Spatially explicit land use data for Italy: evaluation and comparison of sample based and wall-to wall methods using Collect Earth software and CLMS-derived data

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Land representation for LULUCF reporting

Governance Regulation (EU 2018/1999) requires a **spatially explicit** land use representation, allowing Member States to accurately monitor territorial dynamics and policy impacts.

IPCC guidelines for National GHG Inventories prescribe 3 approaches and 3 methods for land representation

3 APPROACHES

- **Approach 1**: total land use area (no data on conversions)

  represents land-use area totals within a defined spatial unit (such as a country, province or municipality). Only the net changes in land-use area can be tracked through time

- **Approach 2**: total land use area, including changes between categories

  Provides land use changes both from and to a category. Tracking changes without spatially-explicit location data (i.e. locations of specific land-use and land-use conversions are not known).

- **Approach 3**: spatially-explicit land use conversion data

  both spatially and temporally consistent and explicit. Sample-based, survey-based and wall-to-wall methods can be considered Approach 3

Land representation for LULUCF reporting

3 METHODS

- **Sample based:**

  from ground surveys (such as a national forest inventory or national land survey) or remote sensing. Sample-based methods provide an accurate statistical representation of land-use and land-use change but do not provide information on every specific area of the land territory (i.e. is not wall-to-wall spatially explicit);

- **wall-to-wall:**

  maps of land cover and land cover change that, when combined with other data, can be used to generate land-use and land-use change information.

- **statistical survey:**

  information on land-use and land-use change and land management practices; this data is often used in combination with other data to develop a complete land use estimate

These methods are not mutually exclusive; for example, wall-to-wall methods typically require samples for calibration, validation and uncertainty analysis, and some sample methods require wall-to-wall maps for scaling as well as for dimensioning the sample size and designing the sample grid.

Combining methods and approaches depending on data availability

(Table 6.3A – Volume 4 of IPCC Guidelines Refinement 2019)

Methods	Approach 1	Approach 2	Approach 3
Sample-based	Single sample Temporary sample unit	Samples collected from permanent units but changes only tracked across two consecutive sample periods	Permanent and consistent georeferenced ground plots
Survey-based	Single census at one point in time. Repeat census but without reference to previous censuses.	General surveys between two periods. National census data that can refer a past period.	Specific survey designs that identify activities through time for each land unit within a known region.
Wall-to-wall	Single map Inconsistent maps developed at different times.	Inconsistent maps through time combined with Approach 2-type samples (e.g. using maps as stratifications). Maps developed using consistent methods changes tracked across two consecutive maps only not tracked through a time-series of maps.	Tracking pixels / land units using time-series consistent data

In many cases the data inputs and processes can be combined resulting in a higher quality of the land representation than can be achieved with any one single data source

