An introduction to Geospatial data for GHG emissions estimations

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Outline

- **Requirements under Reg.841 and IPCC Approach 3**
- **Some basic Geospatial data concepts**
- **Overview of the datasets available**
- **Competences needed at the country level to use these data**

Requirements under Reg.841 and IPCC Approach 3

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METHODOLOGICAL REQUIREMENTS
Reg. 2018/841

Art.18 amends Reg.525/2013 adding (among other):

(4) The following Annex is inserted:

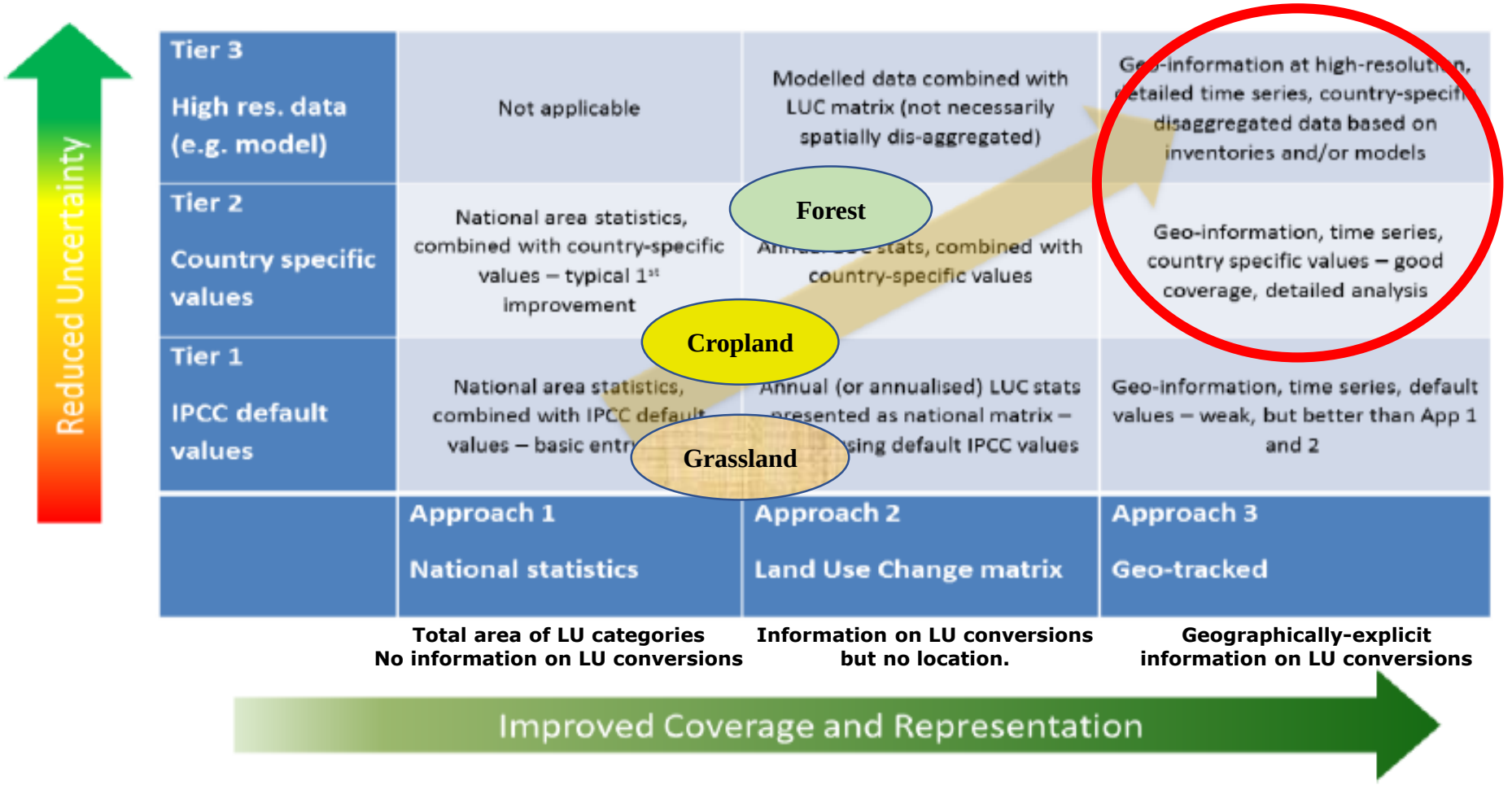
'*ANNEX IIIA*

Methodologies for monitoring and reporting referred to in point (da) of Article 7(1)

Approach 3: Geographically-explicit land-use conversion data in accordance with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

METHODOLOGICAL REQUIREMENTS

Reg. 2018/841



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Approach 3 for Land Representation

From the IPCC Guidelines:

"Approach 3 is both spatially and temporally consistent and explicit

The main advantage of spatially-explicit data is that analysis tools such as Geographic Information Systems can be used to link multiple spatially-explicit data sets (such as those used for stratification) and describe in detail the conditions on a particular piece of land prior to and after a land-use conversion."

Table 3.6A (IPCC 2019 Refinement)	
Method	***Approach 3 Examples***
Sample based methods	• Permanent and consistent georeferenced ground plots. • Continuous and consistent samples using remote sensing data.
Survey-based methods	Specific survey designs that identify activities through time for each land unit within a known region.
Wall-to-Wall methods	Tracking pixels / land units using time-series consistent data.

Some basic Geospatial data concepts

What is a "Spatially-explicit" data?

Object: an agricultural field

Spatial Information: map

- **WHERE it is**
- **GEOMETRY**
- **SPATIAL RELATIONSHIPS (roads, etc.)**

Attribute Information: database

Owner	.....
Crop	.....
Tillage	.....
Fertilization	.....

This all is managed in a *Geographic Information System*

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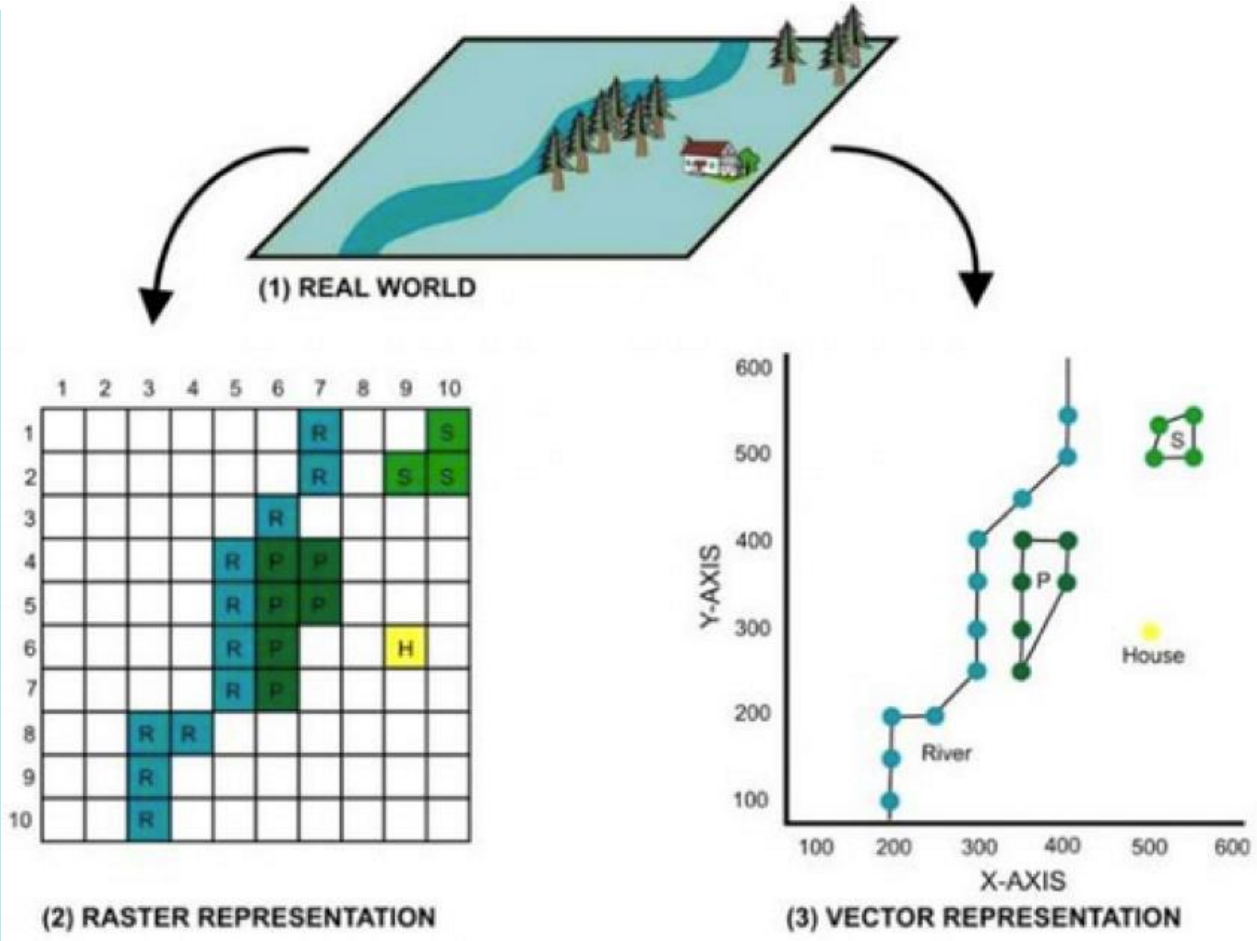
The two data models of Geospatial Data: Raster vs. Vectors



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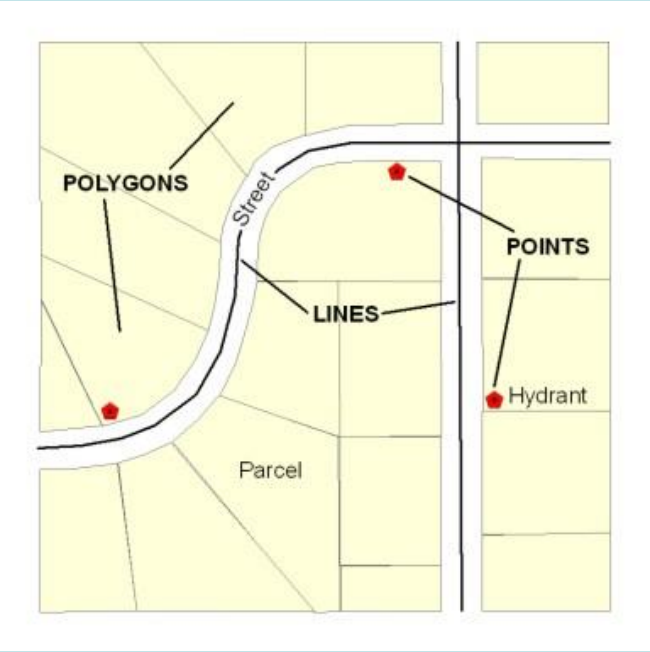
Vectors



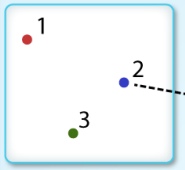
Vector data are tipically used to represent land units, boundaries, points, line features.
An attribute table is associated with entrances for each land unit.

Examples:

- **surveys (e.g. in homogenous land units, or point samples)**
- **cadastral maps**
- **administrative maps.**

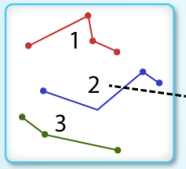
Attribute tables

Example Attributes for Point Data



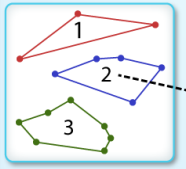
ID	Plot Size	Type	VegClass
1	40	Vegetation	Conifer
2	20	Vegetation	Deciduous
3	40	Vegetation	Conifer

Example Attributes for Line Data



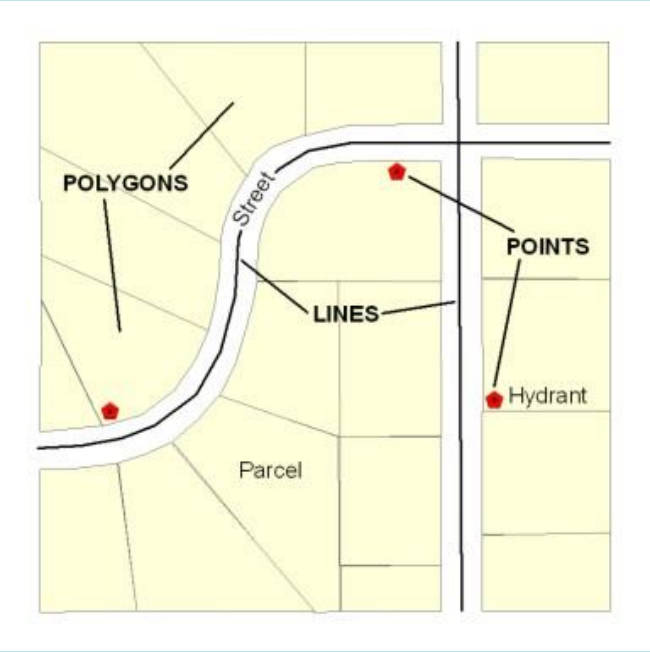
ID	Type	Status	Maintenance
1	Road	Open	Year Round
2	Dirt Trail	Open	Summer
3	Road	Closed	Year Round

Example Attributes for Polygon Data



ID	Type	Class	Status
1	Herbaceous	Grassland	Protected
2	Herbaceous	Pasture	Open
3	Herbaceous / Woody	Grassland	Protected

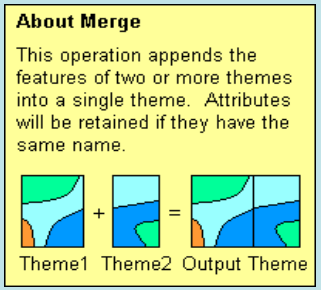
Vectors

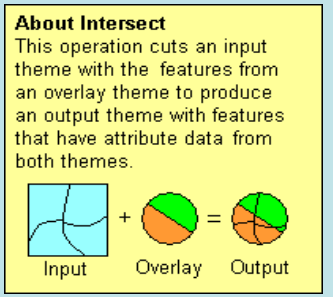


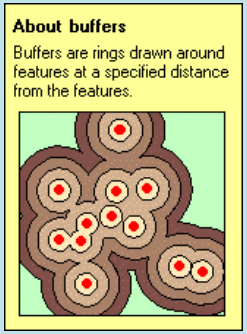
Spatial operations can be performed on the vectors.

