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# REFINING GREENHOUSE GAS MONITORING IN THE LULUCF SECTOR IN CZECHIA AND SLOVAKIA USING EARTH OBSERVATION

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Accurate greenhouse gas (GHG) monitoring in the land use, land use change, and forestry (LULUCF) sector is mandated by European Union climate policy. Regulation (EU) 841/2018 requires Member States to transparently and precisely account for GHG emissions and removals in LULUCF. In response, we propose a refined approach to national carbon accounting for the Czech Republic (Czechia) and Slovakia, focusing on aboveground biomass carbon. This approach addresses gaps in current GHG inventories and aligns with the EU's monitoring, reporting, and verification requirements for carbon removals.

Due to their shared history, Slovakia and Czechia have developed LULUCF reporting systems based on similar data sources and methodological approaches. As a result, both countries face not only comparable strengths but also the same limitations and challenges in meeting EU requirements for transparent and spatially explicit reporting.

We introduce an idea for an enhanced land use classification scheme tailored to conditions in Slovakia and Czechia. The scheme updates traditional LULUCF classes – distinguishing settlements (urban built-up vs. sparse urban), croplands (annual vs. permanent crops), woodlands (forests vs. other woody vegetation), grasslands, wetlands, and other lands – to better reflect carbon-relevant typologies. Multiple Earth observation data sources are integrated to map these classes. We analyse the usage of machine learning techniques to produce high-resolution land cover maps. In particular, a convolutional neural network (CNN) could be employed in combination with object-based image analysis (OBIA) to detect and delineate fine-scale landscape elements that contribute to carbon stocks. This CNN+OBIA approach could allow identification of small but significant features (e.g. solitary trees, hedgerows) that are often overlooked yet important for carbon sequestration. The segmented land cover objects could be later classified using machine learning algorithms (e.g. support vector machines or random forests) to finalise the land use map, capturing detailed spatial information on carbon pools.

The refined classification and mapping methodology should enable more precise estimation of carbon stocks and GHG removals for each land use/land cover class. Aboveground biomass carbon content and emissions/removals should be quantified for urban areas, agricultural lands, forests and other woodlands, grasslands, wetlands, and other land classes, capturing changes over time. This comprehensive dataset is expected to improve the accuracy and completeness of LULUCF carbon balance assessments for Slovakia and Czechia. Ultimately, our approach supports enhanced transparency and accuracy in national GHG inventories, providing a robust basis for monitoring, reporting, and verification of carbon removals under EU climate commitments.

## LULUCF Today in Slovakia and Czechia

The classification of LULUCF classes relies on information from the land registry (cadastral data) provided by the Geodesy, Cartography and Cadastre Authority of the Slovak Republic (GCCA) and the Czech Office for Surveying, Mapping and Cadastre (COSMC). These authorities serve as the primary source for determining the spatial distribution of each LULUCF class. Every year, the GCCA publishes the Statistical Yearbook of Soil Resources in the Slovak Republic, which delivers updated cadastral data used to define the areas assigned to LULUCF. Information on LULUCF classes from COSMC data is prepared annually by the private company.

In Czechia and Slovakia, cadastral data contain ten land categories in total. Six of these are agricultural, while the remaining four represent other types of use.

| Cadastral land category | LULUCF clasess | |
|---|---|---|
| | Slovakia | Czechia |
| arable land | cropland | |
| hop-fields | | |
| vineyards | | |
| gardens | | |
| orchards | | |
| grasslands | grassland | |
| forests | forest land | |
| water bodies | wetlands | |
| built-up areas with courtyards | settlements | |
| miscellaneous land | other land | settlements* |

**Table 1** — Cadastral and LULUCF classes used in Czechia according CHMI (2022), and Slovakia.
*According to additional attributes, it may sometimes also be classified as wetlands.