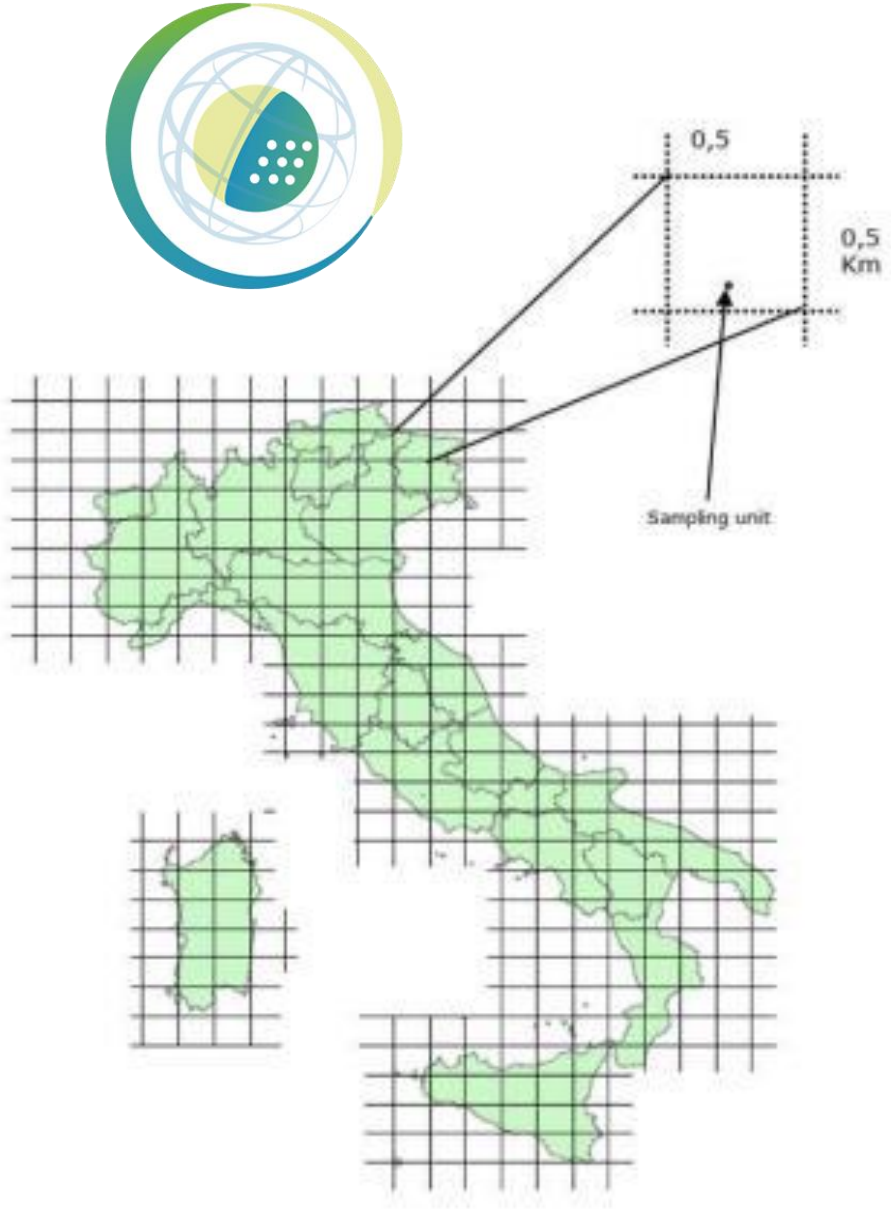
Current reporting state (Sampling Approach 3 hybrid)

1. National Forest Inventory (INFC) for the classes **Forest and Other wooded land (shrubland)**:
   - Years 1985, 2005, 2015, 2025
   - 300'000 sampling points (subset of IUTI)
   - NFI data have a higher hierarchical order than that of IUTI, so that differences among the two datasets have been reconciled by adjusting the subcategory natural grassland.
2. Italian Land Use Inventory (IUTI) for the classes **Cropland and Pasture/Grassland Settlements, Wetlands, Other Lands,** :
   - Years 1990, 2000, 2008 (1'200'000 points), 2018 (300.000 points)
   - Due to the technical characteristics of the IUTI assessment (i.e., classification of orthophotos), it was not possible to clearly distinguish among some subcategories included in cropland and grassland, therefore these areas were disaggregated using as proxies the national statistics (ISTAT) on annual crops, perennial woody crops, grazing land, and grassland.
   - Annual figures for areas in transition between different land uses have been derived applying a rule-based method, informed by expert judgement, based on known patterns of land-use changes in Italy.