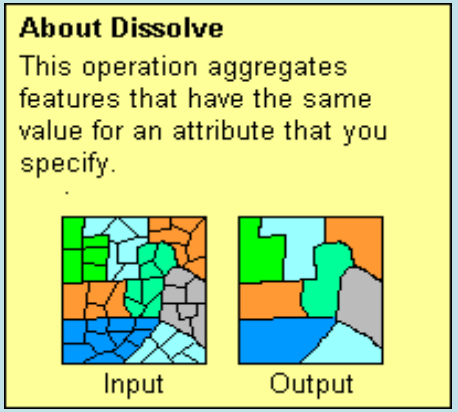
Formats: Shapefiles (.shp), Google Earth files (.kmz, .kml)

Spatial operations









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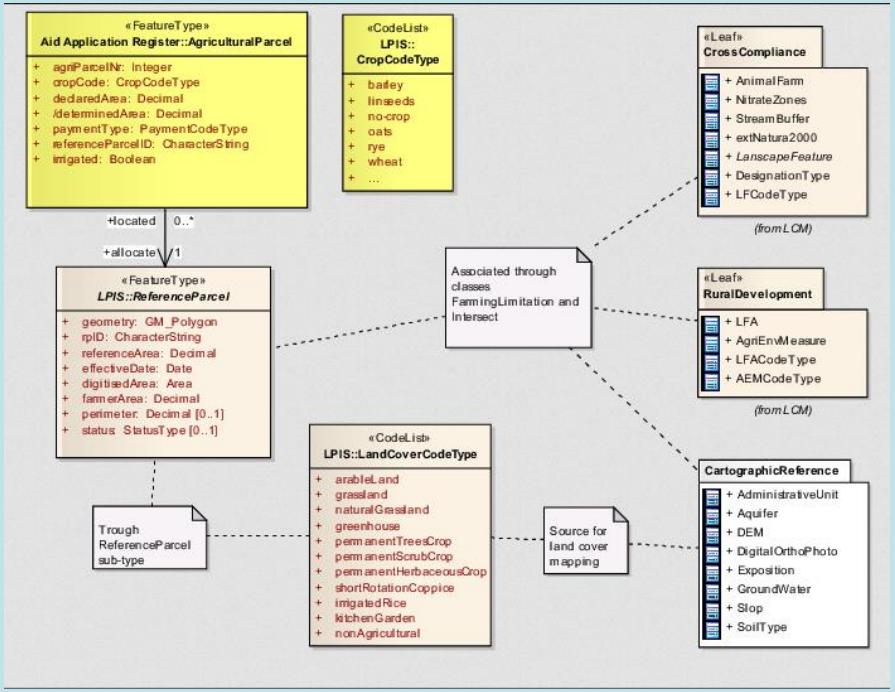
Vectors

Example: the Land Parcel identification System (LPIS)

A vector layer with all the Land Parcels, with attribute tables describing each parcel.



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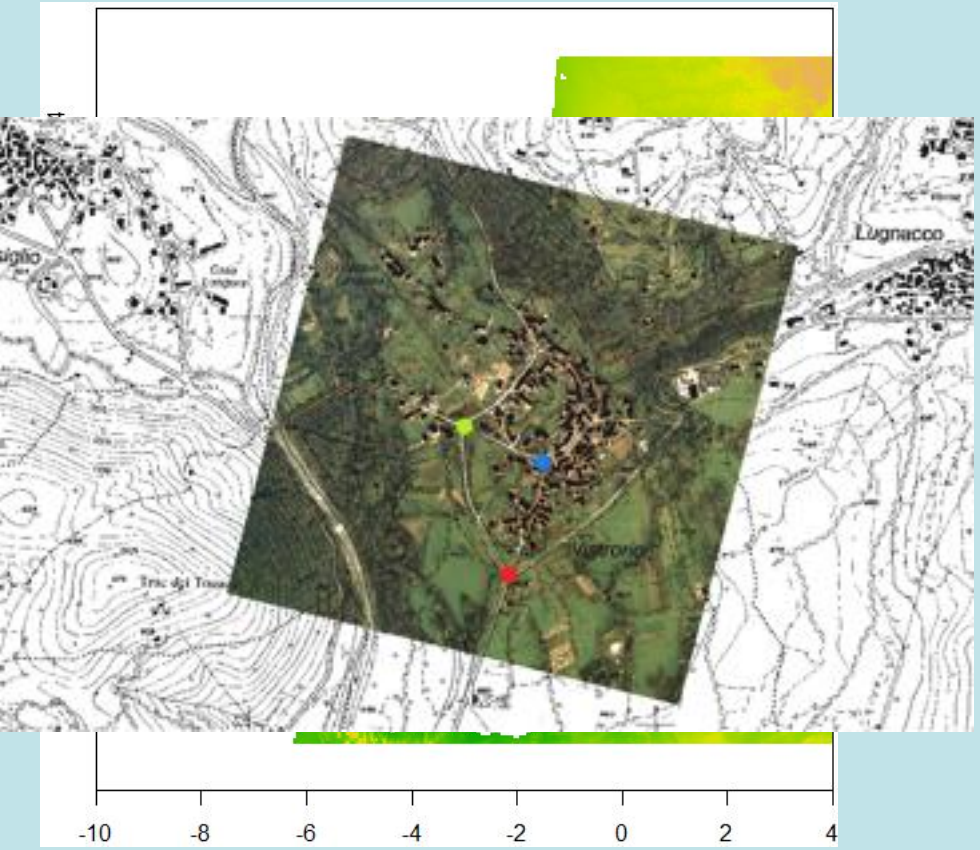
Rasters



Raster data

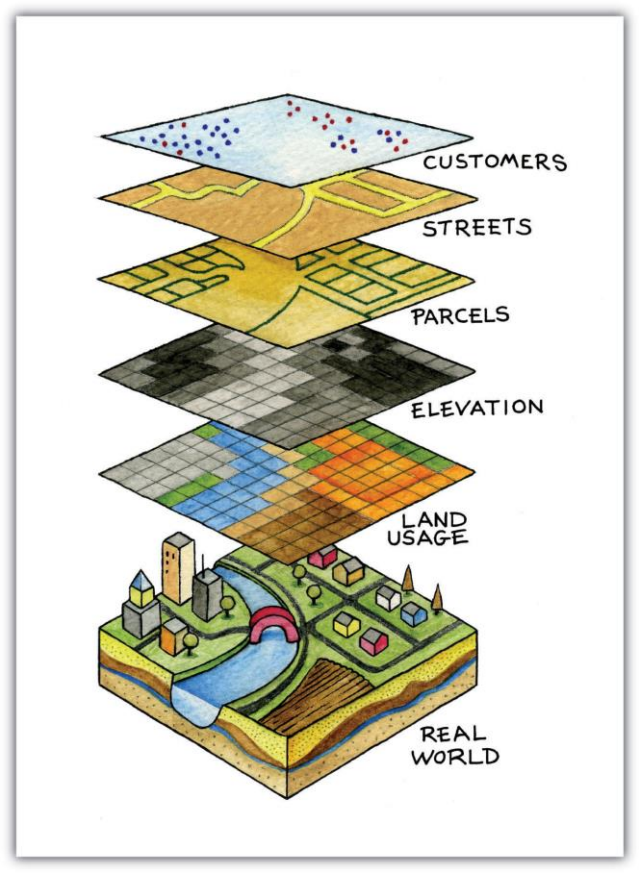
Data are recorded as pixel units in a grid. Each pixel has a value associated.

Examples:

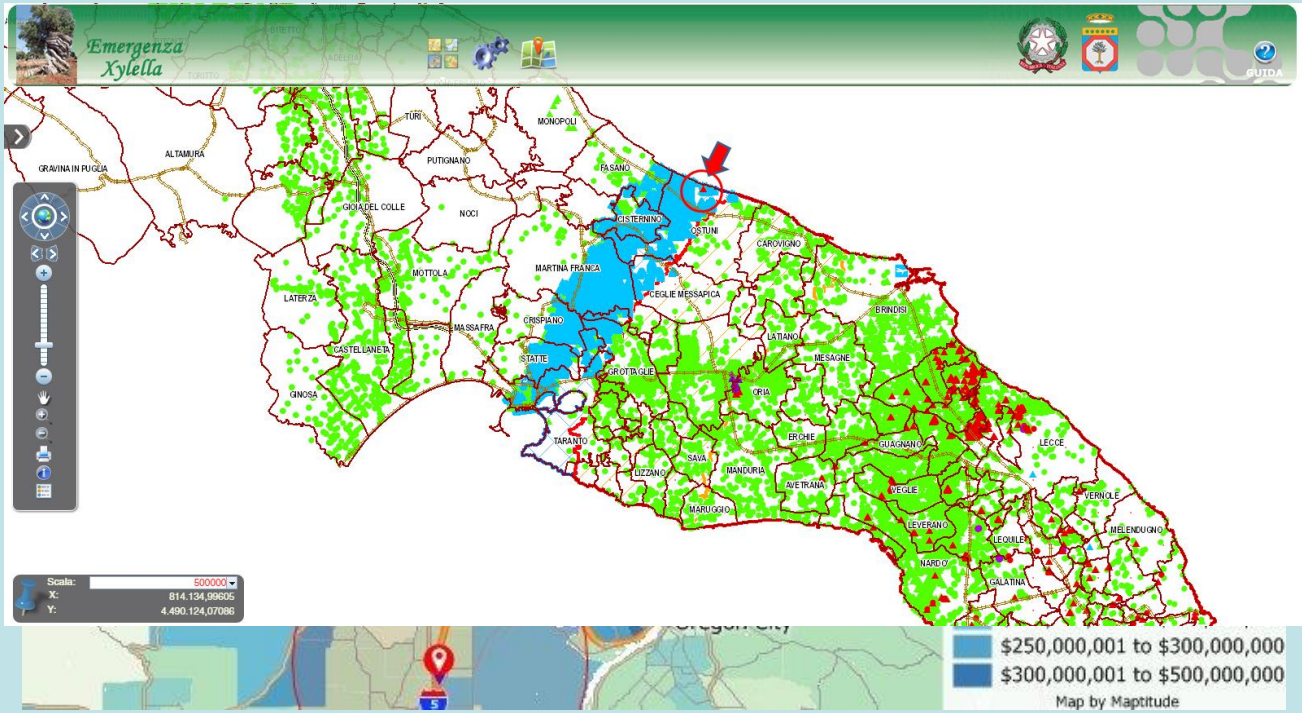
- **Photographs**
- **Remote Sensing and derived products**
- **Geo-statistical spatialization of sample data**

These are the data generally used in Geospatial modelling: the model is applied within each pixel.

GIS analyses:
Overlaying different layers to obtain new information



Example: buffering the infected areas and selection of suitable areas



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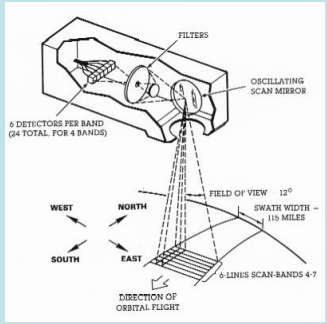
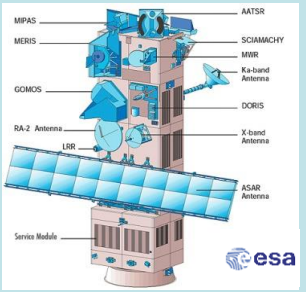
Remote Sensing

Remote Sensing (RS) is a series of techniques and tools for the collection of information about an object without coming into physical contact with that object.

