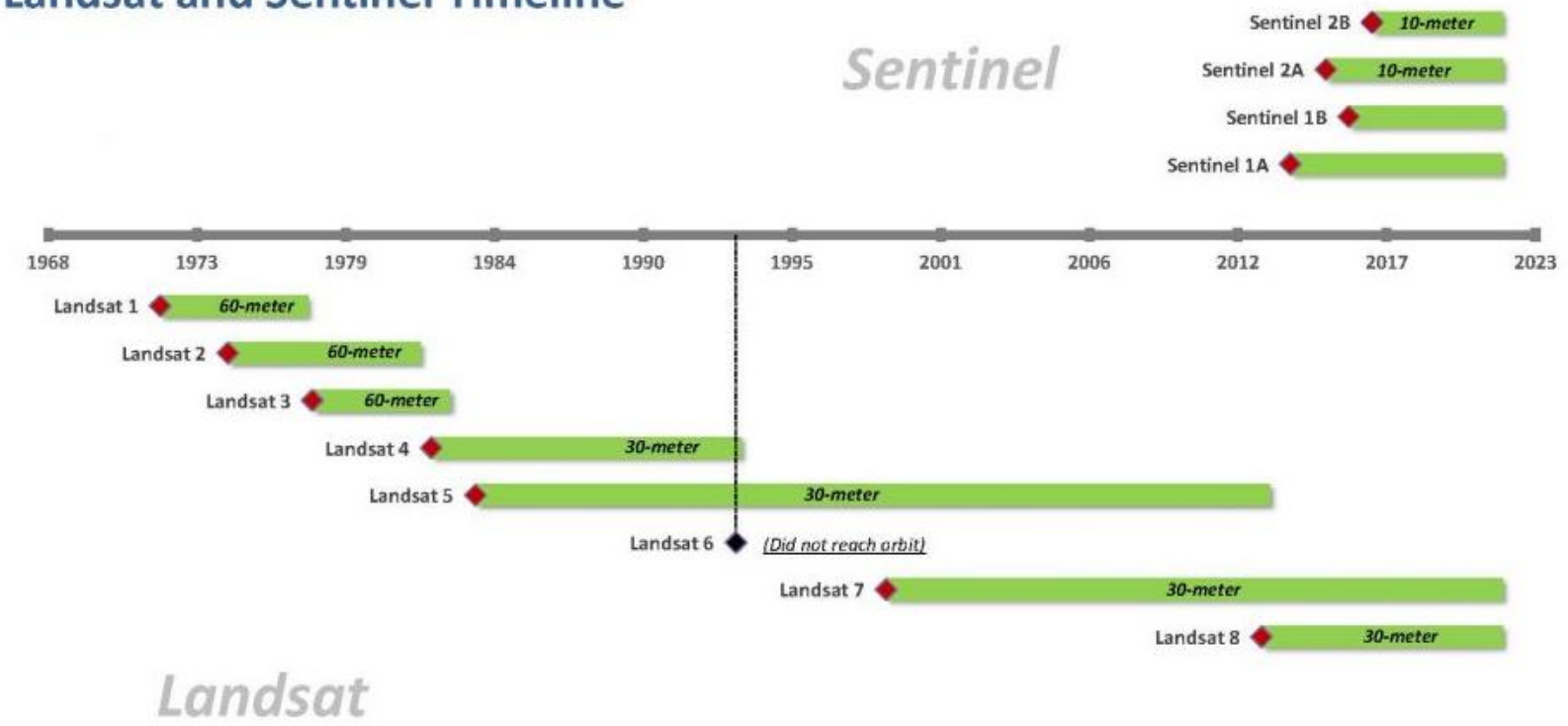
Code	LULUCF Category / Level 1	Code	Level 2	Code	Level 3
1	Forest Land	11	Coniferous forest	110	Coniferous forest
		12	Deciduous forest	120	Deciduous forest
		13	Unstocked forest	130	Unstocked forest
2	Cropland	21	Annual cropland	210	Annual cropland
		22	Perennial cropland	221	Viticulture
				222	Orchards
				223	Other perennial crops
				225	Other woody biomass in cropland
3	Grassland	31	Grassland	311	Grassland
				312	Other woody biomass in grassland
4	Wetlands	41	Water	410	Water
		42	Wetland	420	Wetland
5	Settlements	51	Non-vegetated Settlements	511	Unvegetated settlements
		52	Vegetation in settlements	521	Trees in settlements
				522	Grassland in settlements
6	Other Land	61	Other Land	611	Rocks and screes
				612	Glaciers
				613	Alpine dwarf shrub heaths
		62	Other Land (difference)	620	Other Land (difference)

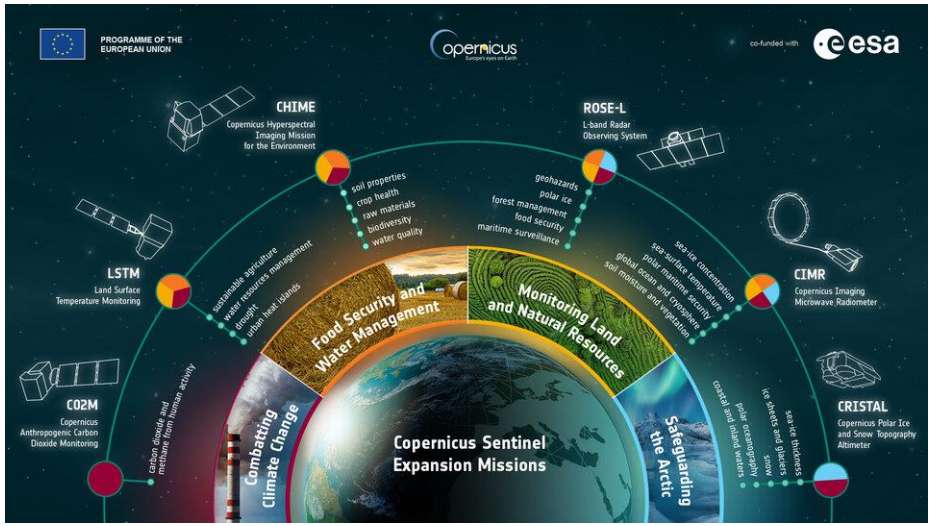




EO-integrated LULUCF Activity Data prototype covering a 9-year period 2015-2023

Landsat and Sentinel Timeline

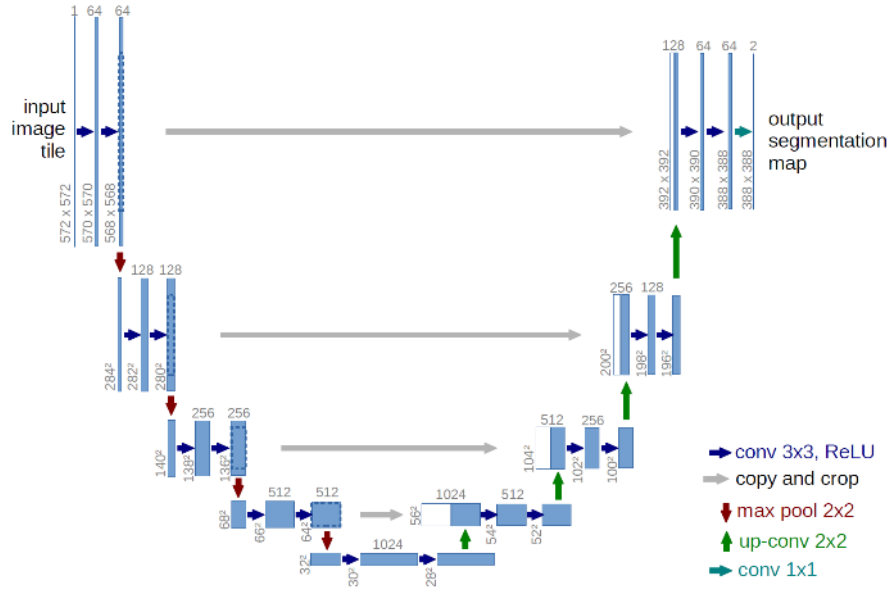




Addressing main challenge of Consistency and Completeness between Landsat and Sentinel era

Classification: AI U-Net training algorithm

- CLMS CLCplus Backbone 2018, 2021 & 2023
- INVEKOS LPIS (Land Parcel Inventory System)
- Cadastral data from BEV (Bundeseich und Vermessungsamt) for Wetlands



