Land representation

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LAND REPRESENTATION

Overall aim: ensure transparency, comparability, and completeness

A **consistent land representation** is needed for to estimate LULUCF carbon stock changes and greenhouse gas emissions and removals.

The land representation has to be complete:

- *total land area of country has to be represented*
- *managed and unmanaged land has to be reported*

The LULUCF Regulation (EU 2018/841, amended by EU 839/2023) requires a **spatially explicit land use** representation, allowing Member States to accurately monitor territorial dynamics and policy impacts.

KEY CONCEPTS

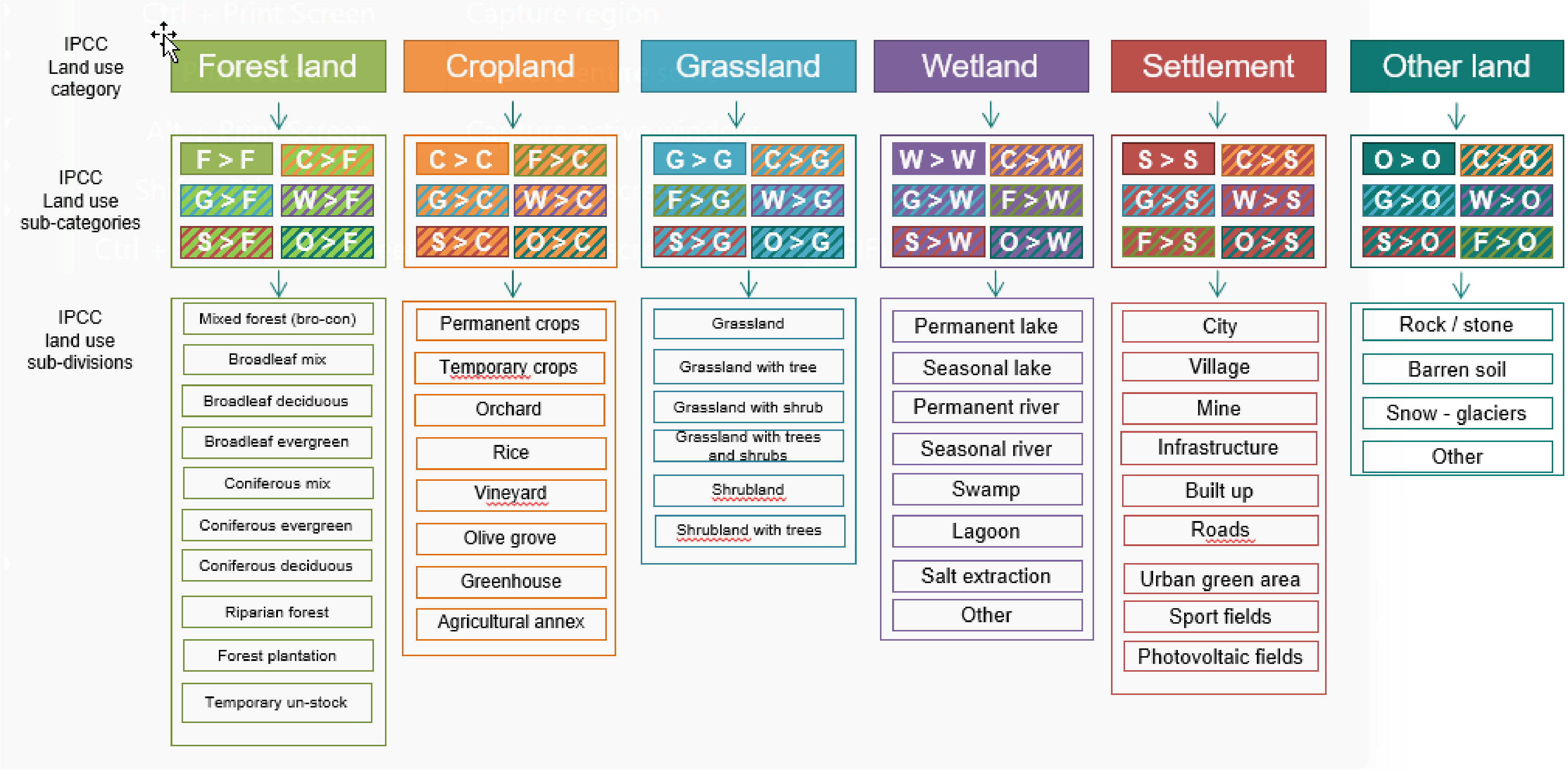
Six land use categories, reported as either land remaining in a land-use category (i.e., remaining in the same use throughout the inventory time-series) or land converted to a new land-use category (representing a change in land use).

Land representation must appropriately capture **land-use categories and any conversions between them**, as needed to estimate carbon stock changes and greenhouse gas emissions and removals.

Land representation has to be assessed based on **country-specific definitions** of land-use categories, in line with the IPCC definitions.

Additional **stratifications** (e.g., grazing land under grassland category) have to be estimated and reported separately, avoiding duplication land in the broad land-use category.

STRATIFICATION: EXAMPLE



IPCC APPROACHES FOR LAND REPRESENTATION

Three approaches may be used to represent areas of land-use for the IPCC categories:

→ **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. Use of stratification (e.g., soil type, vegetation type). can improve emissions estimates. Compatible and comparable spatial resolutions need to be ensured.