A sensor

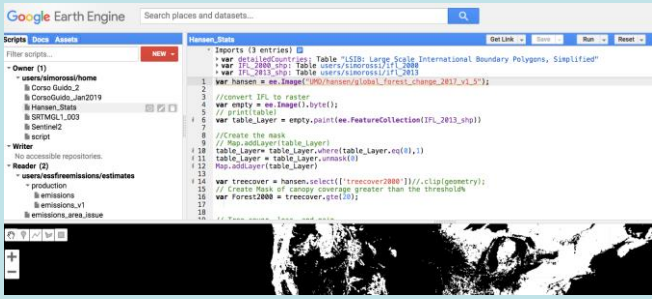


A carrying platform



Receiving stations

Processing tools



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Remote Sensing: from radiation to products

Remote Sensing (RS) is a series of techni
the collection of information about an obje
into physical contact with that object.

RS measures <u>radiation</u>
<u>*...NOT*</u> vegetation state, growth stage, etc.!!!

Radiation data have to be interpreted and "translated" into meaningful information.

"The inverse problem": how the characteristics which we want to investigate are correlated with the radiation: from radiation to its cause.

Level 1
MODIS Raw Radiances
MODIS Calibrated Radiances
MODIS Geolocation Fields

MODIS Atmosphere Products
MODIS Aerosol Product
MODIS Total Precipitable Water
MODIS Cloud Product
MODIS Atmospheric Profiles
MODIS Atmosphere Joint Product
MODIS Atmosphere Gridded Product
MODIS Cloud Mask

MODIS Land Products
MODIS Surface Reflectance
MODIS Land Surface Temperature and Emissivity (MOD11)
MODIS Land Surface Temperature and Emissivity (MOD21)
MODIS Land Cover Products
MODIS Vegetation Index Products (NDVI and EVI)
MODIS Thermal Anomalies - Active Fires
MODIS Fraction of Photosynthetically Active Radiation (FPAR) / Leaf Area Index (LAI)
MODIS Evapotranspiration
MODIS Gross Primary Productivity (GPP) / Net Primary Productivity (NPP)
MODIS Bidirectional Reflectance Distribution Function (BRDF) / Albedo Parameter
MODIS Vegetation Continuous Fields
MODIS Water Mask
MODIS Burned Area Product

MODIS Cryosphere Products
MODIS Snow Cover
MODIS Sea Ice and Ice Surface Temperature

MODIS Ocean Products
MODIS Sea Surface Temperature
MODIS Remote Sensing Reflectance
MODIS Chlorophyll-a Concentration
MODIS Diffuse Attenuation at 490 nm
MODIS Particulate Organic Carbon
MODIS Particulate Inorganic Carbon
MODIS Normalized Fluorescence Line Height (FLH)
MODIS Instantaneous Photosynthetically Available Radiation
MODIS Daily Mean Photosynthetically Available Radiation

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radar)

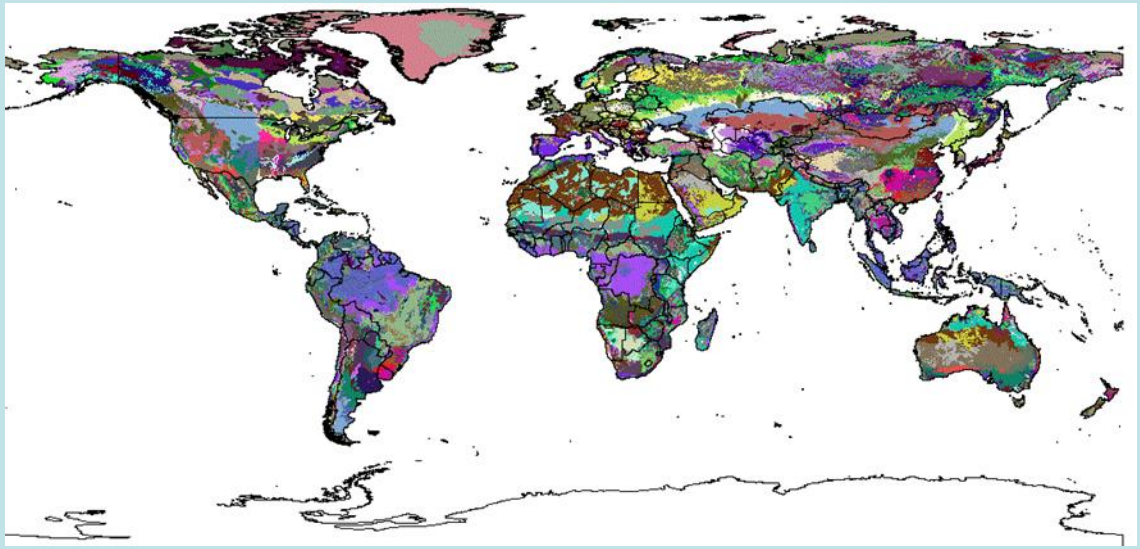
ropean
mmission

Example of Stratification

Criteria: Land Use, Climate, Global Ecological Zone, Soil

Classes identified: 2016

Existing classes: 651



Strata	GEZ	soil	climate	n. pixels
1	Tropical rainforest	Organic	Warm Temperate Moist	0
2	Tropical rainforest	Organic	Warm Temperate Dry	0
3	Tropical rainforest	Organic	Cool Temperate Moist	0
4	Tropical rainforest	Organic	Cool Temperate Dry	0
5	Tropical rainforest	Organic	Polar Moist	0
6	Tropical rainforest	Organic	Polar Dry	0
7	Tropical rainforest	Organic	Boreal Moist	0
8	Tropical rainforest	Organic	Boreal Dry	0
9	Tropical rainforest	Organic	Tropical Montane	15
10	Tropical rainforest	Organic	Tropical Wet	3276
11	Tropical rainforest	Organic	Tropical Moist	1107
12	Tropical rainforest	Organic	Tropical Dry	53
13	Tropical rainforest	Sandy	Warm Temperate Moist	0
14	Tropical rainforest	Sandy	Warm Temperate Dry	0
15	Tropical rainforest	Sandy	Cool Temperate Moist	0
16	Tropical rainforest	Sandy	Cool Temperate Dry	0
17	Tropical rainforest	Sandy	Polar Moist	0
18	Tropical rainforest	Sandy	Polar Dry	0
19	Tropical rainforest	Sandy	Boreal Moist	0
20	Tropical rainforest	Sandy	Boreal Dry	0
21	Tropical rainforest	Sandy	Tropical Montane	14
22	Tropical rainforest	Sandy	Tropical Wet	6809
23	Tropical rainforest	Sandy	Tropical Moist	143
24	Tropical rainforest	Sandy	Tropical Dry	5
...	...	...	...	...
2012	Water	Other	Boreal Dry	0
2013	Water	Other	Tropical Montane	0
2014	Water	Other	Tropical Wet	0
2015	Water	Other	Tropical Moist	0
2016	Water	Other	Tropical Dry	0

Remote Sensing

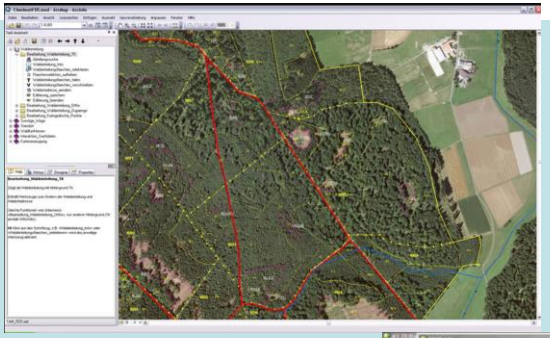
Important things to consider:

- **Spatial resolution (minimum mapping unit)**
- **Temporal resolution**
- **(Spectral resolution)**

Spatial data processing

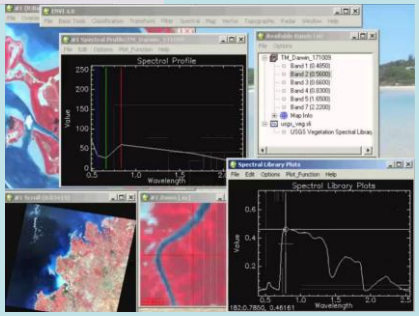
Know-how

- **Algorithms development**
- **Expertise in GHG Inventory methodologies**



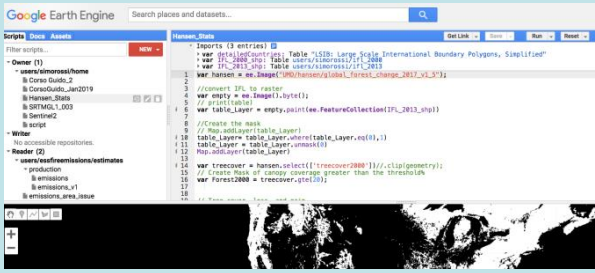
Software:

- **GIS software (e.g. ArcGIS, QGIS, gvSIG)**
- **Image Processing software (e.g. ENVI, ERDAS)**
- **Geodatabases (PostGIS/PostgreSQL)**



Programming languages

- **e.g. R, IDL, Python**
- **Cloud computing platforms (Google Earth Engine)**



Infrastructures

- **Cluster/grid computing infrastructures (JRC JEODPP)**

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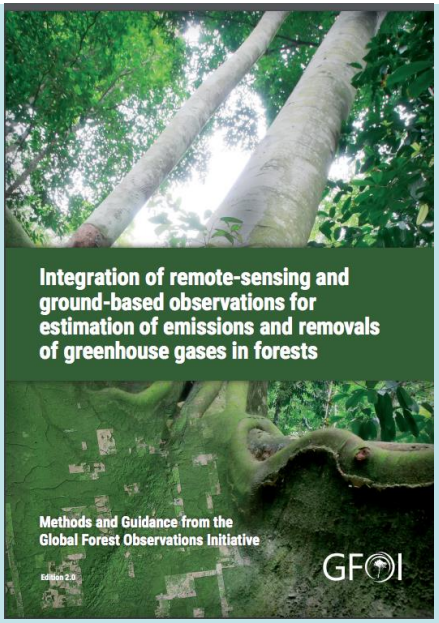
Overview of the available datasets

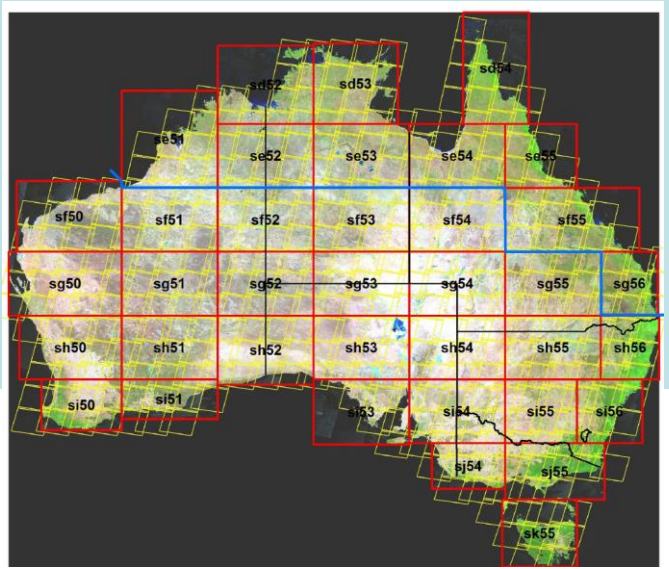
Geospatial data for land use tracking and GHG estimations

Geospatial data and in particular Remote sensing imagery is extensively used to monitor forests areas and deforestation in Developing Countries (REDD+).

Applications in LULUCF is still limited, although some examples exist (e.g. Australia GHGI with Landsat 1972-2018)

Ortophotos are often used in preparing NFIs





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Geospatial data: limitations

Important things to consider:

- ***Definitions***

GHG land categories are defined at the MS level with varying thresholds for e.g. tree crown cover in forests. Is the dataset I'm using compatible?

- ***Spatial resolution (minimum mapping unit)***

Spatial resolution is a key element to consider in order to verify if a dataset can be used for GHG inventories, also depending on the variable considered. Is the minimum area mapped compatible with the dataset I'm using?