Post-Processing rulesets

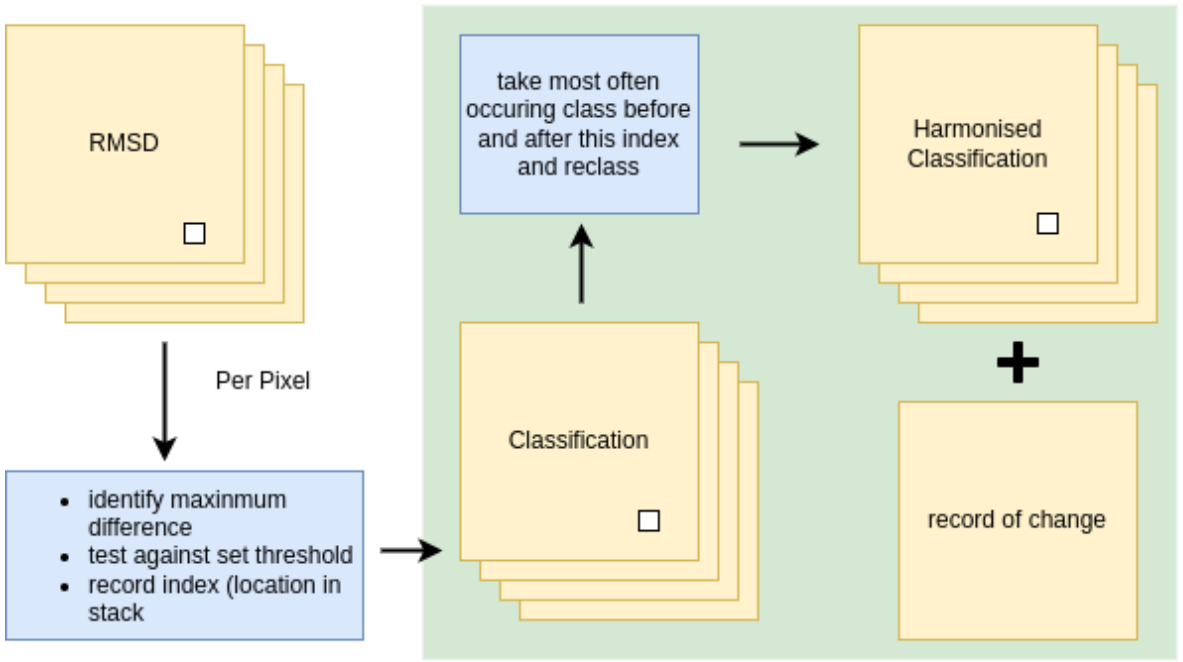
	Rule	Method
Unstocked forest	Grassland, shrubs and cropland within management boundary of the forest	Forest mask
Other woody biomass in cropland/grassland	single standing trees and small forest patches outside of the forest map from BFW and within cropland/grassland	Neighbour analysis using buffer
Vegetation within settlements	Vegetation (grassland, single trees, tree rows, etc.) within settlements (e.g. parks, house gardens)	Settlement mask

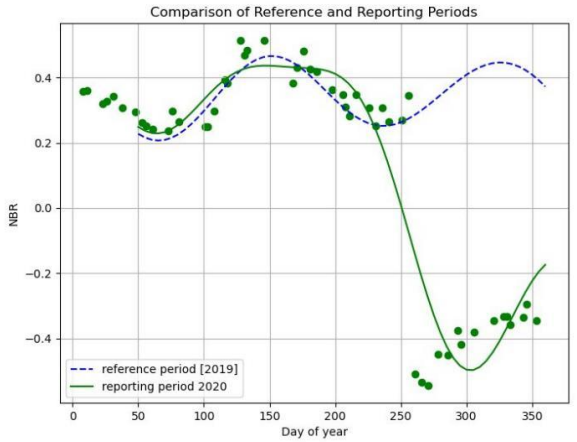
Scalable solution other countries + EU

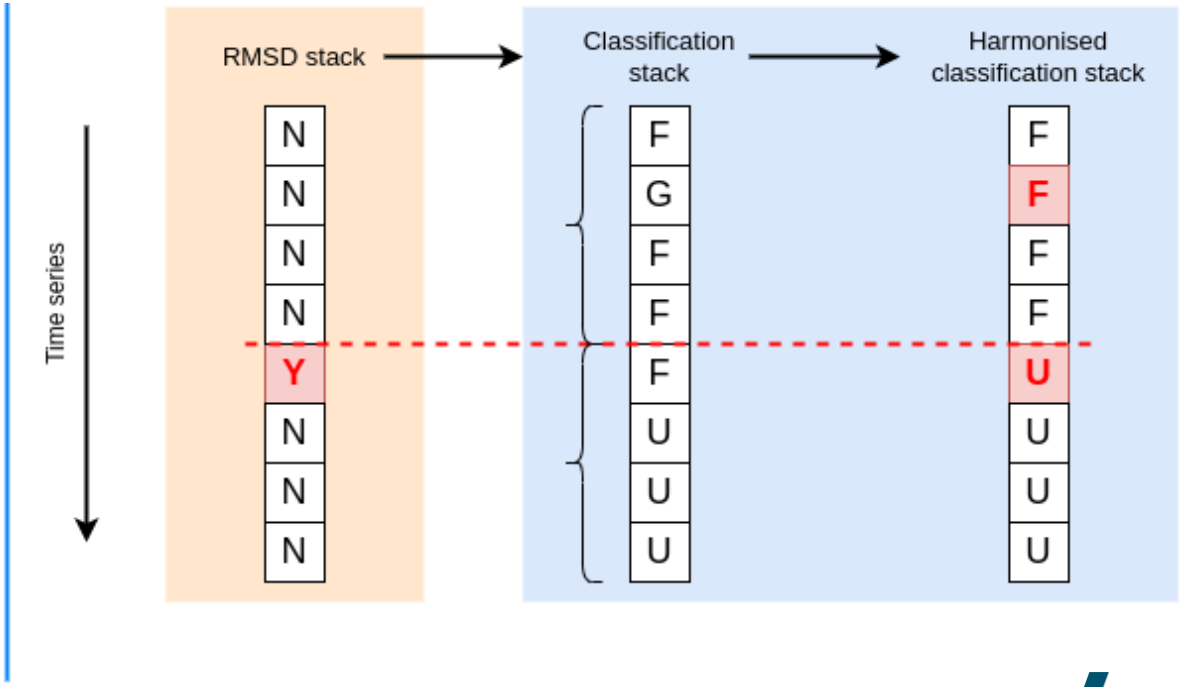
Compliance LULUCF regulation (2023 revision)

