



Integrating Pan-European Data Sets Improves Spatial and Temporal Characterisation of Land Use Management

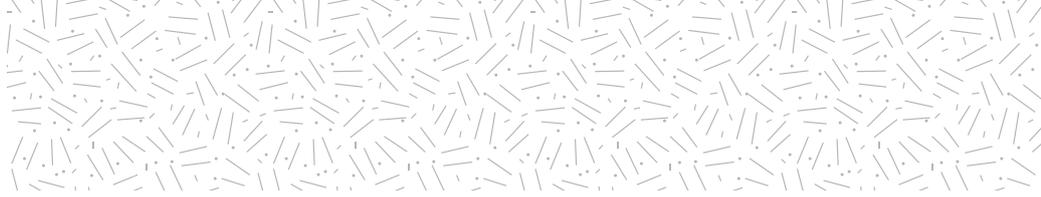
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Key Messages

- **Pan-European land use management has been mapped at a high spatial resolution for 2000, 2010 and 2018.** Using existing European data sets such as Corine land cover, Natura 2000 sites, agricultural inputs from the CAPRI model and livestock densities, land-use management intensities have been mapped for forest, agricultural and urban areas. These layers can be viewed and downloaded from the [LAMASUS Data Explorer](#).
- **In 2018, in the EU, intensively managed forests cover around 40% of forest area, 60% of cropland areas are intensively managed, while intensive grassland management can be found in 35% of grassland and grazing areas.** Knowing where intensively managed areas are located across the EU means better targeting of policy measures and incentives that move towards more sustainable forestry and agricultural practices.
- **Hotspot mapping identifies areas where intensive agricultural management and soil degradation occur together.** By overlaying the LAMASUS land use management geodatabase on maps of soil degradation indicators produced by the Joint Research Centre (JRC) of the European Commission, clear hotspots of intensive agricultural management and degraded soils emerge. These hotspot maps can be used to target agricultural policies in areas with the highest risk of soil degradation.

A geographical database for pan-European land-use management has been developed as part of the Horizon Europe LAMASUS project. Using the Copernicus [Corine Land Cover](#) product as the basis for developing maps of land use management, high-resolution layers (100m) have been produced for the years 2000, 2010 and 2018. Unmanaged primary forests have been differentiated from



highly intensive areas used for wood and biomass production. Arable and permanent cropland have been classified into intensively managed irrigated areas and more extensively managed rainfed areas. Intensively and extensively managed grassland and grazing systems have been mapped using livestock densities and maps of grazing probability.

Together, these land use classes have been integrated into a single product that can be viewed and downloaded from the [LAMASUS Data Explorer](#). This integrated dataset allows modellers to test different scenarios related to sustainable forest and agricultural land use management. For example, using the land use management geodatabase, [modelling](#) has shown those areas where agricultural de-intensification can deliver biodiversity and climate benefits with minimal cost. The land use management geodatabase could also be directly useful for policy purposes, e.g. as a complementary Common Agricultural Policy (CAP) analytical indicator for farming intensity, or in combination with other indicators such as soil degradation to produce risk maps.

Intensively managed land across the EU27

The land use management geodatabase has been produced at a high resolution (100 m). When aggregated, it shows that intensively managed forests cover around 40% of forest area, 60% of cropland areas are intensively managed, while intensive grassland management can be found in 35% of grassland and grazing areas.

The land use management geodatabase also allows for the visualisation of spatial patterns across Europe. For example, Figure 1 (a) shows the large amount of intensive forest management in parts of Sweden and Finland, intensively managed cropland in northern France, intensively managed grassland driven by high livestock densities in the Netherlands, and the high-intensity urban areas across the city of Athens, Greece. Aggregating the land use management geodatabase to the country level, Figure 1 (b) highlights those countries in the EU27 with the highest shares of intensively managed arable cropland. Benelux countries (BE/NL/LU), Slovenia (SI) and Italy (IT) have the largest shares of very intensively managed cropland, covering more than 40% of their arable land, while some Eastern European countries, such as Bulgaria (BG), two of the Baltic states (LT and LV) and Romania (RO), are characterised by systems with much lower intensity management.