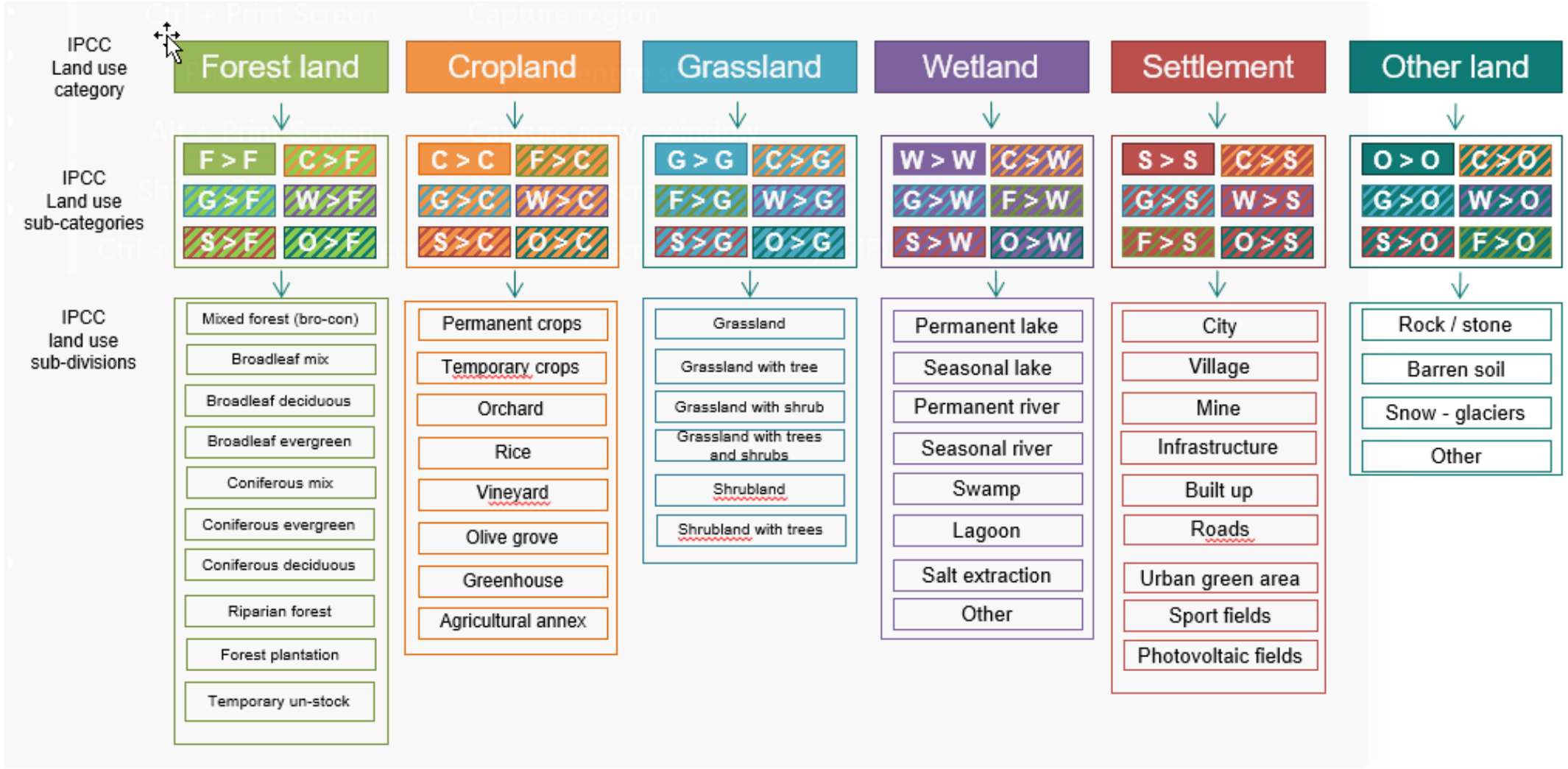
On-going improvements: the Open Foris Collect Earth tool

Need: continuous and consistent samples using remote sensing data.

Assessment of the Italian land use and land use change 2000–2023 through Collect Earth (CE), a FAO software based on Google Earth, satellite imagery. National IUTI orthophotos are also used. Sampling design from IUTI framework: ~ 100,407 georeferenced points selected on a 0.5 × 0.5 km grid. Based on unaligned systematic sampling for uniform distribution.