Change assessment: Inter-annual harmonization

Workflow Diagram







QA/QC: Uncertainty assessment

Validation results

	2017 OA	2018 OA	2019 OA	2020 OA	2021 OA	2022 OA	2023 OA
	96.15%	96.15%	95.50%	95.71%	95.71%	95.71%	95.71%

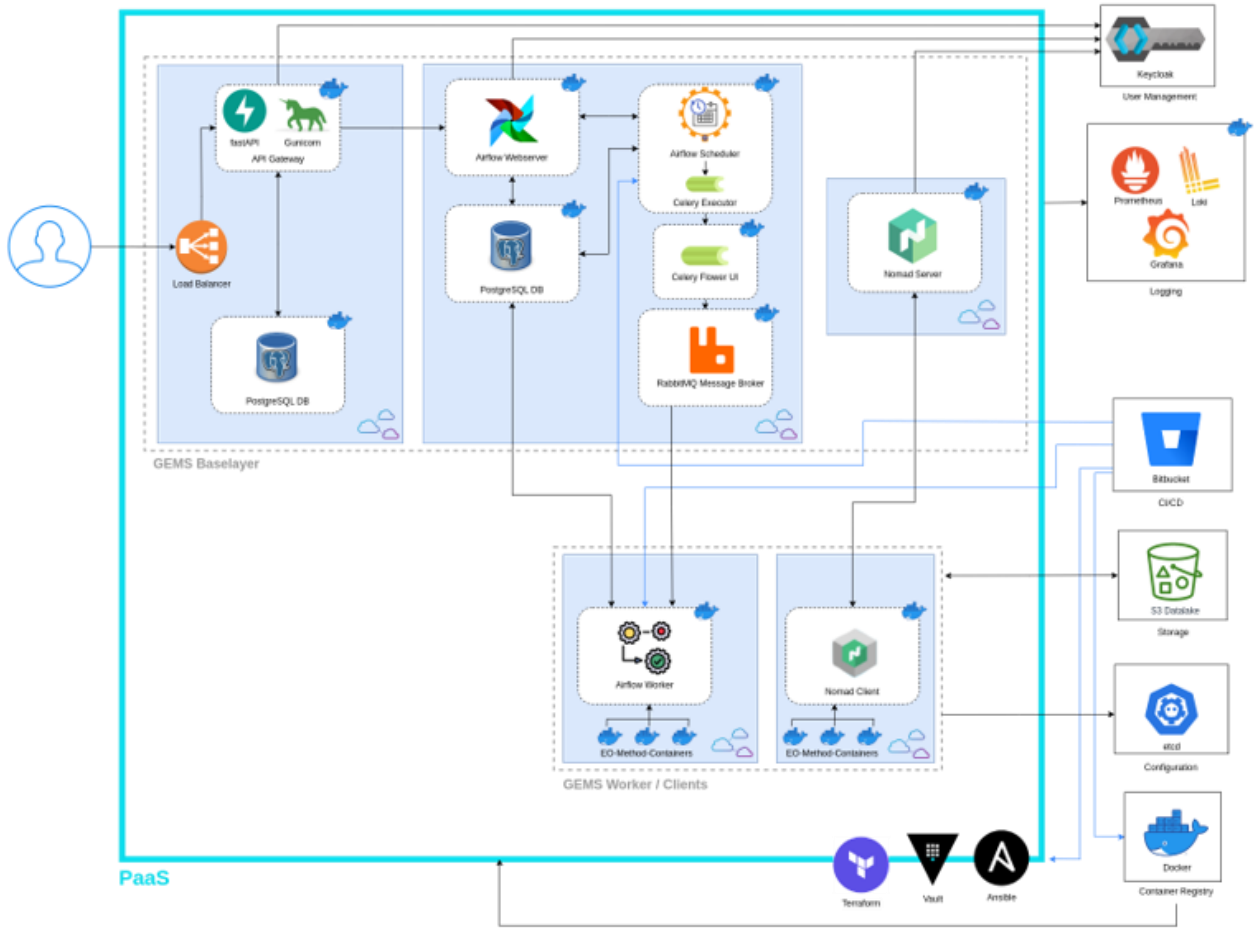
	2017 UA	2018 UA	2019 UA	2020 UA	2021 UA	2022 UA	2023 UA	2017 PA	2018 PA	2019 PA	2020 PA	2021 PA	2022 PA	2023 PA
Coniferous forest	96.85%	96.86%	95.60%	96.23%	96.23%	96.23%	96.23%	97.30%	97.30%	97.26%	97.28%	97.28%	97.28%	97.28%
Deciduous forest	92.41%	92.41%	92.41%	92.41%	92.41%	92.41%	92.41%	95.39%	95.39%	93.36%	93.36%	93.36%	93.36%	93.36%
Unstocked forest	90.02%	89.99%	89.98%	89.99%	89.99%	89.99%	89.99%	67.18%	67.17%	58.68%	62.64%	62.65%	62.65%	62.64%
Annual cropland	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Viticulture	66.00%	66.00%	66.00%	66.00%	66.00%	66.00%	66.00%	95.73%	95.73%	95.73%	95.73%	95.73%	95.73%	95.73%
Orchards	74.00%	74.00%	74.00%	74.00%	74.00%	74.00%	74.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Other perennial crops	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	0.91%	0.91%	0.91%	0.91%	0.91%	0.91%	0.91%
Other woody biomass in cropland	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Grassland	95.97%	95.97%	95.16%	95.16%	95.16%	95.16%	95.16%	98.32%	98.32%	98.31%	98.39%	98.39%	98.39%	98.39%
Other woody biomass in grassland	98.00%	98.00%	98.00%	98.00%	96.00%	96.02%	96.01%	43.25%	43.25%	43.24%	43.24%	42.74%	42.91%	42.79%
Water	99.98%	99.99%	100.00%	100.00%	100.00%	100.00%	100.00%	99.92%	99.92%	99.92%	99.92%	99.92%	99.92%	99.92%
Wetland	96.00%	96.00%	96.00%	96.00%	96.00%	96.00%	96.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Non-vegetated settlements	98.41%	98.41%	98.41%	98.42%	98.42%	98.42%	98.42%	95.87%	95.89%	95.87%	94.70%	94.72%	94.72%	94.74%
Trees in settlements	98.01%	98.01%	98.00%	98.00%	98.00%	98.00%	98.00%	67.35%	67.30%	67.29%	67.29%	67.25%	67.26%	67.26%
Grassland in settlements	68.21%	68.11%	68.06%	66.07%	66.04%	66.02%	66.02%	73.68%	73.57%	73.54%	72.94%	72.90%	72.87%	72.87%
Rocks and screes	98.42%	98.41%	98.42%	98.41%	98.41%	98.41%	98.42%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Glaciers	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
Alpine dwarf shrub heaths	94.00%	94.00%	94.00%	94.00%	94.00%	94.00%	94.00%	86.70%	86.70%	86.70%	86.70%	86.70%	86.70%	86.71%

	2017 Area (kha)	2017 Uncertainty (kha)	2018 Area (kha)	2018 Uncertainty (kha)	2019 Area (kha)	2019 Uncertainty (kha)	2020 Area (kha)	2020 Uncertainty (kha)	2021 Area (kha)	2021 Uncertainty (kha)	2022 Area (kha)	2022 Uncertainty (kha)	2023 Area (kha)	2023 Uncertainty (kha)
110	2958.85	±90.46	2973.06	±87.00	2939.72	±98.37	2954.82	±94.61	2954.95	±95.22	2954.06	±96.05	2953.34	±96.65
120	778.93	±58.33	779.58	±58.99	791.96	±64.60	792.67	±65.23	792.34	±65.78	791.67	±66.17	791.04	±66.71
130	250.52	±65.77	248.97	±67.59	282.43	±81.60	267.65	±76.38	268.34	±76.82	269.09	±77.71	269.21	±78.19
210	1249.96	±0.00	1250.09	±0.00	1250.06	±0.00	1250.12	±0.00	1249.89	±0.00	1249.88	±0.00	1249.58	±0.00
221	28.87	±5.59	28.87	±5.59	28.87	±5.59	28.87	±5.59	28.87	±5.59	28.87	±5.59	28.87	±5.59
222	4.14	±0.69	4.15	±0.69	4.15	±0.69	4.15	±0.69	4.15	±0.69	4.15	±0.69	4.14	±0.69
223	13.75	±5.48	13.75	±5.48	13.75	±5.48	13.75	±5.48	13.75	±5.48	13.75	±5.48	13.75	±5.48
225	2.88	±0.00	2.87	±0.00	2.87	±0.00	2.87	±0.00	2.87	±0.00	2.87	±0.00	2.87	±0.00
311	2065.25	±59.10	2067.74	±60.35	2052.36	±64.97	2049.70	±65.97	2039.48	±71.16	2040.67	±70.88	2040.18	±71.37
312	6.18	±6.34	6.18	±6.34	6.24	±6.44	6.18	±6.34	6.12	±6.34	6.20	±6.45	6.24	±6.55
410	71.89	±1.74	71.72	±1.74	72.93	±0.12	72.97	±0.12	73.00	±0.12	72.95	±0.12	72.92	±0.12
420	11.87	±0.66	11.88	±0.65	11.88	±0.65	11.87	±0.66	11.87	±0.66	11.87	±0.66	11.88	±0.65
511	289.66	±33.08	274.50	±10.36	279.86	±11.81	283.43	±11.95	280.57	±9.86	281.34	±9.88	283.41	±10.14
521	37.79	±6.13	38.17	±6.42	38.69	±6.77	39.11	±7.05	52.58	±26.89	53.04	±26.82	54.15	±27.15
522	85.39	±27.21	83.88	±27.49	80.89	±27.45	78.35	±27.90	77.37	±28.05	75.77	±27.97	73.29	±28.32
611	354.36	±7.14	354.62	±6.76	353.65	±6.19	353.62	±6.13	353.88	±5.83	353.88	±5.88	354.83	±5.89
612	17.63	±0.00	17.63	±0.00	17.63	±0.00	17.63	±0.00	17.63	±0.00	17.63	±0.00	17.65	±0.00
613	152.03	±27.15	152.28	±27.57	152.01	±27.71	152.19	±28.12	152.27	±28.27	152.25	±28.14	152.60	±28.25

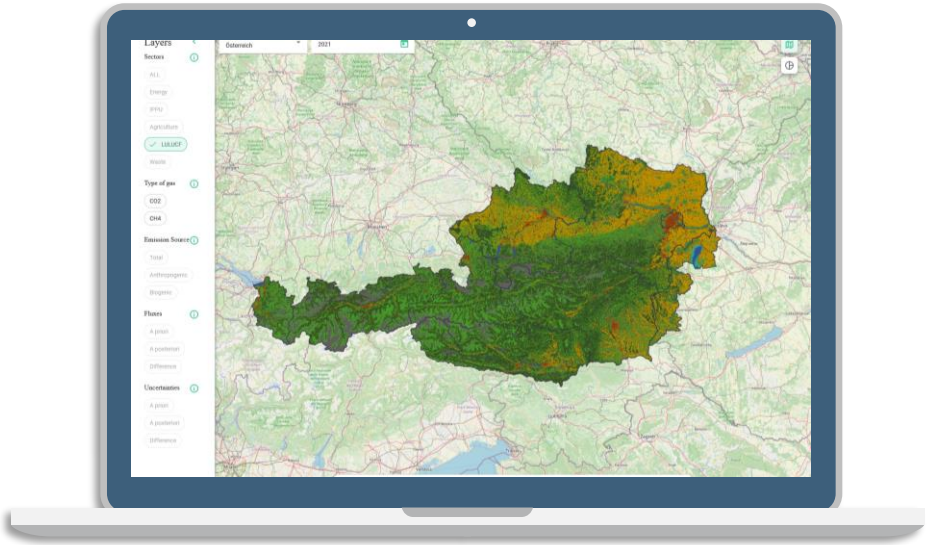
	2018 (NIR 2023)	CLC+ Backbone 2018			CLC+ LULUCF Instances 2018			GHG-KIT 2018		
	Area (km²)	Area (km²)	Difference NIR / CLC+ BB (km²)	Difference NIR / CLC+ BB (%)	Area (km²)	Difference NIR / LULUCF Instances (km²)	Difference NIR / LULUCF Instances (%)	Area (km²)	Difference NIR / GHG-KIT (km²)	Difference NIR / GHG-KIT (%)
Forest	40,130	40,249	-119	+0.3	43,545	-3415	+8.5	39,346	+784	-2.0
Cropland	14,036	11,747	+2288	-16.3	14,128	-92	+0.7	13,023	+1012	-7.2
Grassland	15,137	22,941	-7804	+51.6	17,761	-2624	+17.3	20,195	-5058	+33.4
Wetlands/ Water	1,533	847	+686	-44.8	1,045	+488	-31.8	963	+571	-37.2
Settlements	5,696	3,340	+2356	-41.4	3,679	+2016	-35.4	4,439	+1257	-22.1
Other land	7,341	4,772	+2569	-35.0	3,785	+3556	-48.4	5,845	+1496	-20.4
TOTAL	**83,873**	**83,897**	**-24**	+0.0	83,944	**-71**	+0.1	83,811	+61	-0.1