METHODS FOR DERIVING LAND USE AREA

Sampling-Based

- Use sampling points, from ground surveys (such as a national forest inventory or national land survey) or remote sensed data, to estimate total areas
- A national defined sampling grid is key to ensure representativeness, and the needed stratification.
- 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

Wall-to-Wall

- Use spatially continuous maps or remote sensing datasets
- Provide full geographic coverage (pixel based)
- Allow visualization and spatial tracking of land-use change
- Require samples for calibration, validation and uncertainty analysis

Survey based method

- 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

SAMPLING VS WALL-TO-WALL

	Sampling-Based	Wall-to-Wall
Coverage	Partial (sampled points/areas)	Complete (full area)
Data Source	Field plots, survey points	Satellite images, maps
Accuracy	High for measured points	Depends on classification accuracy
Cost	Lower	Higher (processing, data)
Best for	Estimating detailed attributes (biomass, soil C)	Detecting spatial patterns & conversions
Limitations	may underestimate small/rare changes	Requires consistent map calibration/validation

COMBINING METHODS AND APPROACHES DEPENDING ON DATA AVAILABILITY

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 – Continuous and consistent samples using remote sensing data
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

Table 3.6A – Volume 4 of 2019 IPCC Refinement

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

USING SAMPLING METHOD

Design a sampling grid: number of sampling plots (sample size) should be large enough to ensure accurate estimates of land use and land-use change, being the sampling method applicable over the whole national area.

Good practice includes:	Assessing the number of samples, to be used with repeated measurements over time, aimed to the identification of land use and land use changes with the acceptable level of uncertainty, also considering the applied stratification, if any.
	Sampling frequently enough to capture changes and management activities that affect emissions and removals.
	Maintaining consistent sampling intervals to avoid bias in change detection rates.
	Ensuring changes in sampling methods over time do not create inconsistencies in land-use reporting.
	Keeping detailed documentation of sampling and assessment procedures.

COMBINING MULTIPLE DATA SOURCES

Integrating remote sensing data products with other data sources is often necessary to collect the information required for estimating emissions and removals and to correctly allocate lands to the IPCC land-use categories over time.

When combining different data types and sources, good practice includes:

- ✓ Reporting the **spatial and temporal resolution** of each data sources;
- ✓ Ensuring **consistency** among data sources that use different temporal or spatial scales;
- ✓ Verifying that spatial datasets meet **national mapping standards** (e.g., appropriate equal area projections) to ensure accurate area calculations, and that raster and/or vector layers align correctly and are within official national boundaries;
- ✓ Ensuring that **land conversion areas remains consistent** throughout the full time-series
- ✓ Applying the **same land conversion period** across all land-use categories;
- ✓ Establishing a **hierarchy** for data sources and integrating them accordingly (i.e., higher-quality data take precedence when inconsistencies occur);
- ✓ **Filling data gaps** to derive consistent time-series of land-use and land-use change;
- ✓ Reporting **uncertainties** associated with land use and land use change estimates
- ✓ **Harmonizing definitions** between the existing independent databases as well as with the land-use categories to minimize gaps and overlaps (for wall-to-wall maps)

INTEGRATING SAMPLING AND WALL-TO-WALL METHODS

Combining ground-based sampling with wall-to-wall spatial observations can substantially improve estimation accuracy as well as spatial and temporal consistency.

A critical consideration in the selection of a **sampling method** is that the chosen methods must be applicable across the full geographical extent of the study area. Moreover, the sample size must be sufficiently large to yield statistically robust estimates for land-use and land-use change categories and their sub-categories.

One of the most advantageous aspects of the **wall-to-wall method** lies in its utility for verification activities, including interoperability and spatially explicit disaggregation of emissions at predefined intervals (e.g., every four years).

Regarding **cost-effectiveness,** substantial financial resources, personnel, and long-term access to high-resolution datasets are required. Considering the monitoring obligations under the LULUCF Regulation (Approach 3), a sampling-based framework represents the most feasible and integrable solution.

WHY CONSISTENCY MATTERS

Ensures observed changes reflect real land-use conversions.

Avoids bias in emission estimates due to inconsistent data.

Improves transparency, comparability, and accuracy.

CONSISTENT TIME SERIES

Definition: the same definition must be applied consistently over time, for each land-use category

Classification: the same classification process has to be applied, possibly with consistent data sources, in term of spatial resolution, for all years

Bias: avoid artificial changes due to method or dataset differences

Evaluate the final products to ensure a consistent representation of land-use with no double counting or omission of lands

CONCLUSIONS

- **Accurate land representation** is key to producing reliable estimates of LULUCF emissions and removals
- **Selection of approach and method** affects the reliability and comparability and transparency of the reported estimates.
- **Consistent time series** ensure credible reporting.
- Ensure the **time-series is dense** enough to identify activities that drive emissions and removals.
- The **wall-to-wall map** can be used as a stratification layers to optimize the design of the sampling grid.
- **Sampling methods** can support the annual collection of land-use and land-use change information, while periodic integration with wall-to-wall maps (e.g., every 3–4 years) enables the spatial attribution of emissions and removals.
- **Reconstruction of historical time series:** Reporting requires data extending back to 1990; however, consistent methodologies are often not maintained across such long period. Consequently, implementing overlap techniques is essential to retrospectively harmonize and extrapolate recent data products backward in time.