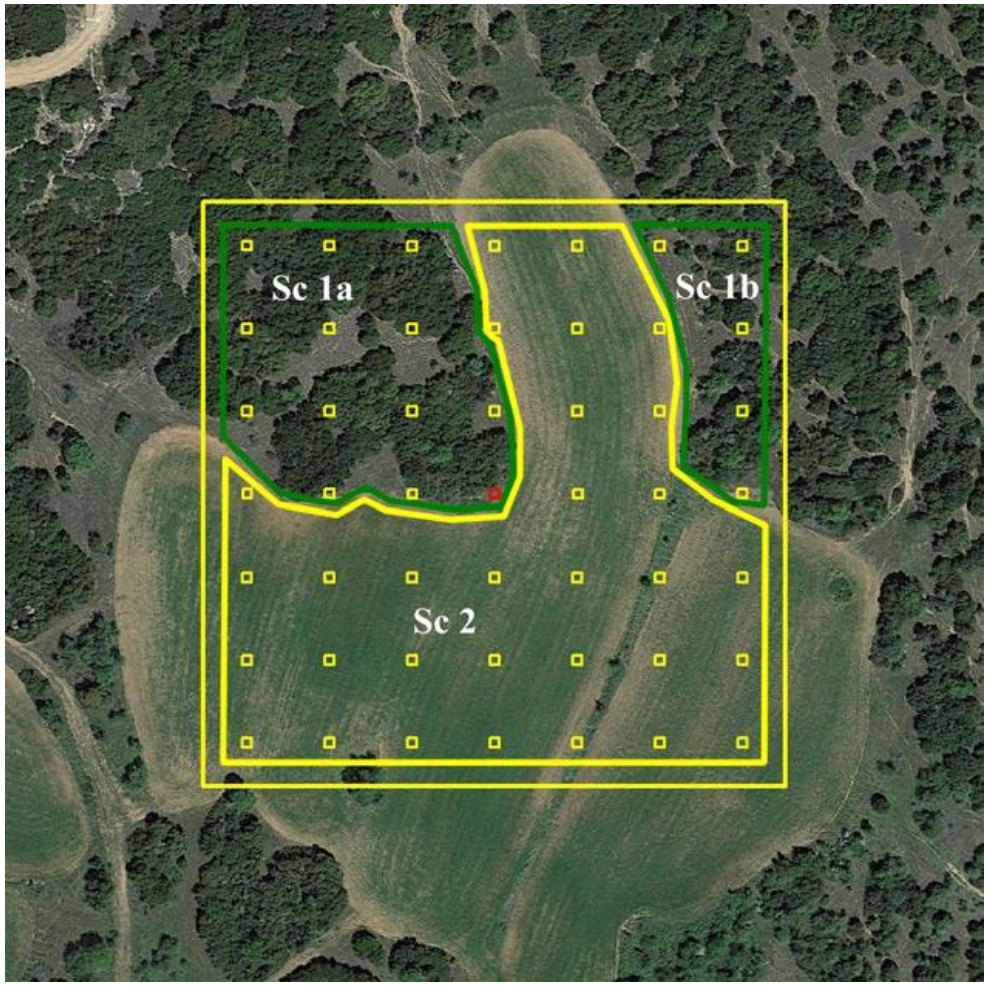
On-going improvements: the Open Foris Collect Earth tool



On-going improvements: the Open Foris Collect Earth tool

Sampling plot structure:

- Each point corresponds to a 0.5 ha square plot.
- Each plot include 49 control points to estimate land cover proportions and classify the sampling plot.
- The classification is attributed to 300 ha surface area through an expansion factor (national area/n. points)



Photointerpretation rules:

- Each plot assigned to one dominant land use.
- Multiple uses resolved by majority or hierarchical rules: settlement > cropland > forest > grassland > wetland > other

	Initial LU 2000	Final LU 2023
Forest	± 0.87%	± 0.87%
Cropland	± 0.73%	± 0.75%
Grassland	± 1.48%	± 1.46%
Otherland	± 6.07%	± 6.12%
Wetland	± 5.04%	± 5.07%
Settlement	± 2.17%	± 2.07%

Uncertainty of the estimates (95% confidence level):

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Possible integration of approach 3 – wall-to-wall

Within the H2020 project ***AVENGERS*** we have combined several **CLMS products** (**year 2018**) aiming at reconciling with Inventory land use surfaces and at spatializing inventory LULUCF and 3D emissions

CORINE Land Cover

- Data type: Vector
- MMU: 25 ha (5 ha for changes)
- 44 LC/LU classes
- Update: 6 years

CLC+ Backbone

- Data type: Raster
- Spatial resolution:10X10 m
- 13 land cover classes
- Update: 3 years

Priority Area Monitoring data

	Coastal Zones (CZ)	Natura 2000 (N2K)	Riparian Zones (RZ)
Spatial resolution	0.5 ha	0.5 ha	0.5 ha
Classes	71	55	55
Update	6 years	6 years	6 years
Area	10 km of the coastline	Buffer areas of the Habitats Directive	Riparian areas of rivers

- ☑ Partially same ingredients of instance LULUCF instance, but different process (rules).
- ☑ Training EEA instance LULUCF 2 Oct – 13 Nov 2024