Accuracy
Comparability

ITC System for LULUCF-Production



Title	Description	Responsible
System Design	Architectural design of a scalable and cloud native microservice infrastructure	GeoVille
System Development	Development and automatic deployment of the system	GeoVille, CloudFlight
LULUCF Method Integration	Integration of LULUCF into the system as an operational product	GeoVille
Change Map Integration	Integration of Change Mapping into the system as an operational product	GeoVille
Shared Cloud Storage	Shared object storage (s3) for exchanging input data and results	EODC
Verification Plan	Formal testing structure definitions	Sistema
Acceptance Testing	Execution of overall Acceptance Tests	Sistema, GeoVille



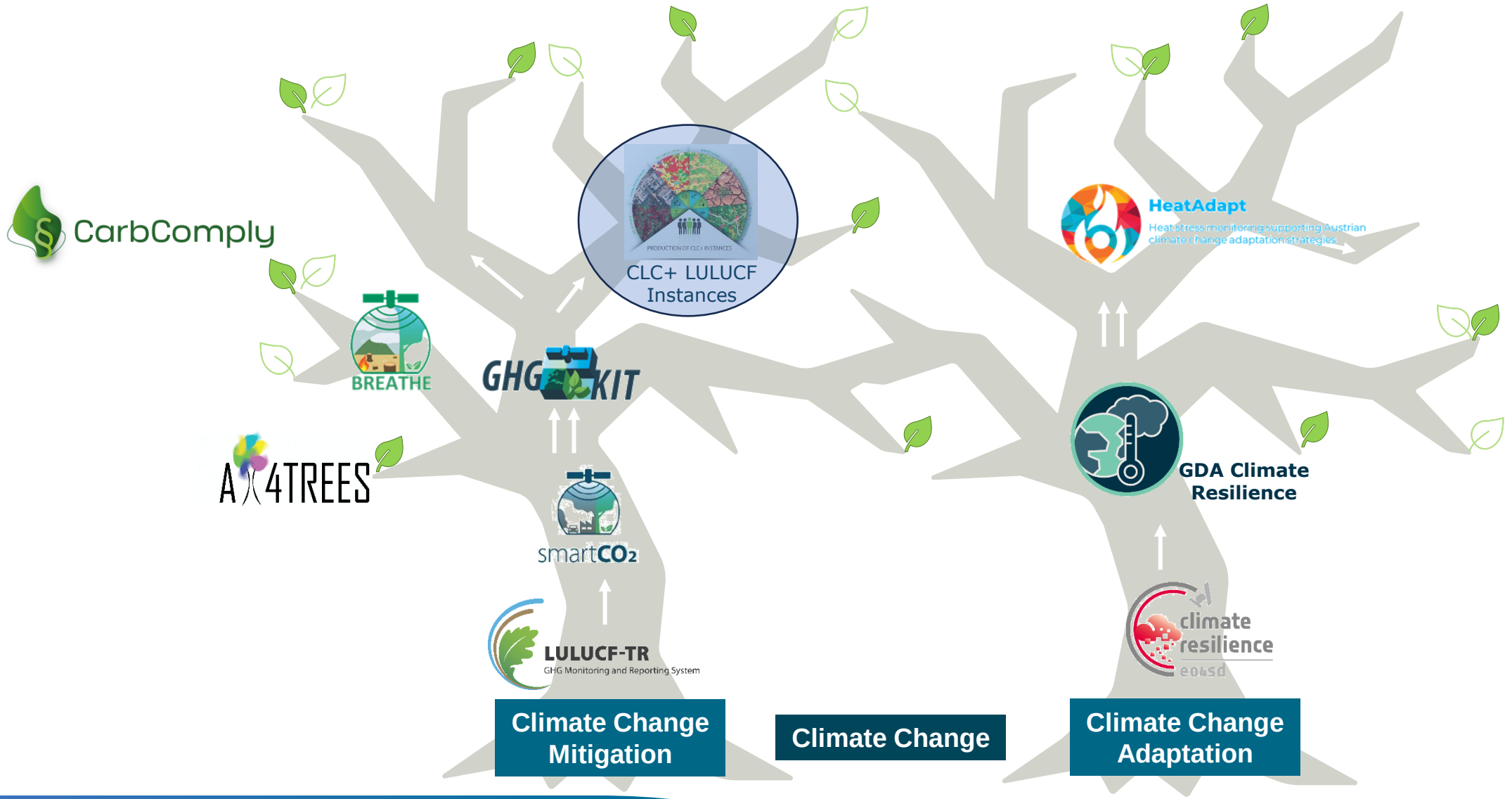
Reaching TRL 6!

GHG-KIT – *Prototyping an EO-enabled kit supporting greenhouse gas reporting*
User & Stakeholder Conference / Closure Meeting

SAVE THE DATE!

26-27 February 2025

TU WIEN *Kuppelsaal*, Vienna

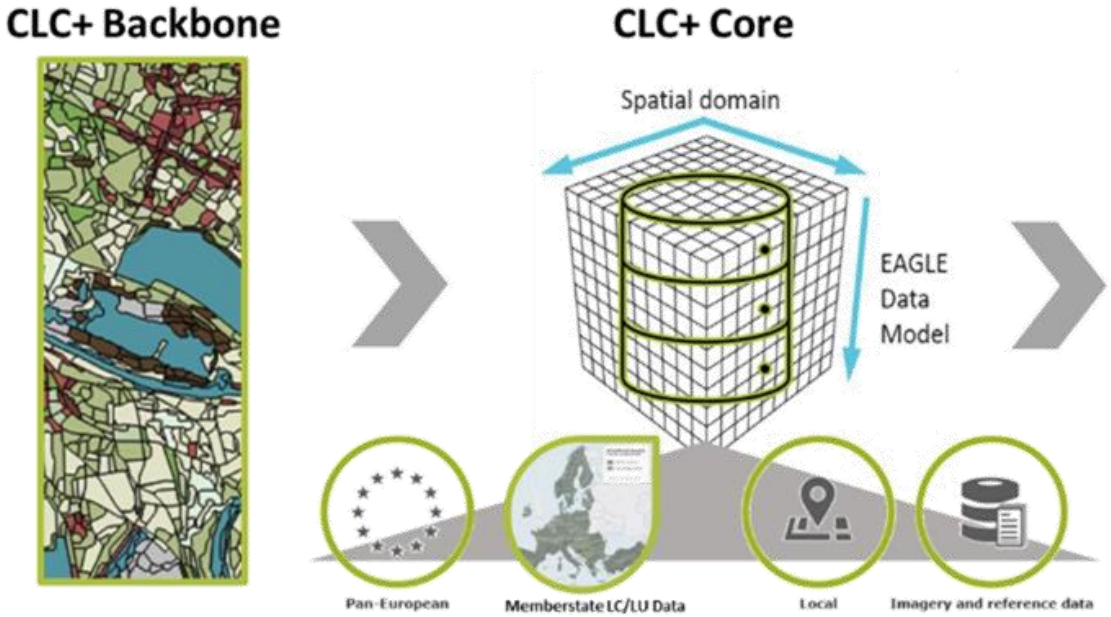


Strategic Innovation Path

GeoVille

Land Monitoring

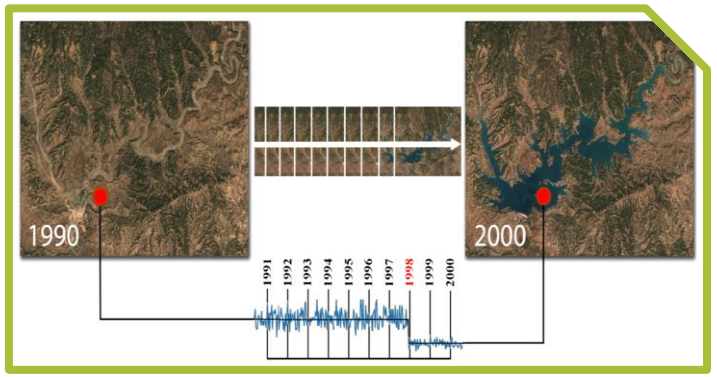
CLCplus LULUCF Instances – Feasibility study change enhancement