## Change in LULUCF Reporting is Needed

Recent developments in European climate policy have underlined the importance of refining this approach. Regulation (EU) 841/2018 requires Member States to provide transparent and spatially explicit monitoring of greenhouse gas emissions and removals in the LULUCF sector. The Slovak and Czech reporting framework, while functional, does not yet meet these requirements in full. To address this gap, we propose a revised classification scheme that captures more carbon-relevant distinctions. Cropland is separated into annual and permanent crops, settlements are divided into dense urban areas and dispersed settlement zones, and wooded land is distinguished between forests and other woody vegetation. Grassland, wetlands and other lands remain in the scheme but are refined to provide clearer information on their carbon dynamics.

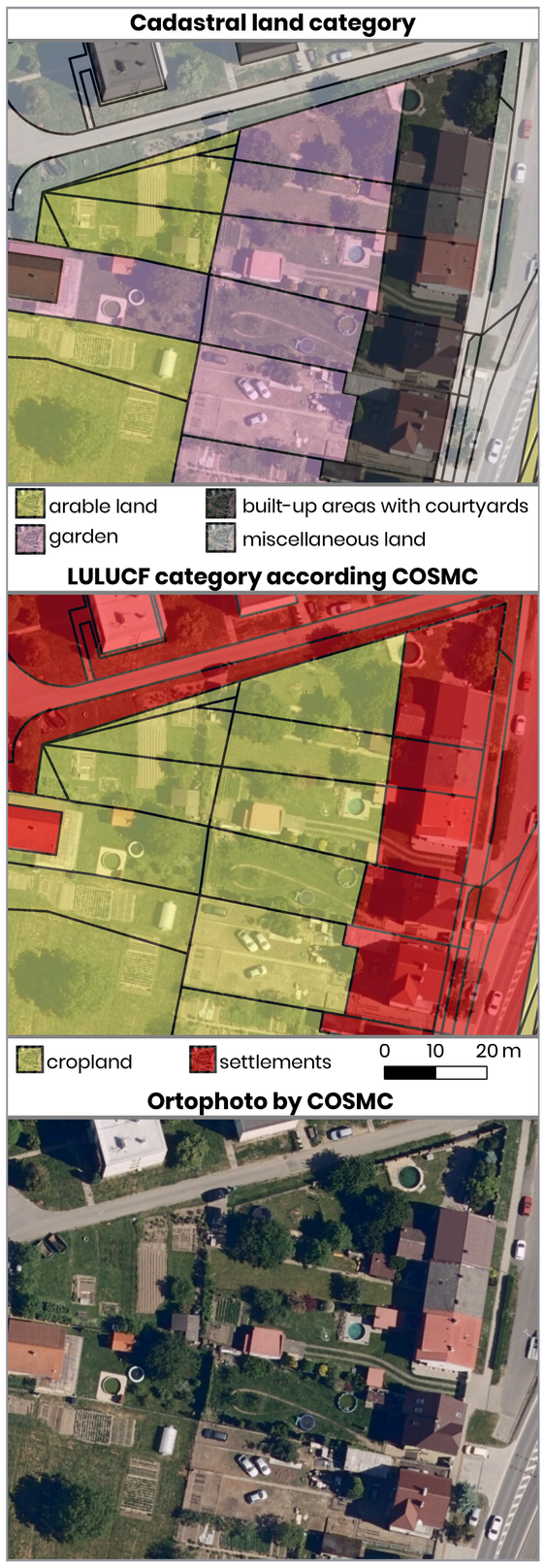


**Figure 1** — Cadastral data from COSMC and their LULUCF category. Gardens are considered cropland even though they rarely serve for productive agriculture in the image.

## Earth Observation (EO) Methods

We intend to combine Sentinel imagery, aerial data, LPIS, and other supplementary detailed thematic datasets with advanced classification. OBIA, together with CNNs, could help detect fine-scale elements like hedgerows or solitary trees. These objects will be classified using machine learning (SVM, Random Forests), producing high-resolution maps of land use and change.

EO methods could help to improve the detection of land-use conversions, especially in agriculture. They allow the inclusion of small but carbon-relevant features often missing in cadastral data. This leads to more accurate carbon estimates and supports transparent, EU-compliant reporting.