Possible integration of approach 3 – wall-to-wall

Methodology of the AVENGERS map (year 2018)

1- Preprocessing

- Reprojection (EPSG 3035)
- Rasterization (10 m resolution)

2- Aggregation of CLC classes

- Verification of semantic correspondences with LULUCF inventory classes
- Exclusion of CLC MIXED CLASSES 24*
- Exclusion of uncertain classes MAES (Mapping and Assessment of Ecosystems and their Services)

LULUCF categories	CLC correspondance
Settlements	111, 112, 121, 122, 123, 124, 131, 132, 133, 141, 142
Cropland annual	211, 212
Rice fields	213
Cropland permanent	221, 222, 223
Managed grassland	231
Natural grassland	321, 333
Other wooded land	322, 323, 324
Forest	311, 312, 313, 334
Other land	331, 332, 335
Wetland	411, 412, 421, 422, 423, 511, 512, 521, 522

Possible integration of approach 3 – wall-to-wall

Methodology of the AVENGERS map (year 2018)

3 - Ambiguity resolution of CLC mixed classes and MAES uncertain classes

CLC Plus Backbone	CLC mixed classes: 241 (Annual crops associated with permanent crops)	242 (Complex cultivation patterns)	243 (Land occupied by agric., with significant nat. vegetation)	244 (Agro-forestry areas)
1: Sealed	Settlements	Settlements	Settlements	Settlements
2: Needle leaved trees	Forest	Forest	Forest	Forest
3: Broadleaved deciduous trees	Cropland permanent	Forest	Forest	Forest
4: Broadleaved evergreen trees	Cropland permanent	Forest	Forest	Forest
5: Low-growing woody plants	Cropland permanent	Cropland permanent	Cropland permanent	Other wooded land
6: Permanent herbaceous	Managed grassland	Managed grassland	Natural grassland	Natural grassland
7: Periodically herbaceous	Cropland annual	Cropland annual	Cropland annual	Cropland annual
8: Lichens and mosses	-	-	-	-
9: Non-and sparsely- vegetated	Natural grassland	Natural grassland	Natural grassland	Natural grassland
10: Water	Wetland	Wetland	Wetland	Wetland
11: Snow and ice	Other land	Other land	Other land	Other land

- Distinction of the LC class within CLC 24* polygons (16% of national surface area) with CLC+ Backbone and assignment of the most probable LU based on the class definition
- Redistributing uncertain MAES classes' areas into LULUCF land use categories

Possible integration of approach 3 – wall-to-wall

Methodology of the AVENGERS map (year 2018)

4- Further redistribution of surfaces between CLC classes using CLC+ backbone and final refinement

CLC		Backbone
211 (Non-irrigated arable land) 212 (Perm. irrigated land)	Managed grassland	6 - Permanent herbaceous