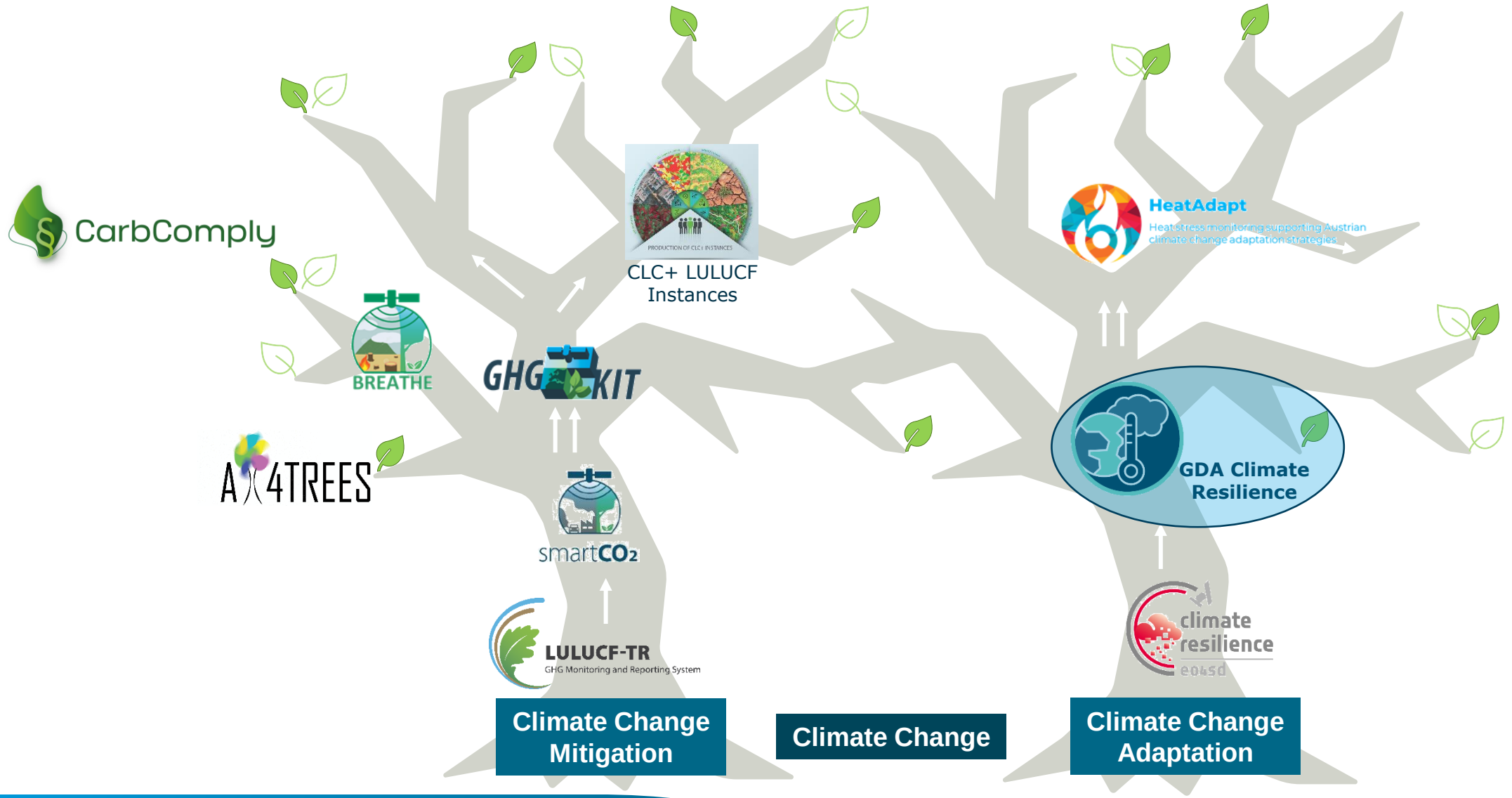
CLCplus Core baseline LULUCF status maps
2018, 2021, 2022, 2023,…

GHG KIT

Inter-annual harmonization method
Adapted to the CLCplus LULUCF Instances
Austrian investment 2.4 M€



LUC time series processor extension
2018-2023 onwards

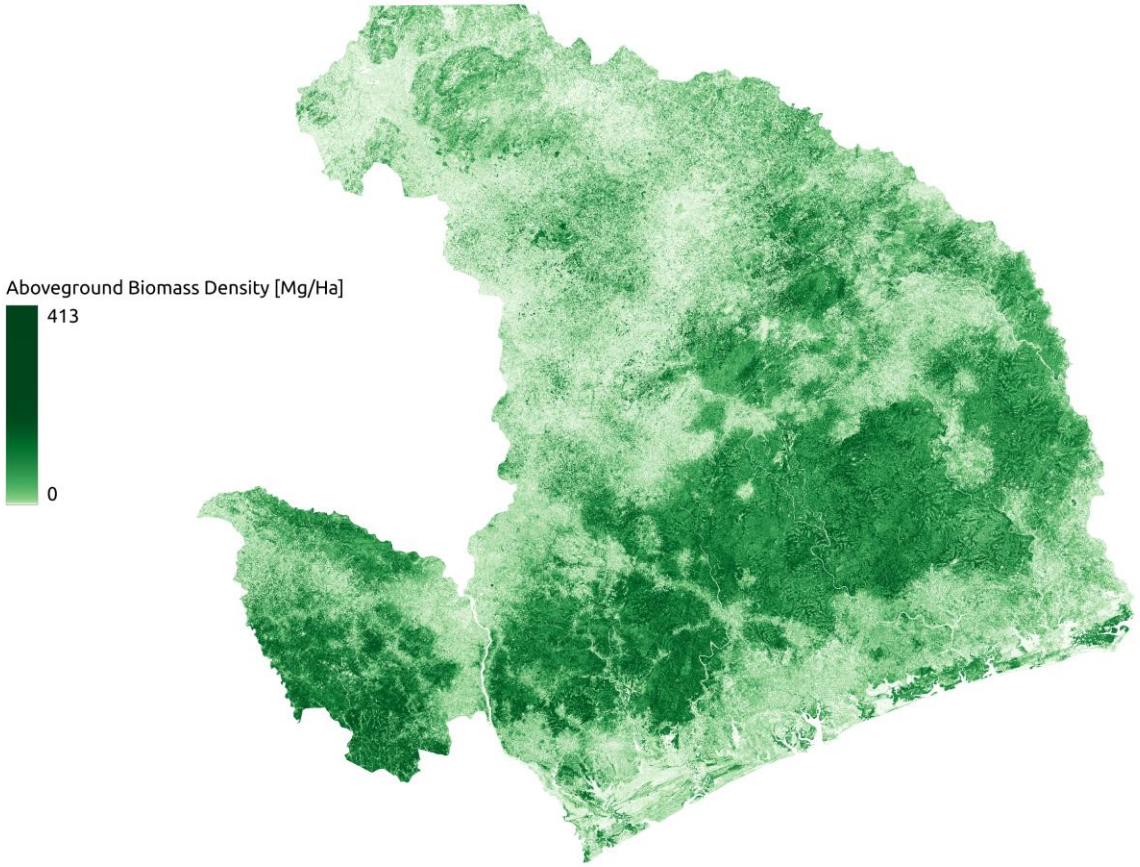


Strategic Innovation Path

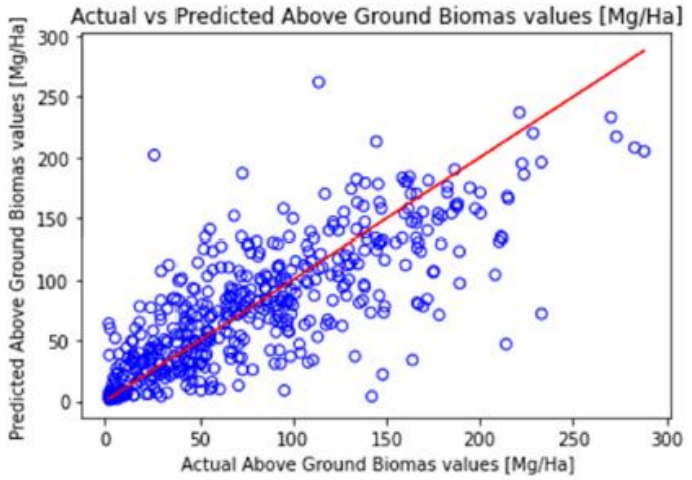
GeoVille

Above-Ground-Biomass Mapping in Mozambique
ESA GDA Climate Resilience - World Bank MRV V2.0