- ***Temporal resolution***

We need to produce yearly inventories: certain data can remain stable (e.g. soil), but others might change continuously (e.g. land use)

Way forward: integration of RS with surveys

ANNEX II

MINIMUM VALUES FOR AREA SIZE, TREE CROWN COVER AND TREE HEIGHT PARAMETERS

Member State	Area (ha)	Tree crown cover (%)	Tree height (m)
Belgium	0,5	20	5
Bulgaria	0,1	10	5
Czech Republic	0,05	30	2
Denmark	0,5	10	5
Germany	0,1	10	5
Estonia	0,5	30	2
Ireland	0,1	20	5
Greece	0,3	25	2
Spain	1,0	20	3
France	0,5	10	5
Croatia	0,1	10	2
Italy	0,5	10	5
Cyprus	0,3	10	5
Latvia	0,1	20	5
Lithuania	0,1	30	5
Luxembourg	0,5	10	5
Hungary	0,5	30	5
Malta	1,0	30	5
Netherlands	0,5	20	5
Austria	0,05	30	2
Poland	0,1	10	2
Portugal	1,0	10	5
Romania	0,25	10	5
Slovenia	0,25	30	2
Slovakia	0,3	20	5
Finland	0,5	10	5
Sweden	0,5	10	5
United Kingdom	0,1	20	2

Geospatial data: some possible uses

- ***Remote sensing***

    - ***Land use mapping***
    - ***Selection of sample points***
    - ***Used in conjunction with land surveys for land tracking or in the construction of biomass density maps.***
    - ***Retrieval of variables relevant for constructing and validating allometric models.***

- ***Spatial datasets***

    - ***Soil (LUCAS Topsoil, HWSD)***
    - ***Agricultural management (LPIS)***

Overview of the datasets available

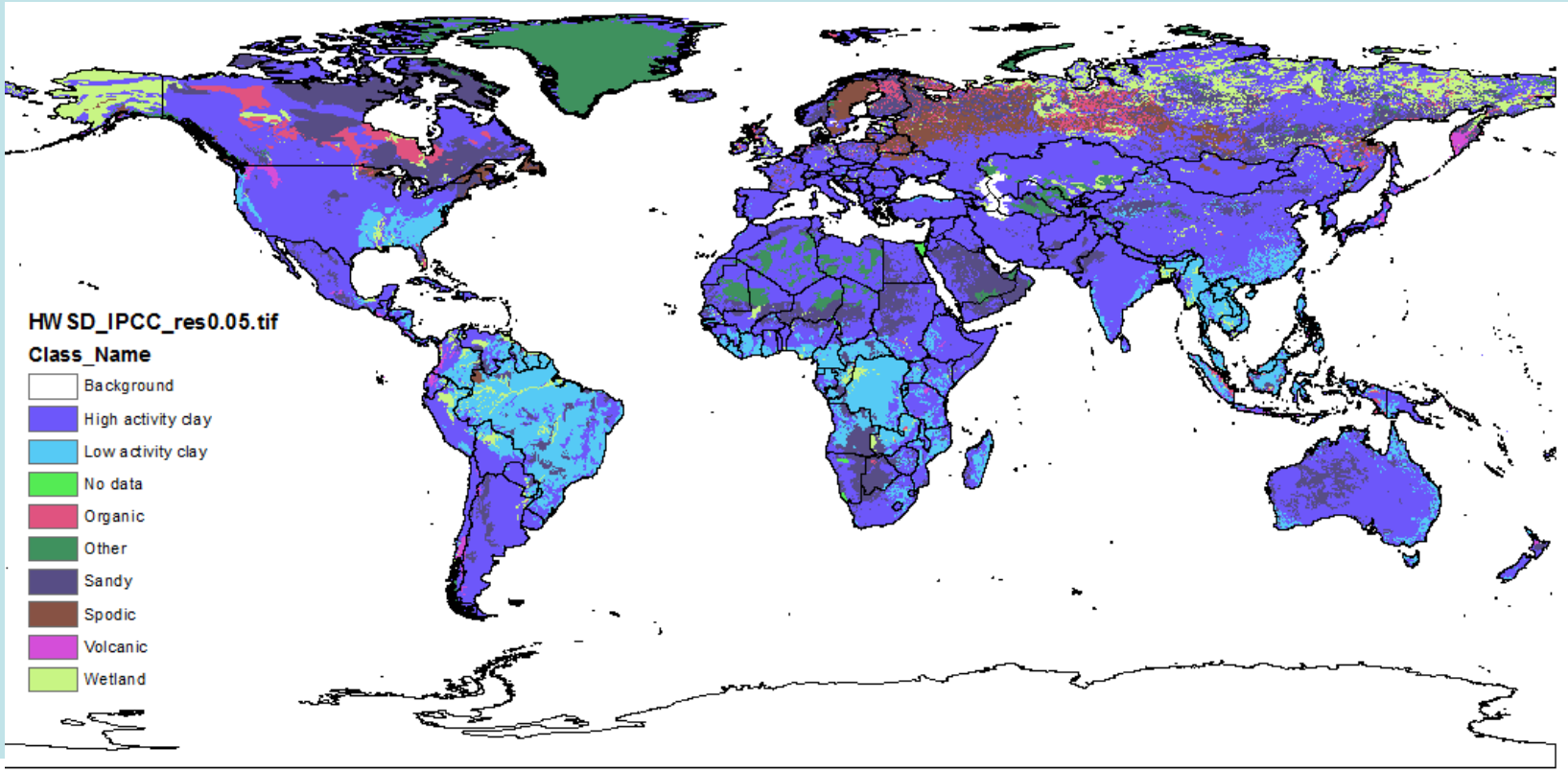
- **“Classic” datasets suggested by the IPCC**
- **ESA Climate Change Initiative**
- **Copernicus**
- **Other recent datasets**

NB: not all the data that will be presented are adequate for use in EU inventories, essentially due to spatial resolution constraints!!!

Spatial data suggested by the IPCC Guidelines

Soil map

HWSD map reclassified to match IPCC soil categories



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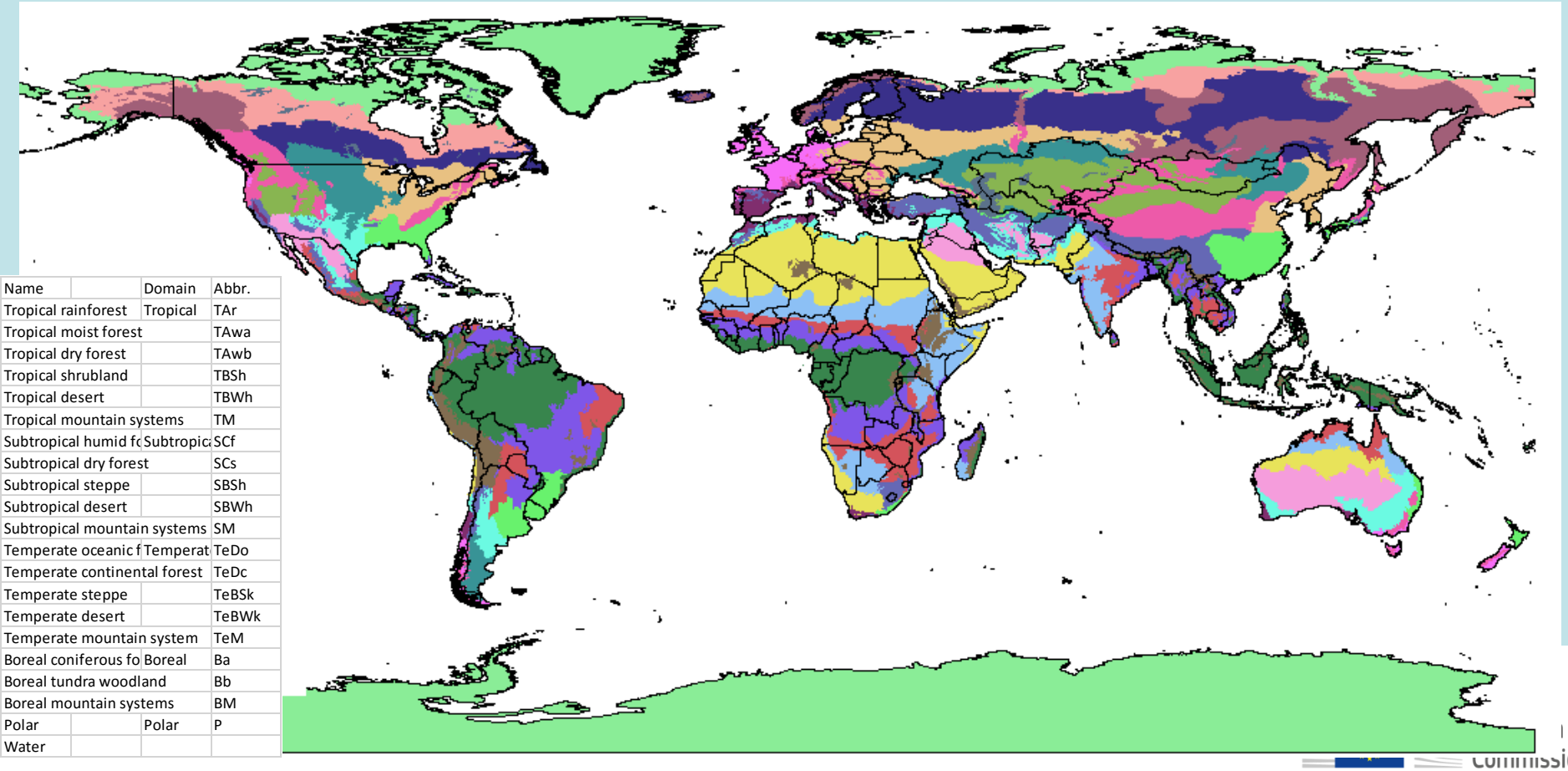
Spatial data suggested by the IPCC Guidelines

Ecological zones (based on climate and vegetation)

FAO Global Ecological Zones

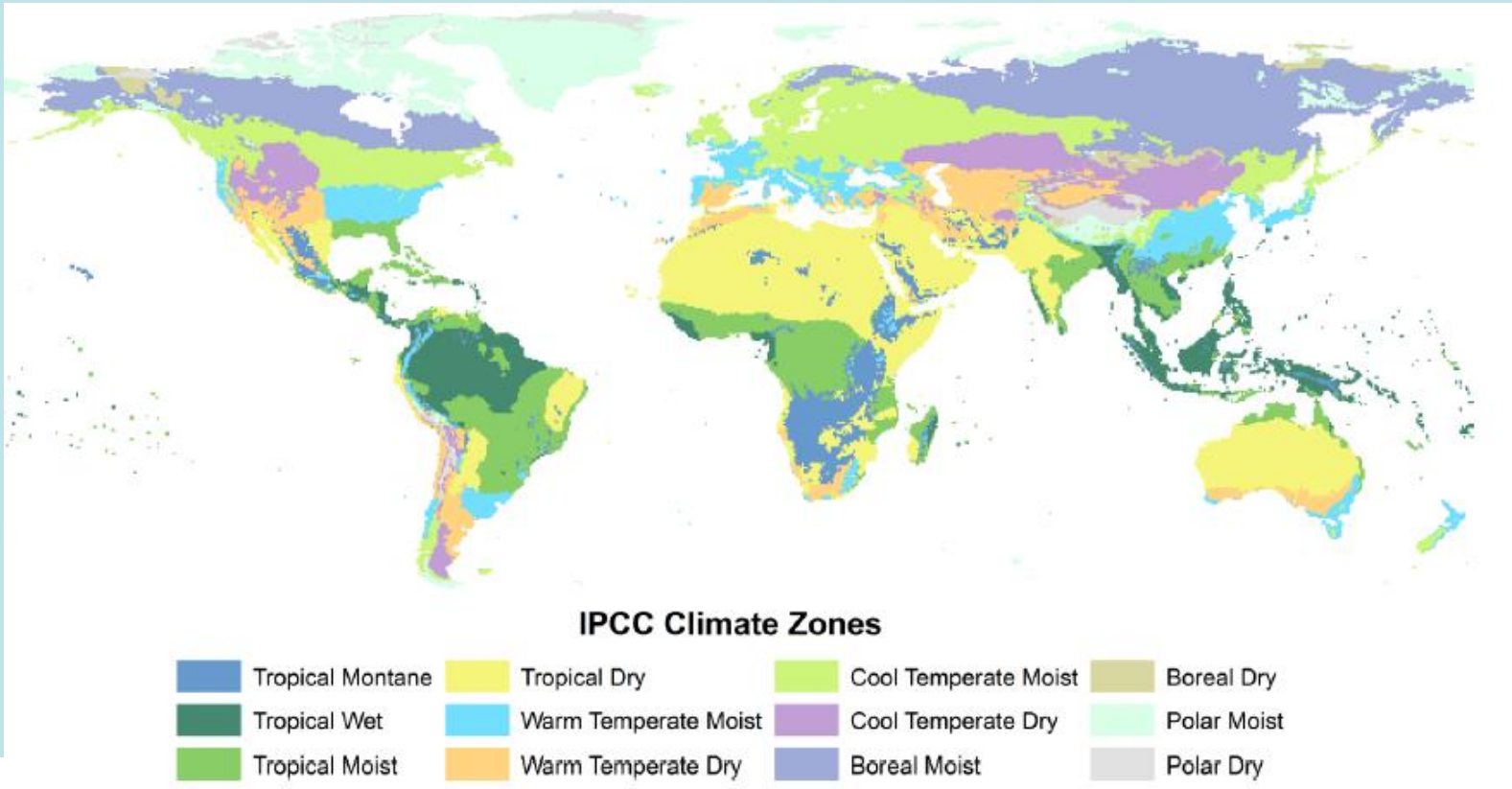


Code	Name	Domain	Abbr.
11	Tropical rainforest	Tropical	TAr
12	Tropical moist forest		TAwa
13	Tropical dry forest		TAwb
14	Tropical shrubland		TBSh
15	Tropical desert		TBWh
16	Tropical mountain systems		TM
21	Subtropical humid fo	Subtropica	SCf
22	Subtropical dry forest		SCs
23	Subtropical steppe		SBSh
24	Subtropical desert		SBWh
25	Subtropical mountain systems		SM
31	Temperate oceanic f	Temperat	TeDo
32	Temperate continental forest		TeDc
33	Temperate steppe		TeBSk
34	Temperate desert		TeBWk
35	Temperate mountain system		TeM
41	Boreal coniferous fo	Boreal	Ba
42	Boreal tundra woodland		Bb
43	Boreal mountain systems		BM
50	Polar	Polar	P
90	Water		

Spatial data suggested by the IPCC Guidelines

Climate maps

JRC-IPCC Climate map



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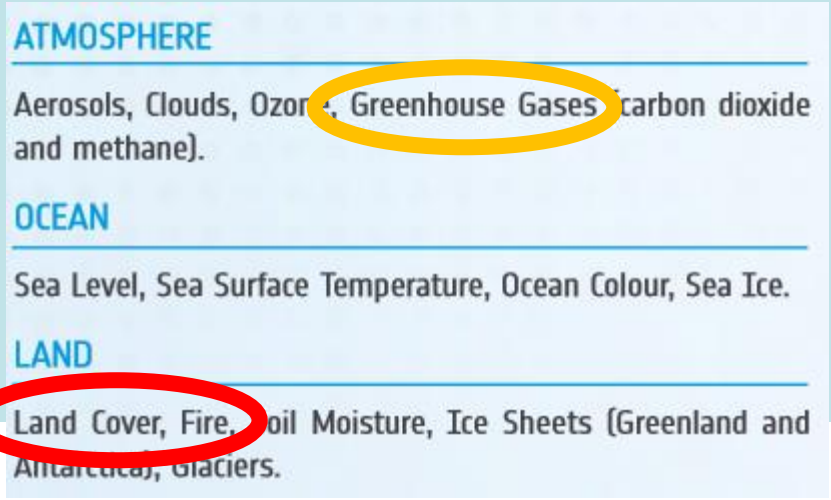
ESA Climate Change Initiative

"The objective of the CCI programme is to realize the full potential of the long-term global Earth Observations archives that ESA together with its Member States have established over the last 30 years, as a significant and timely contribution to the "Essential Climate Variables" databases required by the UNFCCC.
An ECV is a physical, chemical or biological variable or a group of linked variables that critically contributes to the characterisation of Earth's climate."