CLC		Backbone
321 (Natural grasslands)	Forest	2, 3, 4 - Trees

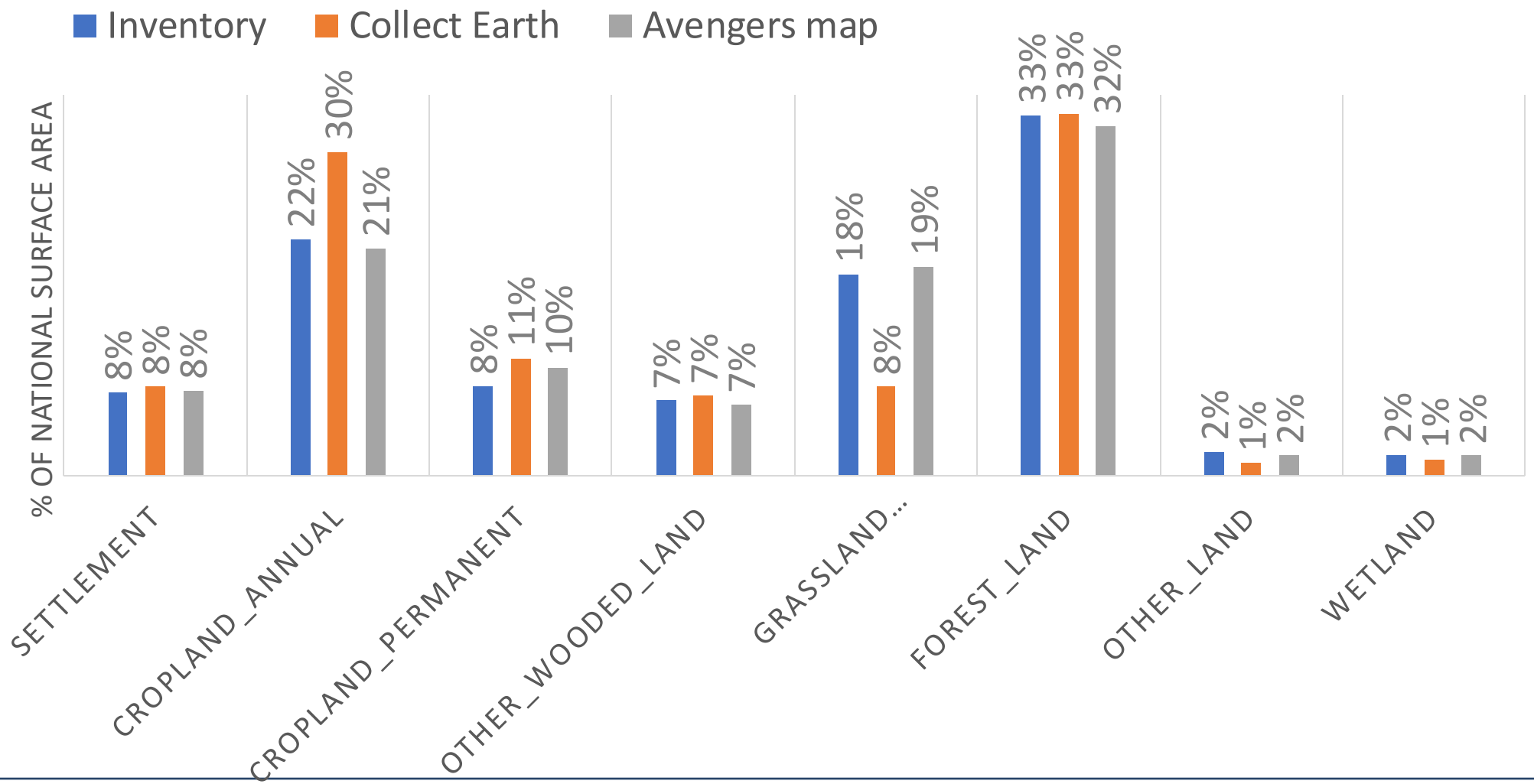
CLC		Backbone
All (excl. 24*)	Settlements	1 - Sealed

CLC		Backbone
321 (Natural grasslands)	Other wooded land	5 - Low-growing woody plants

CLC		Backbone
All (excl. 24*)	Wetlands	10 - Water

CLC		Backbone
324 (Transitional woodland-shrub)	Cropland annual	7 - Periodic herbaceous

Comparing current reporting with tested Approaches 3 (year 2018)



Challenges and goals for Italy

- Resources and testing: Time, collaboration, funding, and high-resolution data over long time series are needed. To meet monitoring obligations (approach 3), we are focusing on sampling approach based on Collect Earth, as the most promising and integrable path.
- Mixed classes and definitions: in a country like Italy, with great spatial and environmental heterogeneity, some mixed classes are difficult to interpret. Moreover, land use definitions (e.g., forest) can introduce subjectivity and limitations related to sensors. An aggregation and disambiguation process is needed. But to do it properly, detailed data and a long historical series are required

Challenges and goals for Italy

- Reconstruction of historical series: the AVENGERS map was built using CLMS data available since 2018. Trying to extend these data backwards in time with overlap techniques (over 6–7 years) and splicing (over the historical series) is risky, especially if we want to compare them with discontinuous data such as forest inventories or IUTI for SL, OL, and WL.
- One of the most promising areas of the wall-to-wall approach is certainly the verification. Interoperability: spatial disaggregation of pollutant emissions every 4 years; soil monitoring.
- Inter-institutional collaboration: it is essential to engage with ISTAT, the Forest Inventory, and other bodies to understand the causes of data discrepancies between sources and to test and integrate new data sets.

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Thank you for your attention

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