- Sentinel-2
- ALOS-PALSAR-2
- ALS
- TLS

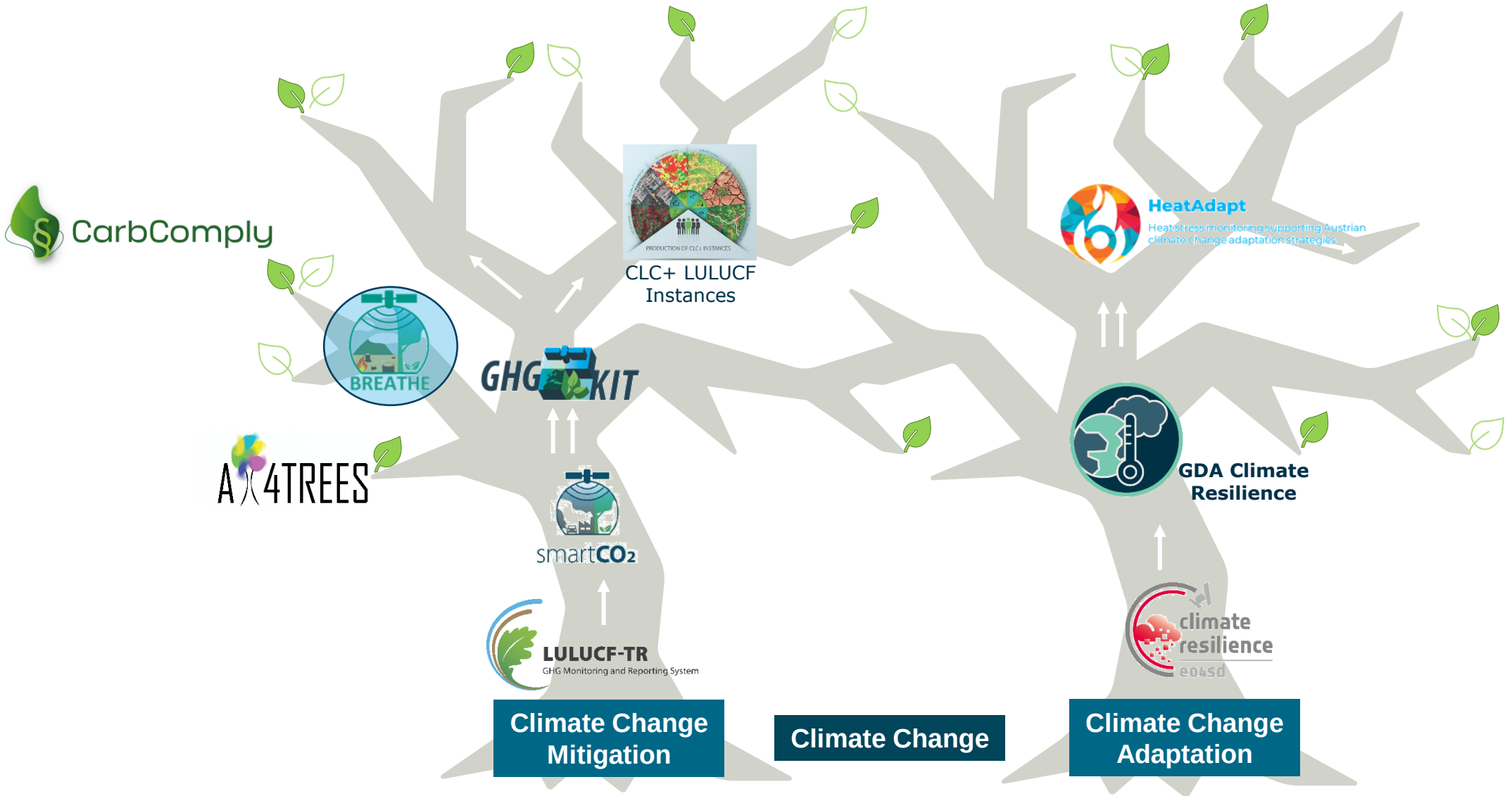


U-NET



R^2	0.76
RMSE	28.98 Mg/ha
Bias	-5.26

GeoVille



Strategic Innovation Path

GeoVille

EUREKA BREATHE - EO-based enhancement and verification of LULUCF inventories for forest & biomass

Prototype EO-integrated MRV System of greenhouse gas (GHG) emissions from Above-Ground-Biomass (AGB) changes in Austria and forest fires in Türkiye

BREATHE's specific aims:

- processing of multisource GHG satellite missions
- detailed information on the Earth's surface - including LULUCF, CLMS and newly developed information about forest and biomass
- Integration of independent field biomass measurements
- atmospheric transport modelling of GHG fluxes resulting from forest fires
- integration of all these different data sources and methods on a cloud-based IT system, compliant with the UNFCCC reporting standards.

BREATHE

https://breathe-project.eu/

eureka
innovation beyond borders

FFG
Forschung wirkt.

TÜBİTAK

GeoVille

GLOBETECH
Geographical Information Technologies

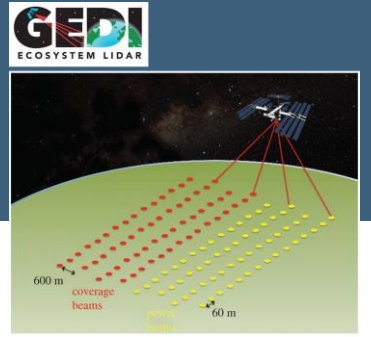
umweltbundesamt
ENVIRONMENT AGENCY AUSTRIA

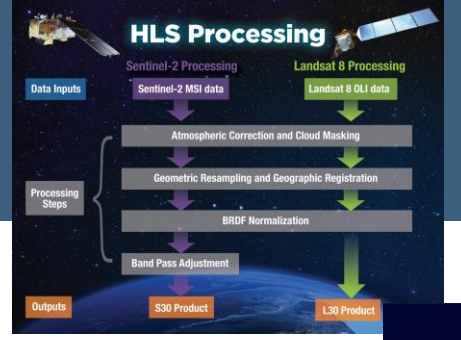
REPUBLIC OF TÜRKİYE
MINISTRY OF AGRICULTURE AND FORESTRY
GENERAL DIRECTORATE OF FORESTRY

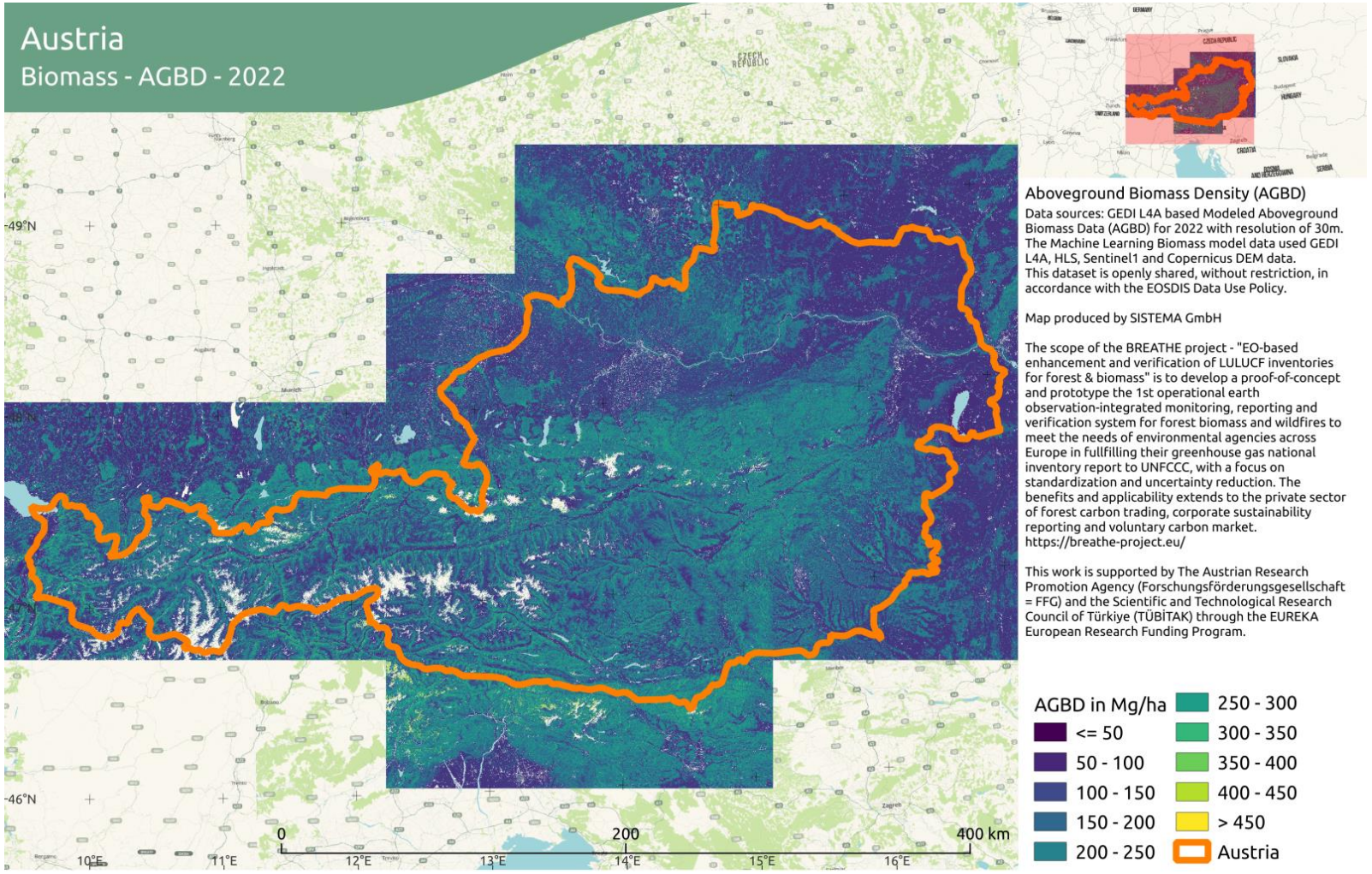
universität wien

SISTEMA
ENVIRONMENTAL INFORMATION MINING

Above-Ground-Biomass Density Mapping 2019-2022







Aboveground Biomass Density (AGBD)