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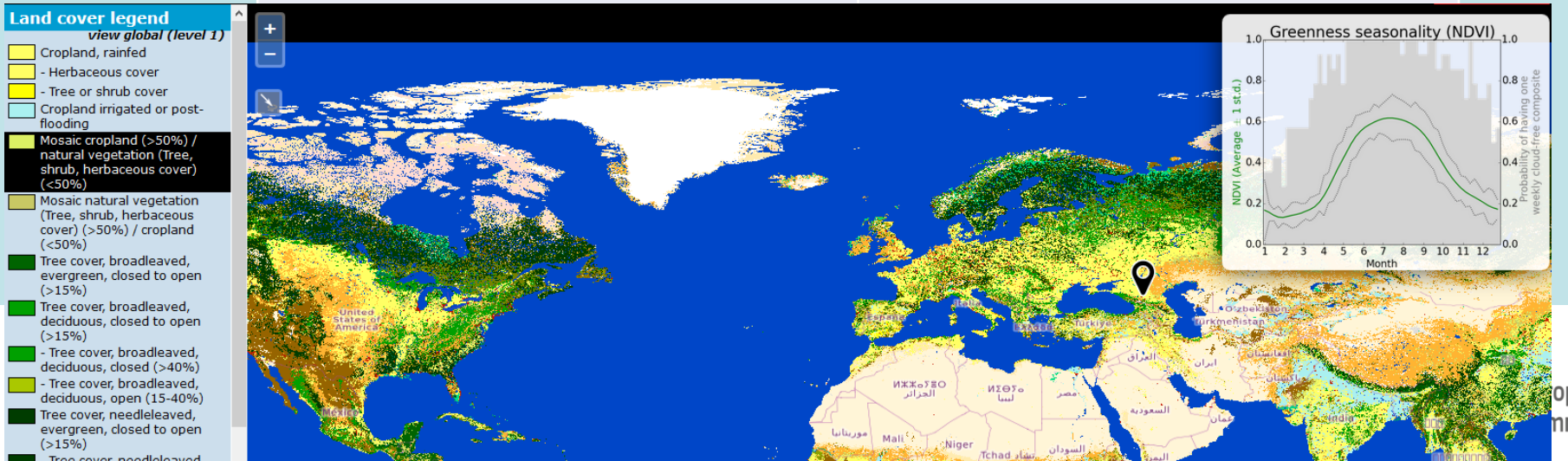
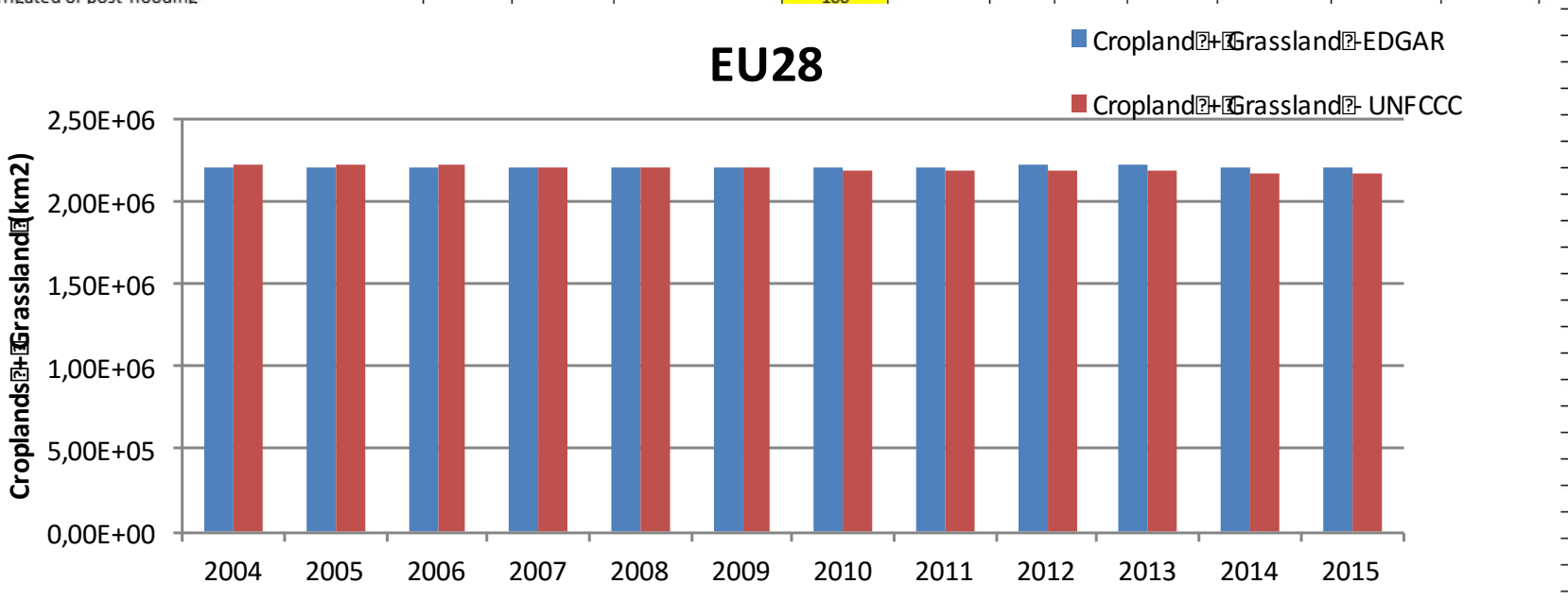
ESA CCI Land Cover

ESA CCI Land Cover	
Producer	ESA, University of Louvain
Pixel size	300 m
Years	1992-2015
Source data	MERIS, AVHRR, SPOT, PROBA-V, ASAR
Description	FAO LCCS Land Cover classes
Link	https://www.esa-landcover-cci.org/



Remapping LCCS classes into IPCC Land Use categories

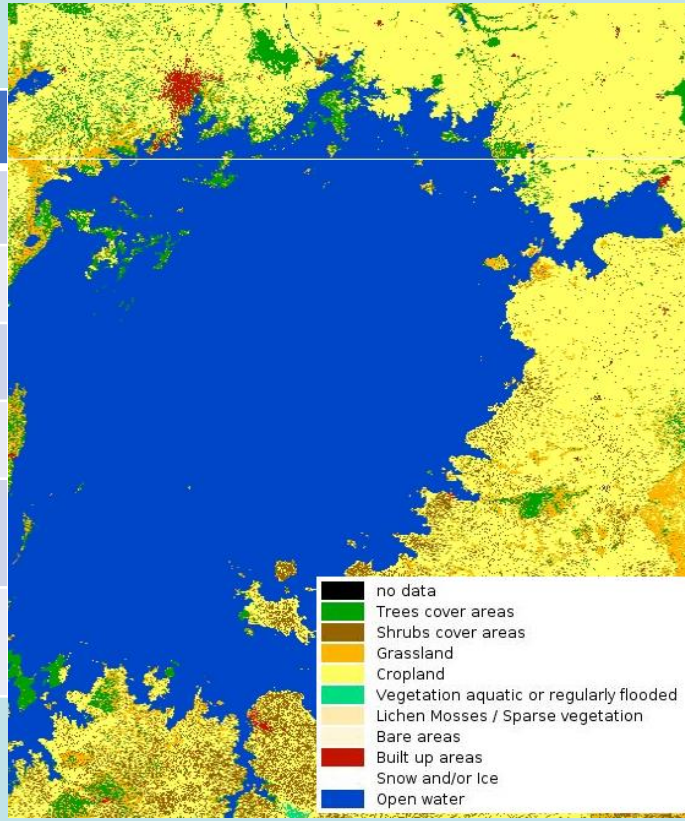
LCCS Class	IPCC	Forest Land			Cropland		Grassland		Wetlands		Settlements	Other land	Sea water
		Broadleaf	Needleleaf	Forest on wetlands	Herbaceous	Woody	Srhubs	Grasses	Wetlands	Inland water			
10	Cropland, rainfed				100								
11	Herbaceous cover				100								
12	Tree or shrub cover					100							
20	Cropland, irrigated or post-flooding				100								
30	Mosaic c												
40	Mosaic r												
50	Tree cov												
60	Tree cov												
61	Tree cov												
62	Tree cov												
70	Tree cov												
71	Tree cov												
72	Tree cov												
80	Tree cov												
81	Tree cov												
82	Tree cov												
90	Tree cov												
100	Mosaic t												
110	Mosaic h												
120	Shrubla												
121	Shrubla												
122	Shrubla												
130	Grasslar												
140	Lichens												
150	Sparse v												
152	Sparse s												
153	Sparse h												
160	Tree cov												
170	Tree cover, flooded, saline water												
180	Shrub/herbaceous cover, flooded,												
190	Urban areas										100		
200	Bare areas											100	
201	Consolidated bare areas											100	
202	Unconsolidated bare areas											100	
210	Water bodies												100
220	Permanent snow and ice											100	



The spatial resolution here is not adequate for EU GHG inventories BUT results obtained with this "translation" are in line with the inventories.

ESA CCI Land Cover higher resolution prototypes

ESA CCI High-Res Land Cover Africa 2016 (Prototype)	
Producer	ESA, University of Louvain
Pixel size	20 m
Years	2016
Source data	ESA Sentinel 2A
Description	10 LC classes
Link	http://2016africalandcover20m.esrin.esa.int/viewer.php



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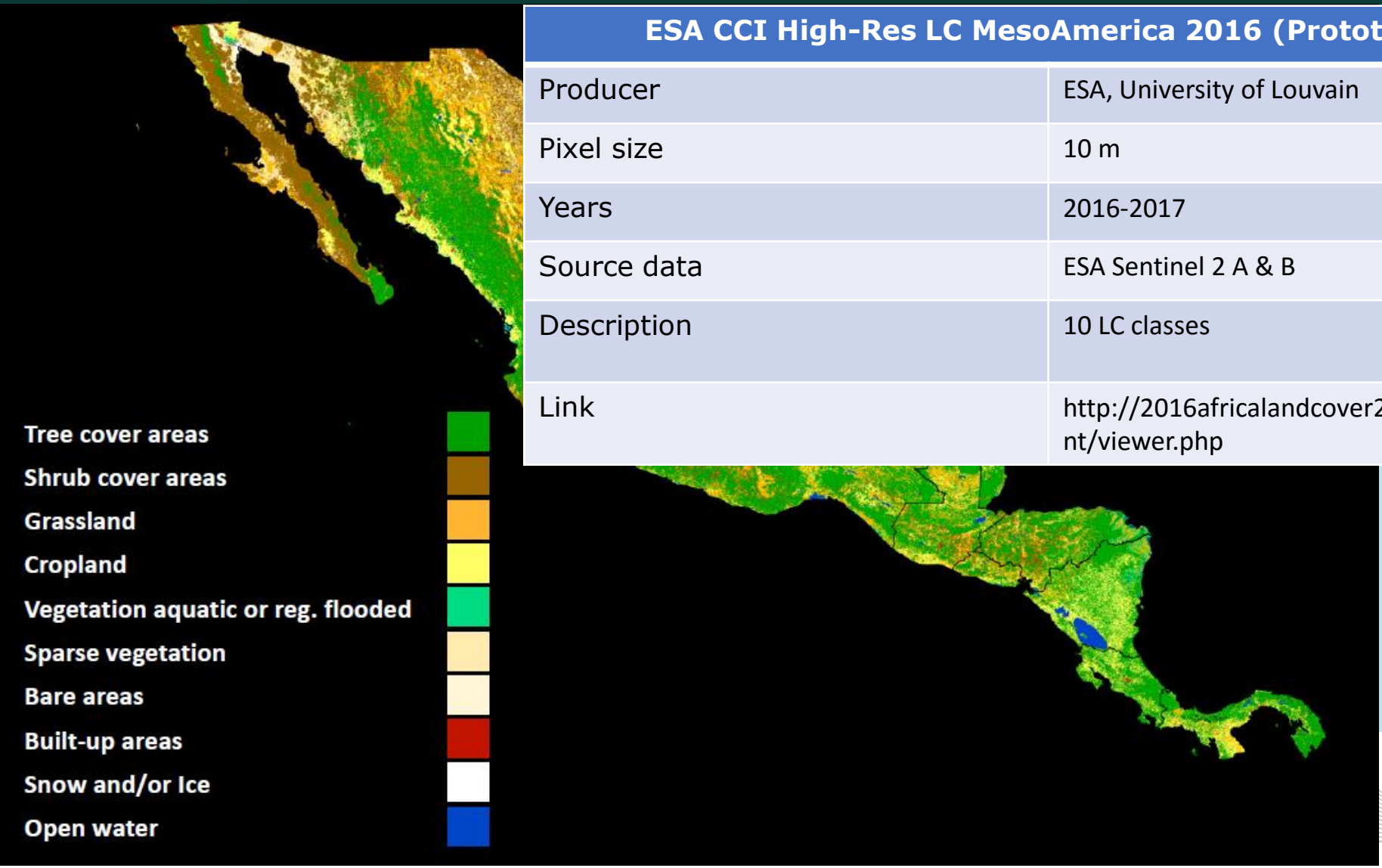
ESA CCI Land Cover higher resolution prototypes