## Refined Classification Approach

- Cropland: split into annual and permanent crops
- Settlements: divided into dense urban vs. sparsed urban farbic
- Woodland: distinguished between forests and other woody vegetation
- Grassland, Wetlands, Other Land: retained but refined for better carbon-relevant information

This scheme reflects landscape diversity more accurately and links better to carbon pools

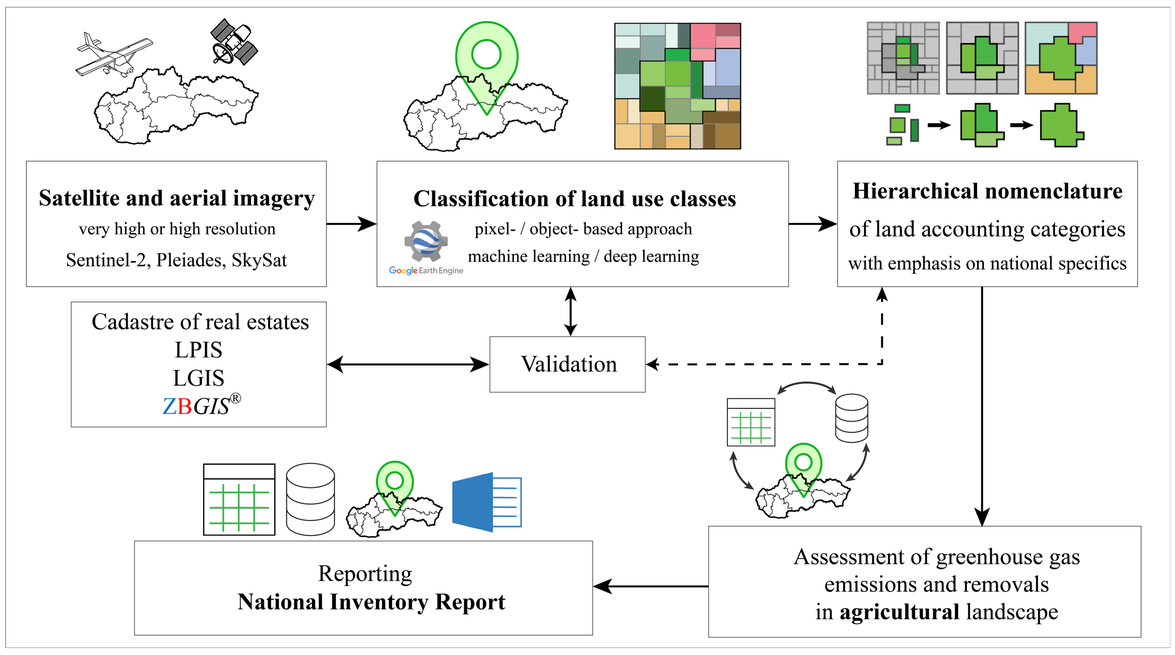


**Figure 2** — Proposed approach for LULUCF reporting in Czechia and Slovakia

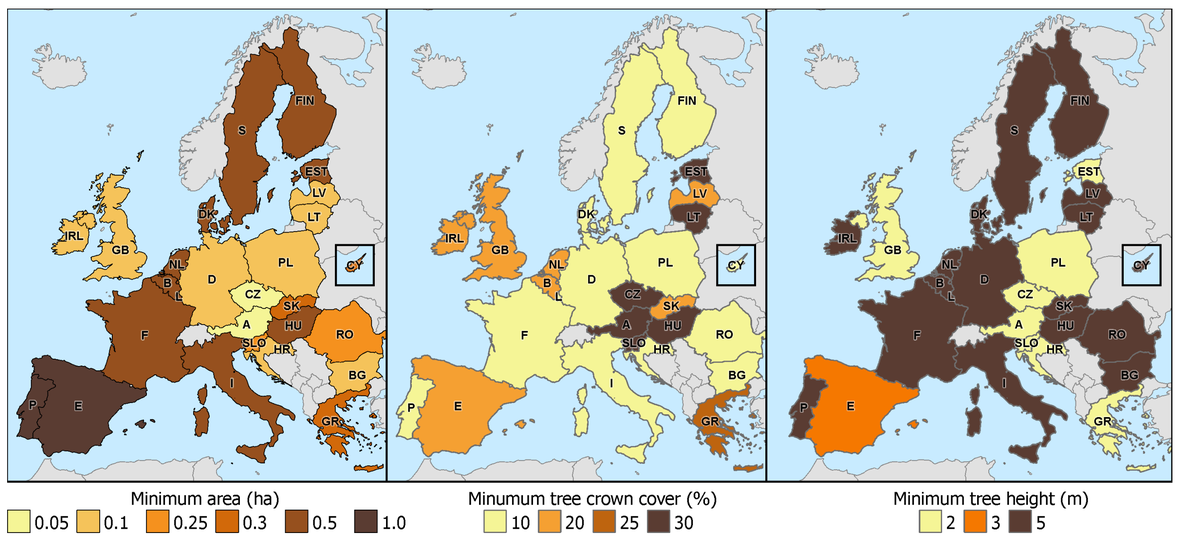