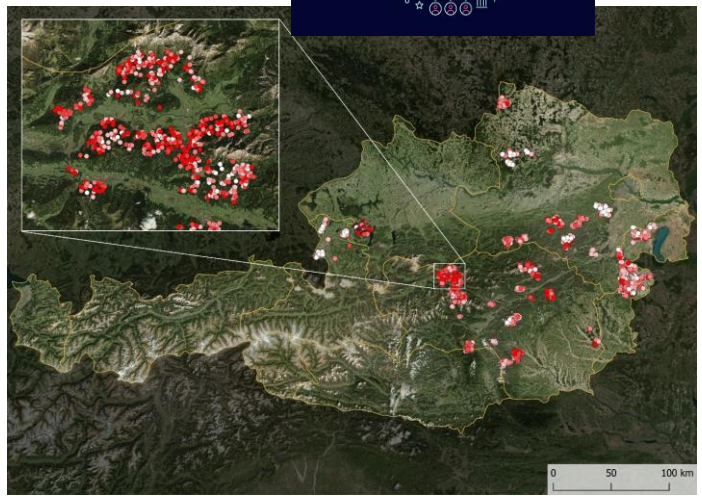
Data sources: GEDI L4A based Modeled Aboveground Biomass Data (AGBD) for 2022 with resolution of 30m. The Machine Learning Biomass model data used GEDI L4A, HLS, Sentinel1 and Copernicus DEM data. This dataset is openly shared, without restriction, in accordance with the EOSDIS Data Use Policy.

Map produced by SISTEMA GmbH

The scope of the BREATHE project - "EO-based enhancement and verification of LULUCF inventories for forest & biomass" is to develop a proof-of-concept and prototype the 1st operational earth observation-integrated monitoring, reporting and verification system for forest biomass and wildfires to meet the needs of environmental agencies across Europe in fullfilling their greenhouse gas national inventory report to UNFCCC, with a focus on standardization and uncertainty reduction. The benefits and applicability extends to the private sector of forest carbon trading, corporate sustainability reporting and voluntary carbon market. https://breathe-project.eu/

This work is supported by The Austrian Research Promotion Agency (Forschungsförderungsgesellschaft = FFG) and the Scientific and Technological Research Council of Türkiye (TÜBİTAK) through the EUREKA European Research Funding Program.

AGBD in Mg/ha
- <= 50
- 50 - 100
- 100 - 150
- 150 - 200
- 200 - 250
- 250 - 300
- 300 - 350
- 350 - 400
- 400 - 450
- > 450
- Austria



Over 9000 In-Situ values over Austria

Year	Mean Absolute Error (Mg/ha)
2019	141.50
2020	146.46
2021	149.04
2022	152.57

https://gtif.esa.int/

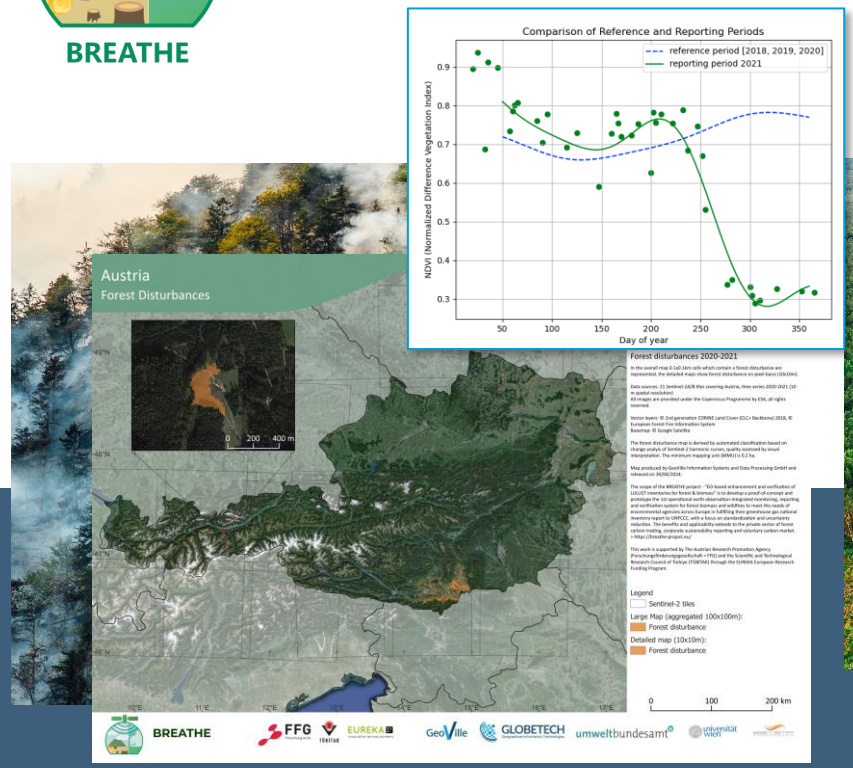
SISTEMA ENVIRONMENTAL INFORMATION MINING

GeoVille

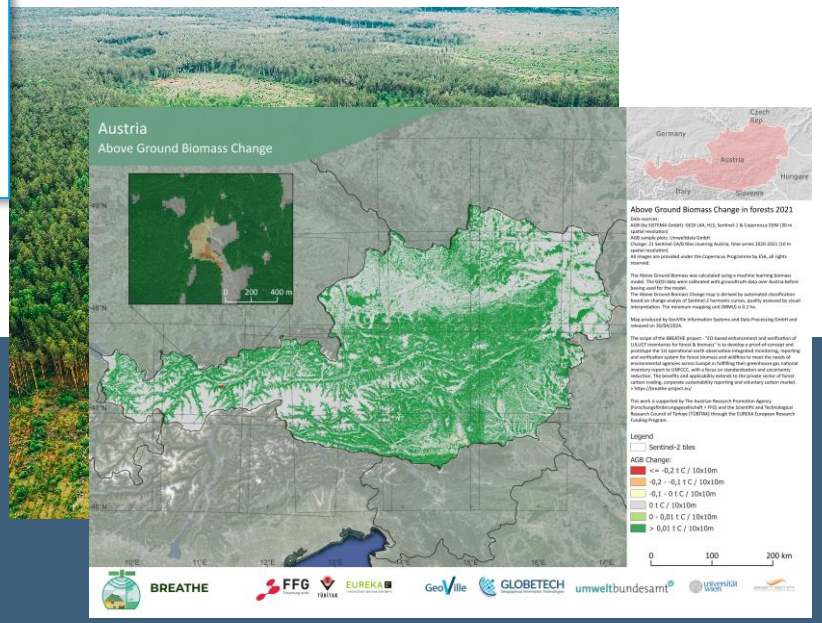
EUREKA BREATHE - EO-based enhancement and verification of LULUCF inventories for forest & biomass

BREATHE

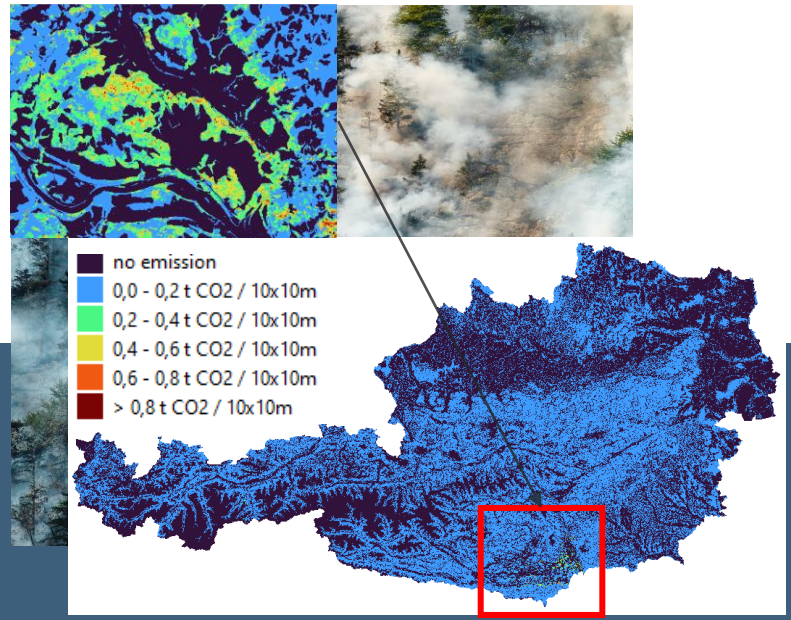
Prototype EO-integrated MRV System of greenhouse gas (GHG) emissions from Above-Ground-Biomass (AGB) changes in Austria and forest fires in Türkiye