ESA CCI High-Res LC MesoAmerica 2016 (Prototype)	
Producer	ESA, University of Louvain
Pixel size	10 m
Years	2016-2017
Source data	ESA Sentinel 2 A & B
Description	10 LC classes
Link	http://2016africalandcover20m.esrin.esa.int/viewer.php

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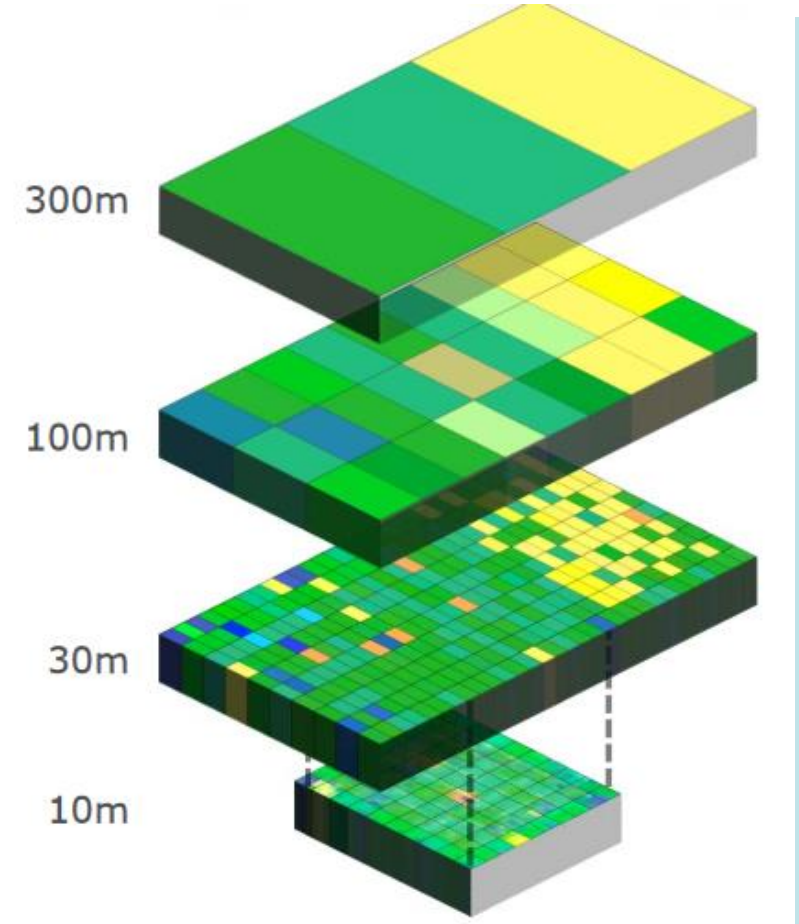
ESA CCI+ High Resolution Land Cover

The project will start next year and will focus on three test areas in South America, West Africa and Siberia.

The goal is to bring the spatial resolution of ESA CCI products at 10 m spatial resolution.



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The Copernicus Programme

Copernicus is the European Union's Earth Observation Programme, managed by the European Commission. It's implemented in partnership with Member States, ESA, ECMWF, EUMETSAT, and others. Data are freely available.

Copernicus is served by a set of dedicated satellites (the Sentinel families) and other satellites, as well by in-situ and airborne measurements.

Global

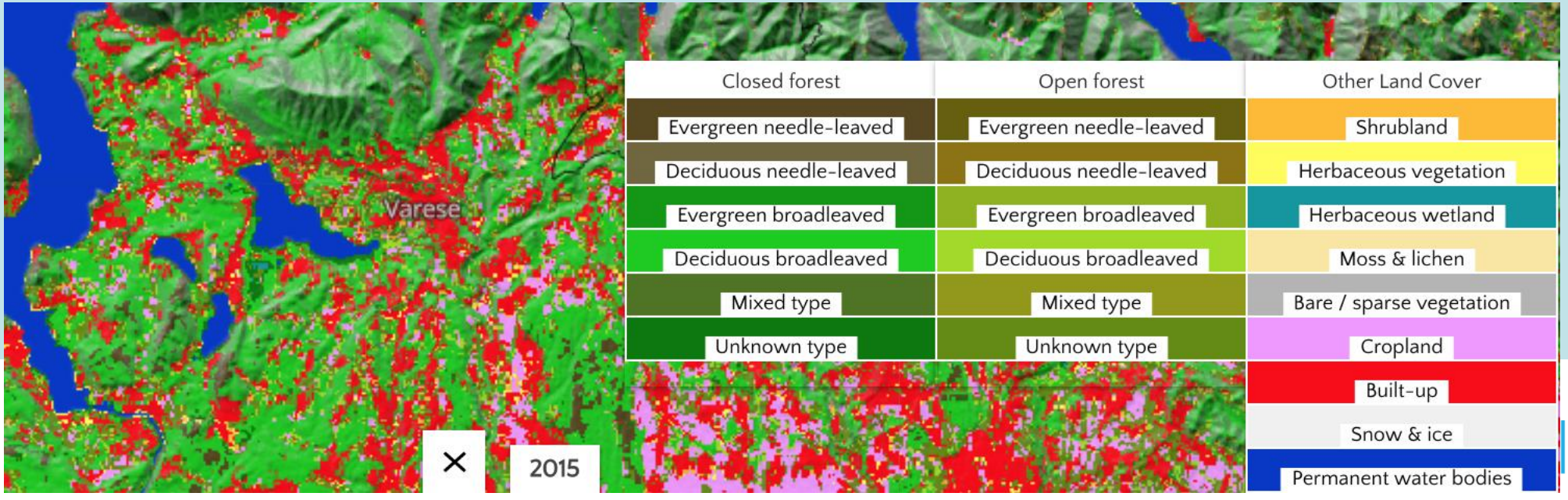
Pan-European

Local

Imagery and reference data

Copernicus Global: 100m Global Land Cover (just released)

COPERNICUS Global LC 100m	
Producer	Copernicus/EEA
Pixel size	100 m
Years	2015-2019, annual updates
Source data	Proba-V
Description	fractional cover layers for 10 land cover classes, 80% accuracy



Copernicus Pan-European: CORINE LC and LC change

	CLC1990	CLC2000	CLC2006	CLC2012	CLC2018
Satellite data	Landsat-5 MSS/TM single date	Landsat-7 ETM single date	SPOT-4/5 and IRS P6 LISS III dual date	IRS P6 LISS III and RapidEye dual date	Sentinel-2 and Landsat-8 for gap filling
Time consistency	1986-1998	2000 +/- 1 year	2006+/- 1 year	2011-2012	2017-2018
Geometric accuracy, satellite data	≤ 50 m	≤ 25 m	≤ 25 m	≤ 25 m	≤ 10 m (Sentinel-2)
Min. mapping unit/width	25 ha / 100m	25 ha / 100m	25 ha / 100m	25 ha / 100m	25 ha / 100 m

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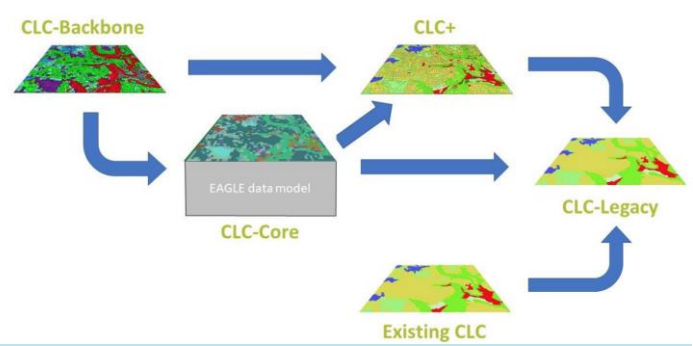
Copernicus Pan-EU: Next Generation CORINE (CLC+, CLC-heritage) (in preparation)



COPERNICUS CLC + and CLC-heritage	
Producer	Copernicus/EEA
Pixel size	10-20 m (0.5/1 ha MMU) CLC+, 100m (25 ha for status, 5 ha for changes) CLC-heritage
Years	2018 onwards every 3 years (CLC+) Background compatibility (CLC-heritage)
Source data	Sentinel 2A&B, Landsat 8, Sentinel 1 (radar)
Description	fractional cover layers for 10 land cover classes, 80% accuracy

"The CLC+ is expected to support the LULUCF reporting obligations from 2021"

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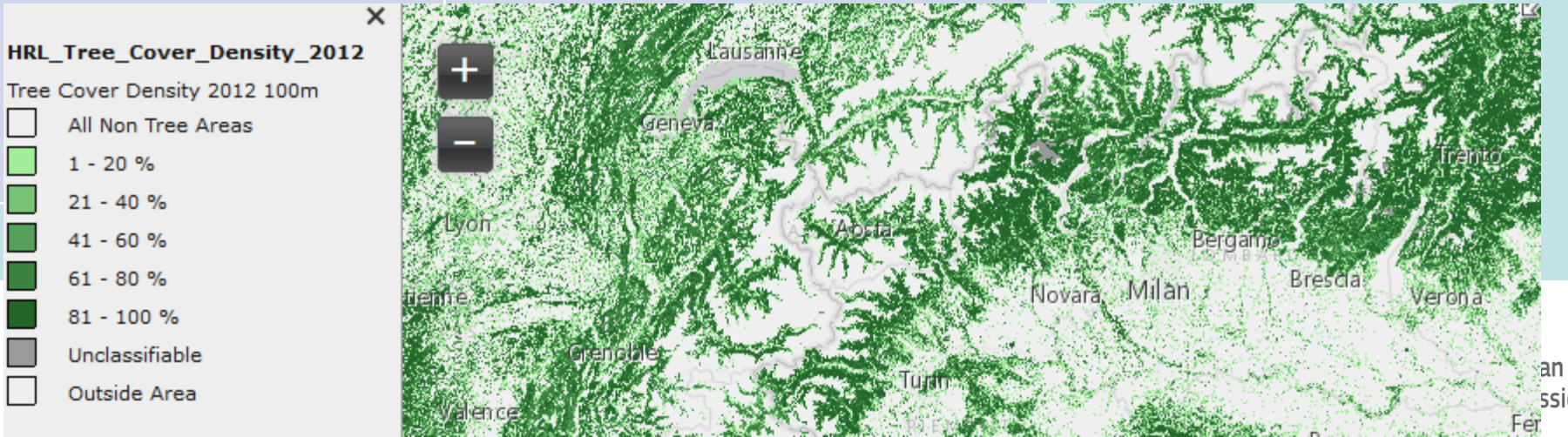
Copernicus Pan-European High Res: 20m Forest

COPERNICUS Pan-EU HRL Forest	
Producer	Copernicus/EEA
Pixel size	20 m (MMU: 0.5 ha)
Years	Status map 2015 and changes 2012 – 2015
Source data	Sentinel 2A, Landsat 8, SPOT-5 and ResourceSat-2.
Description	1. Tree cover density (TCD) (level of tree cover density in a range from 0-100%) 2. Dominant leaf type (DLT) (broadleaved or coniferous majority)

