Integration of regional and national forest inventories in Spain for data exchange and geospatial visualisation

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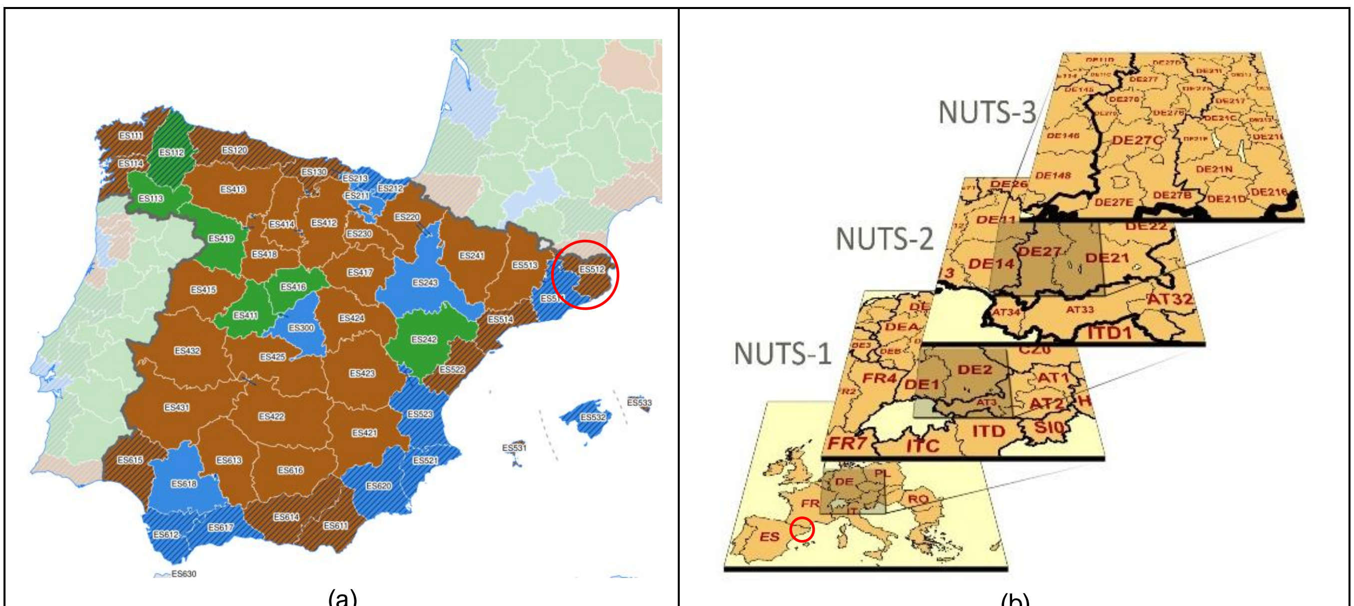
The National Forestry Inventory (NFI) data in Spain have been collected by provinces in a 10-year cycle since 1965. The current edition 4th NFI (2007-2017) is well standardised and centralised by the Ministry of Agriculture through its web entry point with public access for downloading. However, each province belongs to its autonomous region that often has its own additional information in more detail. In Catalonian autonomous region composed of four provinces, we selected the province of Girona (ES512 in Figure 1a) as our study area where its boundary is adjacent to the national border of France. As shown in Figure 1b, this study first addressed the scalability of cross-boundary forest monitoring between provinces (NUTS-3), autonomous regions (NUTS-2), socio-economic regions (NUTS-1) and countries (NUTS-0) to enable data exchange in a Forest Data Space of the project SAGE (The Data Space for a Sustainable Green Europe). Secondly, with the focus on filling the temporal and spatial gaps between the current and next NFI editions, we aimed to contribute regional data derived from in-situ and remote sensing measurements as complementary to analyse the 4th NFI.



(a) (b)

Figure 1. Nomenclature of Territorial Units for Statistics (NUTS) classification system developed by Eurostat: (a) NUTS Level 3 in Spain with the study area province of Girona (ES512); (b) categorisation of regions within the EU into three hierarchical levels.

The NFI sampling method uses permanent sample plots (PSPs) in fixed circular areas with the radius of 25 meters. For this study 1445 PSPs were found in the province of Girona with coordinates referenced to the Forest Map of Spain at scale 1:25,000 (MFE25). According to the NFI map, Girona is characterised by rich biodiversity with the high number of tree species, such as *Quercus ilex, Q. suber, Q. humilis, Pinus sylvestris, P. halepensis, P. uncinata, Fagus sylvatica,* and *Castanea sativa*. In addition, regional data used include the Land Cover Map of Catalonia (MCSC) as well as the Ecological and Forestry Inventory of Catalonia (IEFC) that provided biophysical variables such as leaf area index and allometric equations for dominant tree species.

To visualise forest data from difference sources in different formats, we first converted them into tabular data in TAPIS (a browser-based API Explorer and Table Manager) to join them corresponding to PSP identifiers assigned by the 4th NFI that contain numerous stand attributes such as tree species, diameter, height, density, tree cover, administrative units, and geospatial coordinates. TAPIS reads data and metadata from supported APIs and file formats (csv, dbf, GeoPackage, JSON, GeoJSON) and structures the data as tables that can be managed and transformed. TAPIS input tools support OGC SensorThingsAPI, API Records, Catalog Service for the Web (CSW) as well as S3 Service and Eclipse Dataspace Connector (EDC) Catalogue that enable data exchange in an open or restricted manner. TAPIS also has table tools for statistical analysis and visualisation, including 'Open Map' tool to add a geospatial column and transform geometry among point coordinates, GeoJSON, Geohash, and DGGS (Discrete Global Grid System).

We presented forest data exchange with APIs and catalogue services supported in TAPIS, enabling to share value-added data and sensitive data between Catalonian, Spanish, and European stakeholders. We also demonstrated the innovative tool implementation in TAPIS to open a MiraMon Map Service and visualise integrated geospatial information at selected resolutions effectively using DGGS. The hexagonal and hierarchical Uber H3 DGGS was deployed to provide fast requests to all cells with 16 levels of spatial resolutions to help assess the forest biodiversity and connectivity.

Using interoperable standards, our methodology workflow presented in this study is reproduceable for other provinces, autonomous regions, and countries to increase forest data sharing in support of the European Green Deal Data Space. In future work, we consider integrating high-resolution regional LiDAR data in contribution to digital twins for forest monitoring and representing them in a 3D+ environment.

This work was co-funded by the European Commission's Digital Europe Programme (DIGITAL) under grant agreement No.101195471.