Forest disturbances



Above ground biomass density (AGBD) changes



CO2 emissions & removals

GeoVille

EUREKA BREATHE - EO-based enhancement and verification of LULUCF inventories for forest & biomass

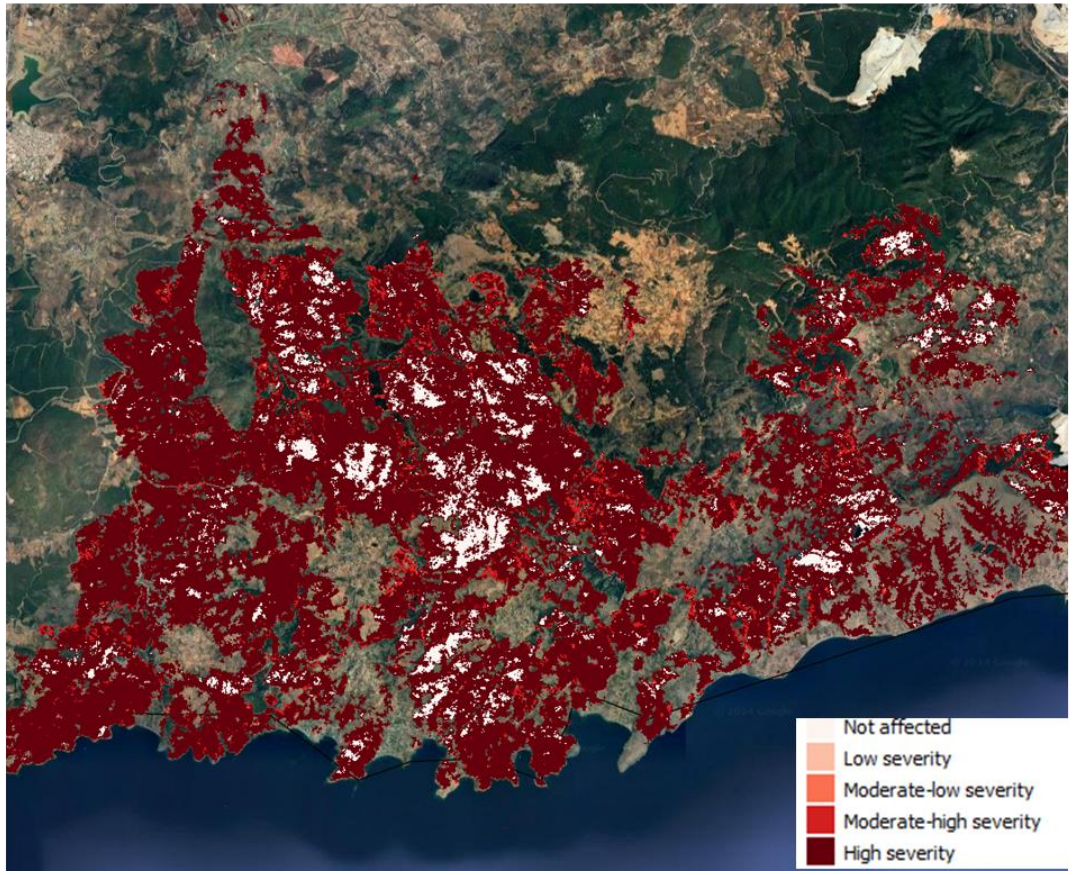
BREATHE

Türkiye – Use Case Muğla:

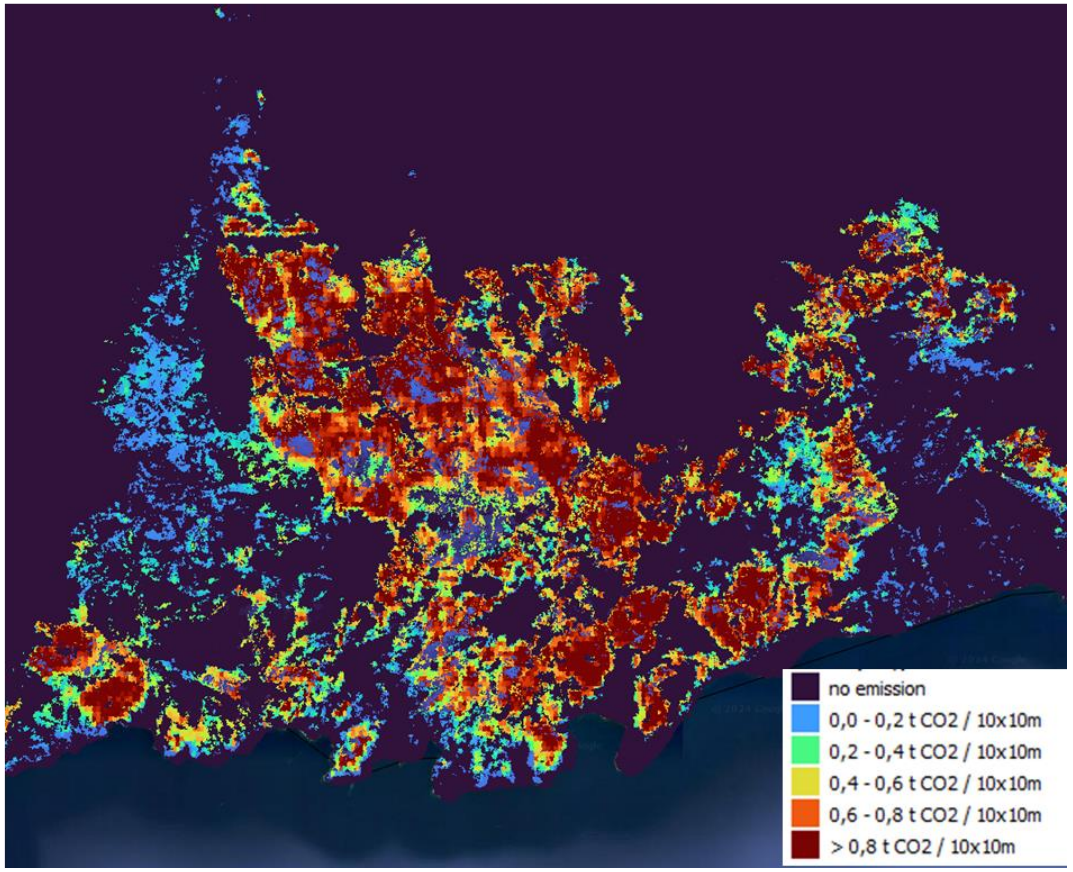
Forest fires (2021)

$$L_{fire} = A * M_B * C_f * G_{ef} * 10^{-3}$$

Fire severity



Emissions by forest fires



REPUBLIC OF TÜRKİYE
MINISTRY OF AGRICULTURE AND FORESTRY
GENERAL DIRECTORATE OF FORESTRY

umweltbundesamt
ENVIRONMENT AGENCY AUSTRIA

GeoVille

«Take-Home Messages»

- ✓ EO-integrated LULUCF and Carbon Removal MRV service covering transition periods of 20-35 years using Landsat and Sentinel time series scalable to other countries and at pan-European level
- ✓ Scientifically proven technological solution (> 5 M€ European/Austrian R&D investments), pre-operational testing & service demonstration in Austria and Türkiye, some elements (LULUCF AD) already operational under Copernicus
- ✓ Roll-out via high performance cloud operation ICT system
- ✓ Compliance with LULUCF regulation (2023 revision) to integrate geospatially explicit information reaching Tier 2-3 approaches for Key categories such as Forest by 2028
- ✓ Addressing the needs of Transparency, Accuracy, Consistency, Completeness and Comparability -TACCC principles of both the compliance and voluntary carbon markets

GeoVille

Breakout Group 1 - Enhancing Earth Observation Monitoring Capabilities

Questions to be addressed:

1. How can EO-based data and methodologies can be leveraged to comply with the TACCC principles of Transparency, Accuracy, Completeness, Consistency and Comparability in support to monitoring and verification of carbon removals?

2. What are the main challenges to address for the operationalization and standardization of an EO-based MRV system of carbon removals in Europe?

3. How can we bridge the gap between the different stakeholders (policymakers, researchers, service providers, financial institutions, carbon rating agencies, farmers,…) across the entire carbon market value chain?

4. Who will set the standards taken as a baseline for the subsidies of the new ETS based on LULUCF ?

5. What are the user requirements for an EO-based carbon removal MRV system?

GeoVille

GLOBAL INSIGHTS
AT YOUR FINGERTIPS

GeoVille is internationally renowned for its leading role in innovative Earth observation services and offers a one-stop-shop for targeted value-added geo-information products and related solutions.

CONTACT US

GeoVille Information Systems
& Data Processing GmbH
Sparkassenplatz 2
6020 Innsbruck, Austria

OR FIND US ONLINE

info@geoville.com
www.GeoVille.com