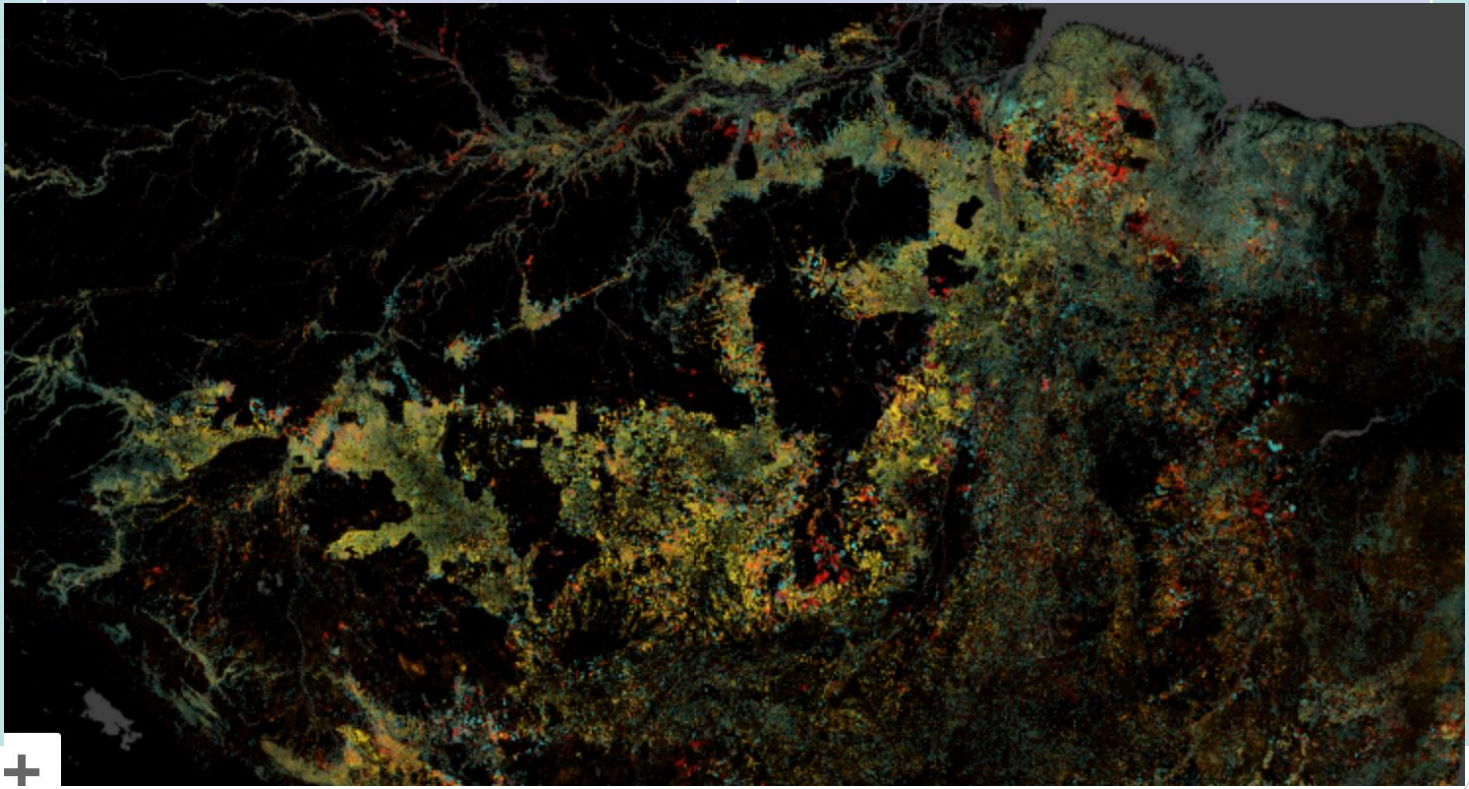


Copernicus Pan-European High Res: 20m Grassland

COPERNICUS Pan-EU HRL Grassland	
Producer	Copernicus/EEA
Pixel size	20 m and 100 m
Years	2014-2016
Source data	Sentinel-2A, Sentinel-1A and B and Landsat 8 OL + radar IRS-P6 LISS-3 (ploughing)
Description	1. Grassland map 2. Ploughing indicator

Global Forest Change 2000–2018 (Hansen)

Global Forest Change 2000-2018	
Producer	Hansen/Univ. Maryland/Google/USGS/NASA



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France: National yearly land cover map at 10m (Sentinel 2 A&B + LPIS)

- Annual Crops
  1. Summer Crops
  2. Winter Crops
- Perennial Crops
  3. Intensive grasslands
  4. Vineyards
  5. Orchards
- Forests
  6. Broad-leaved
  7. Conifer
- Low natural vegetation
  8. Natural grasslands and pastures
  9. Woody moorlands
- Artificial
  10. Continuous urban
  11. Discontinuous urban
  12. Commercial and industrial units
  13. Roads and asphalt surfaces
- Natural mineral surfaces
  14. Bare rocks
  15. Sand and dunes
- Other
  16. Water bodies
  17. Glaciers and eternal snow
- Extension to 23 classes
  - Summer Crops: Soybean, Sunflower, Corn, Rice, Root/tuber
  - Winter Crops: Rapeseed, Straw cereals, Protein crops

Inglada, J., Vincent, A., Arias, M., Tardy, B., Morin, D., & Rodes, I., Operational high resolution land cover map production at the country scale using satellite image time series, Remote Sensing, 9(1), 95 (2017).

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Ongoing JRC research on Forest/LC mapping

Mapping African forests with Sentinel 1 and 2 times series

S1 and S2 time series for 2018 (9)

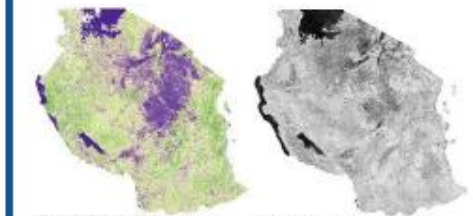
Training dataset

2900 boxes

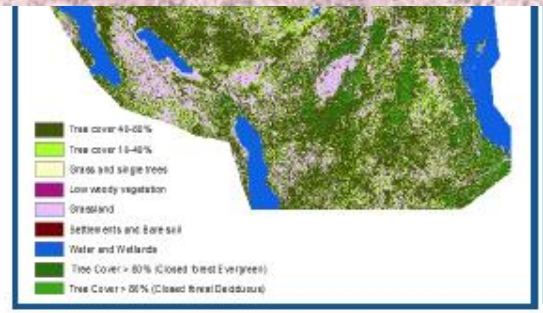
Forest classification

Maps

Why not in Europe? (it might be easier: less seasonality)



openforis COLLECT EARTH



Verhegghen, Jarouskova et al.

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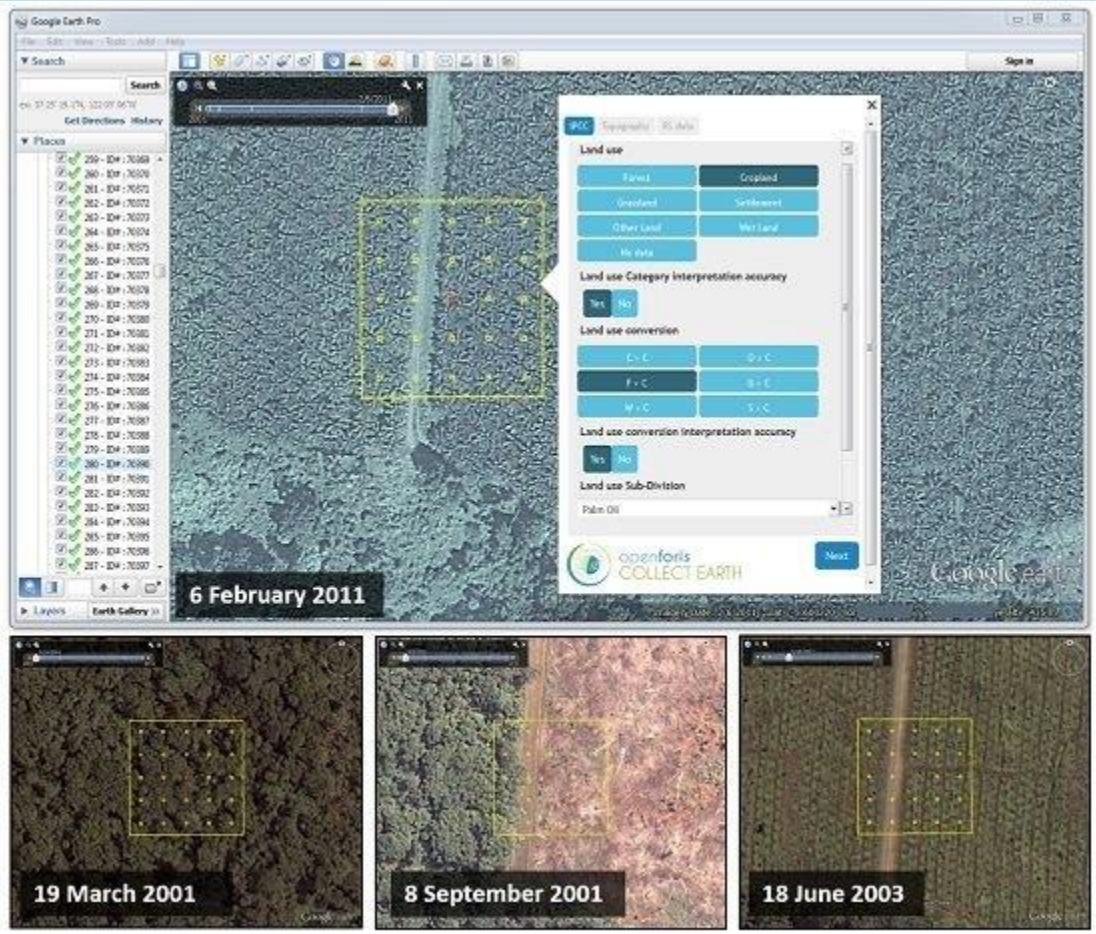
An interesting tool

openforis COLLECT EARTH

Collect Earth is a tool that enables data collection through Google Earth. Users can analyze high and very high resolution satellite imagery for a wide variety of purposes, including:

- **Support to NFI**
- **LULUCF assessments**
- **Monitoring agricultural land and urban areas**
- **Validation of existing maps**
- **Quantifying deforestation, reforestation and desertification**



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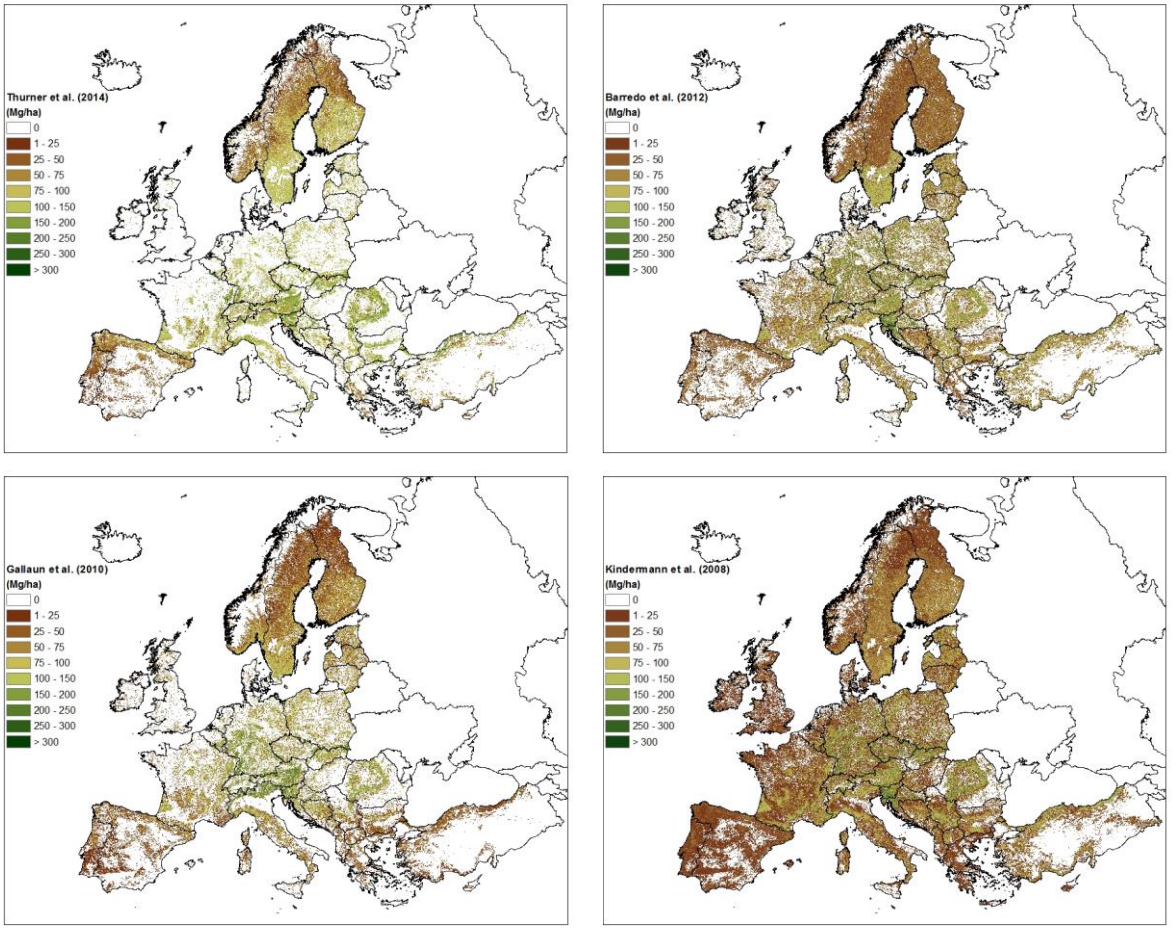
Biomass density maps

- **Sensors:**
  - **Optical (canopy properties)**
  - **Lidar (vertical structure)**
  - **Radar (canopy and structure)**

BM is estimated from RS signal using empirical models calibrated with ground data.