**Figure 3** — Maps of minimum area (ha), minimum tree crown cover (%) and minimum tree height (m) that stands in Europe must meet in order to be considered forest land.

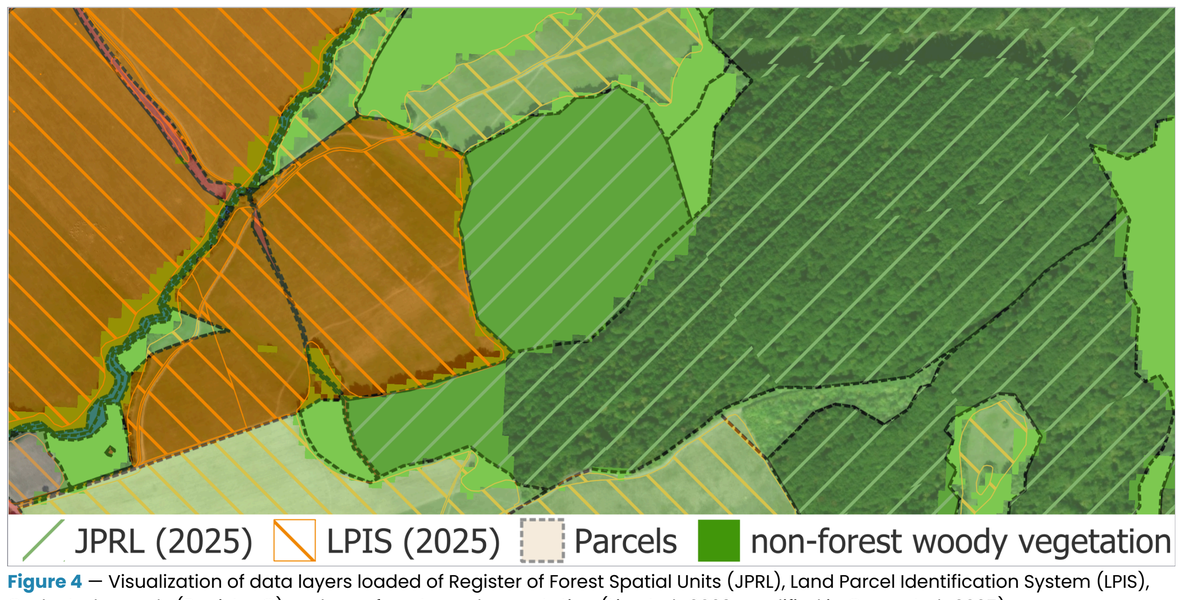


**Figure 4** — Visualization of data layers loaded of Register of Forest Spatial Units (JPRL), Land Parcel Identification System (LPIS), Cadastral parcels (Register C) and non-forest woody vegetation (Liu et al., 2023, modified in Goga et al., 2025).

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CHMI, 2022 Liu et al., 2023 Goga et. al, 2025