Example: use in Brazilian GHG Inventory to cover the whole Amazon.



Avitabile et al. (JRC)

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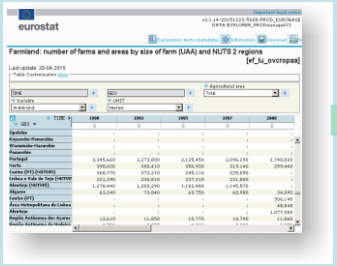
Tier 1 and 3 spatially explicit modelling of CSC in Europe (JRC)

Input to Spatial processing for CO_2 emission/removal

Processing



Processing Statistical Data

Spatial Allocation of Management

Tier 1 IPCC

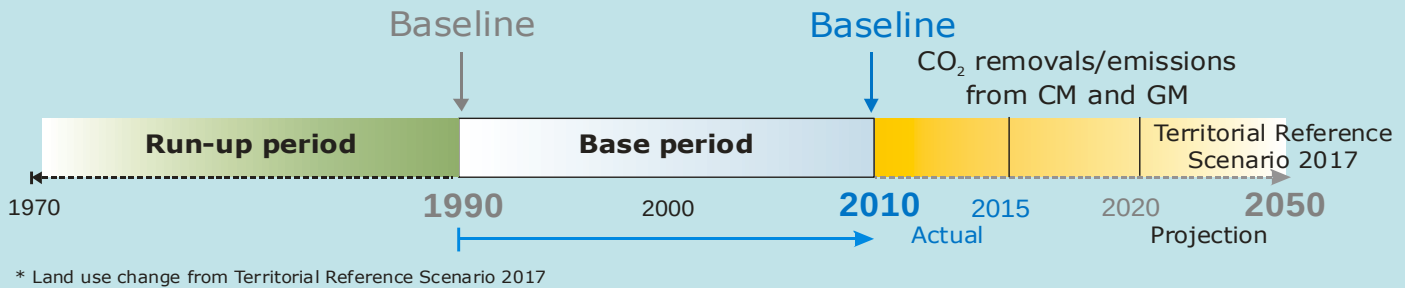
Tier 3 ROTH-C

Models

Changes in SOC Stocks 0-30cm [*t C ha^{-1} year^{-1}*]

Period

1970 - 2015	1970 - 2015 2020 - 2050*	1970 - 2010 2010 - ...



* Land use change from Territorial Reference Scenario 2017

Hiederer 2018

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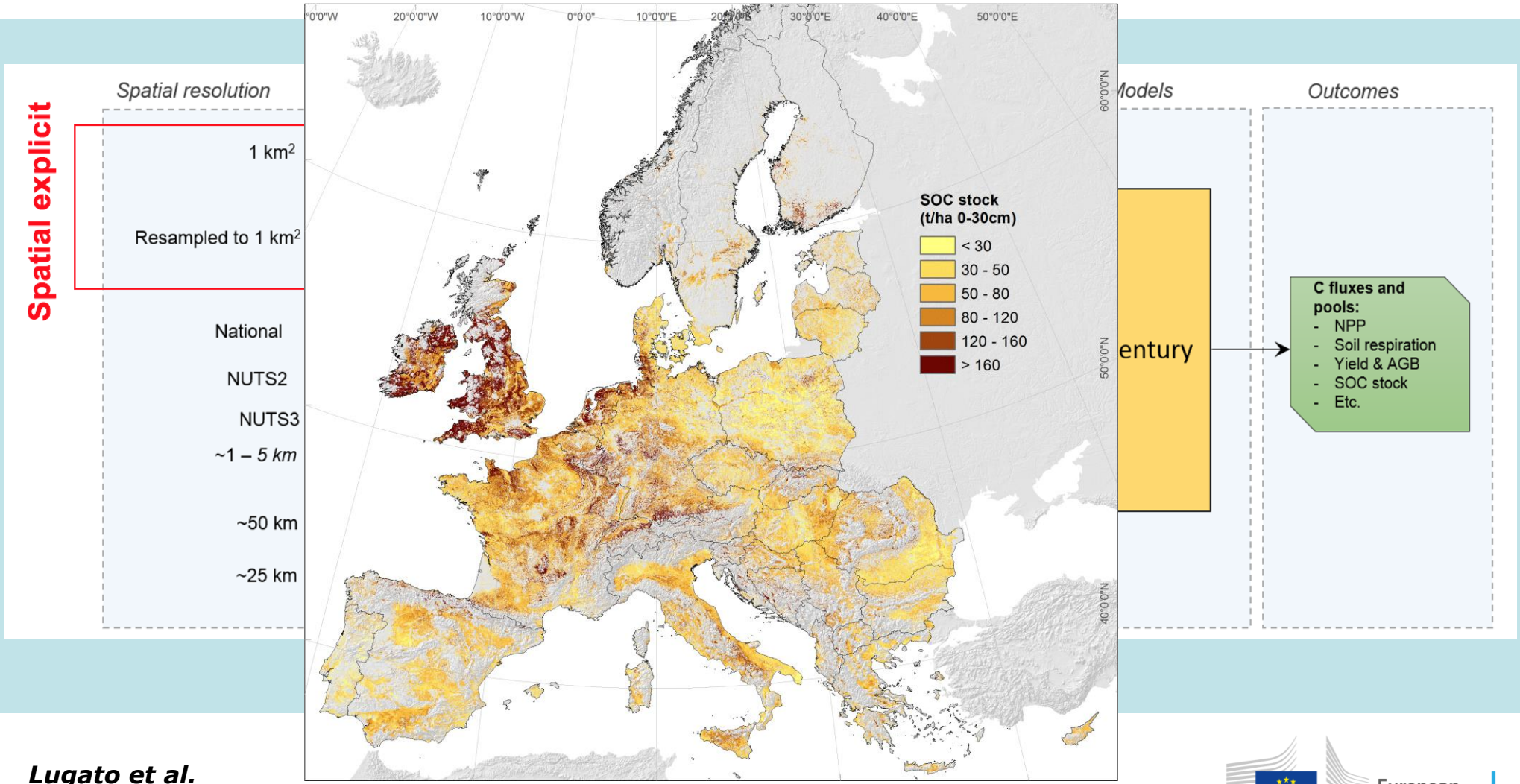
Tier 3 spatially explicit modelling of CSC in Europe (JRC)



Lugato et al.

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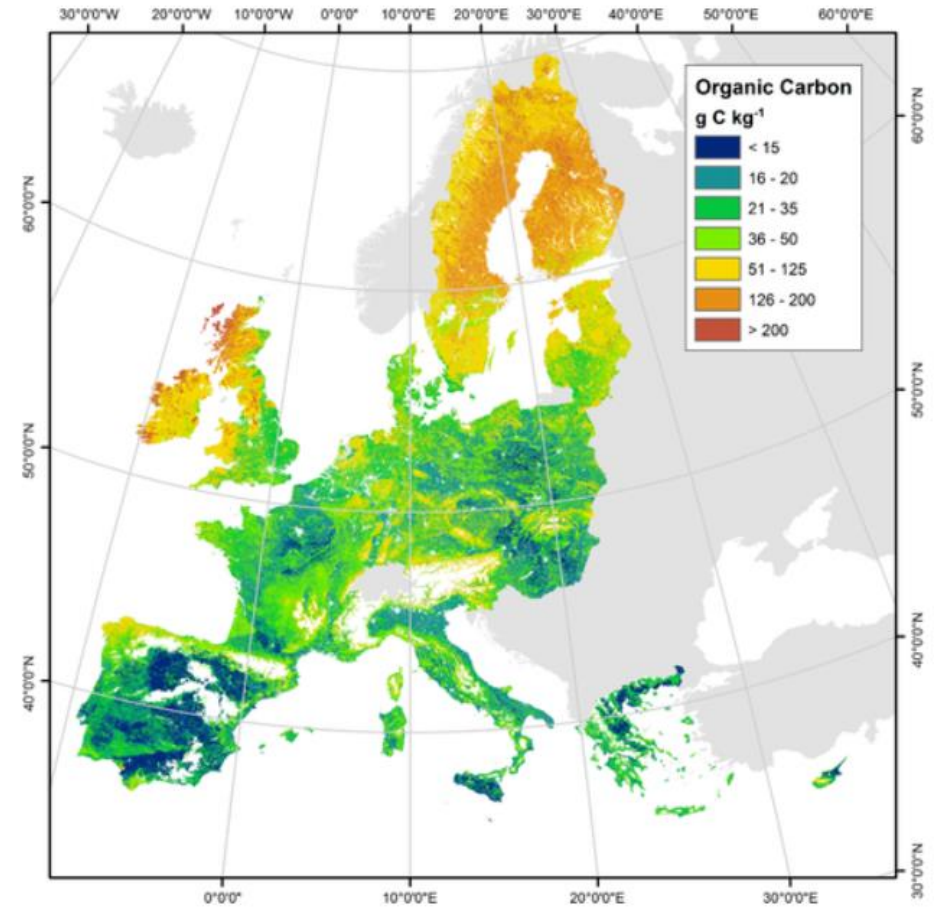
LUCAS (**L**and **U**se and **C**overage **A**rea frame **S**urvey) Topsoil Dataset (JRC/EUROSTAT)

LUCAS Soil component

- **~ 22’000 topsoil samples (0-20 cm)**
- **main physico-chemical soil properties**

- **2009 completed**
- **2015 completed**
- **2018 sample collected under analysis**
- **2021 next**

Spatialisation through geostatistics



Lugato et al.; De Brogniez et al., 2014. EJSS

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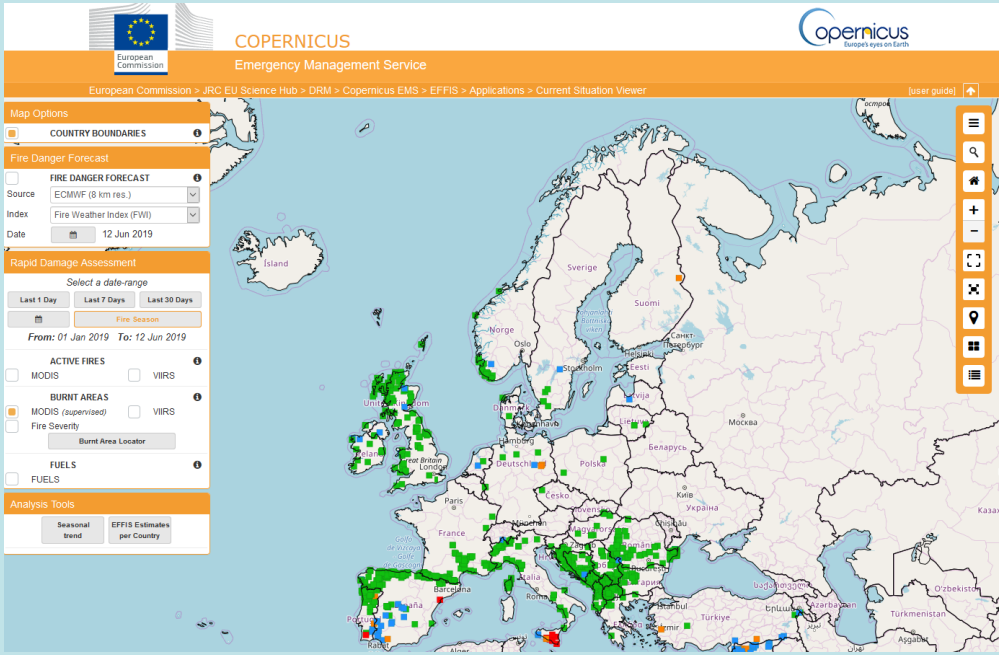
Burned area datasets

Some products available:

- **Copernicus (EFFIS/JRC) burned area products (from MODIS, VIIRS)**
- **MODIS burned area product (MCD64A1)**
- **GFED burned areas dataset (1997-2018)**
- **GFED Global Fire Atlas**
- **ESA ATSR World Fire Atlas (1995-2012)**
- **ESA Sentinel-3 World Fires Atlas (Prototype)**



Tier 1 estimates: FAOSTAT Methodology (Rossi et al. 2016)

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Conclusions

- **Several new products are becoming rapidly available for the operational monitoring and tracking of land use/land cover and for other GHG inventory applications at a much higher resolution than before.**
- **These data are already operationally used in REDD+ activities.**
- **There is a high potential for their use to obtain a “geographically-explicit” land use tracking as required by Reg.841/2018.**
- **HOWEVER, it’s not THAT simple. It might not be enough to take a nice map to track Land Use changes with an acceptable resolution and reliability.**
- **Verification and research on possible applications in Europe, also through the integration with ground sampling, would be important.**
- **Inventory teams should gain the necessary geospatial know-how.**

An introduction to Geospatial data for GHG emissions estimations

Thank you for your attention!

European Commission