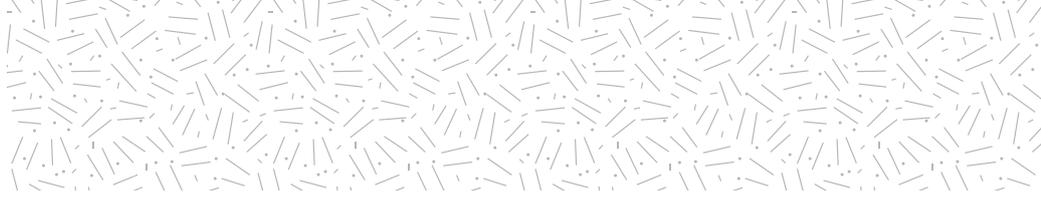
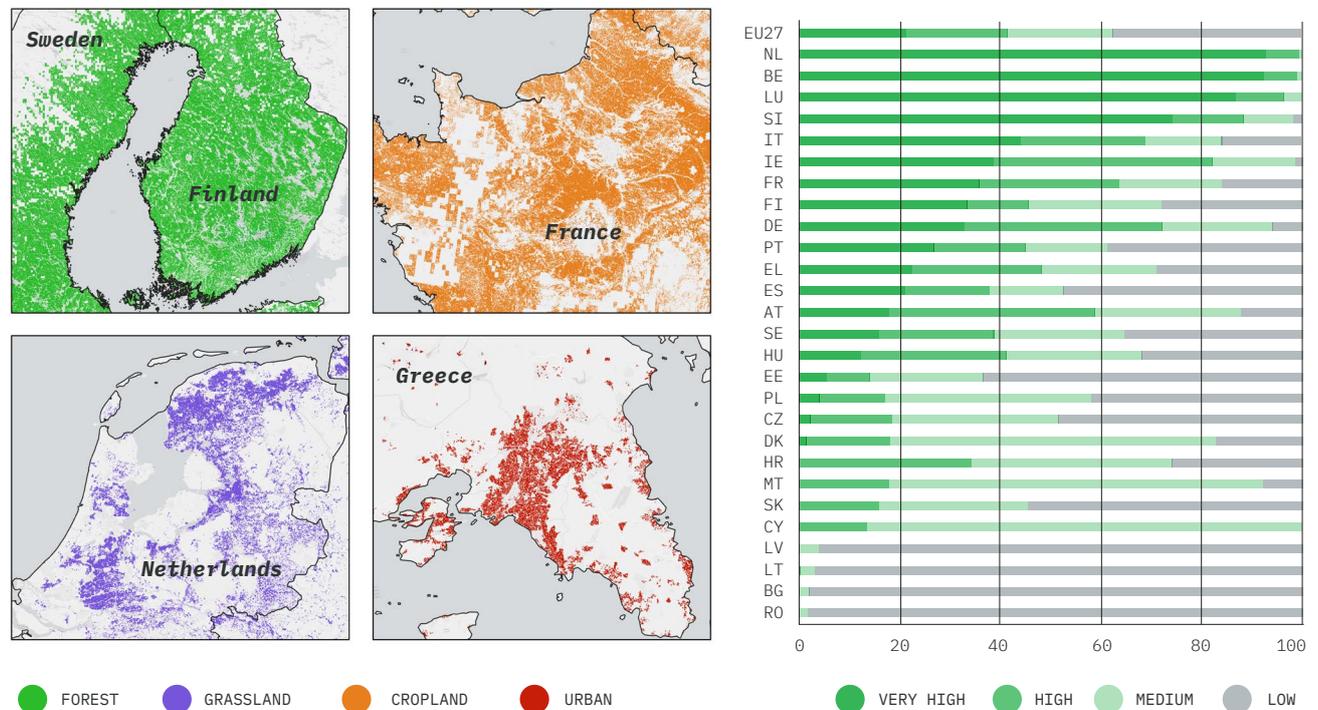


Figure 1. Intensively managed land use across Europe

(a) Examples of the spatial distribution of intensively managed forest, cropland, grassland and urban areas in four locations across Europe. (b) The distribution of intensively managed arable cropland across EU countries, based on the land-use management classes in the geodatabase (defined as very high, high, medium and low, where the latter class also includes very low).



Patterns of intensive agricultural management and indicators of soil degradation

The European Soil Data Centre (ESDAC) at the JRC has produced soil degradation indicators across Europe using a combination of modelling and sample survey data from the Eurostat LUCAS soil module, carried out every three years across EU Member States. These indicators have been combined with the land use management geodatabase to map hotspots (or the co-occurrence) of intensively managed agriculture and soil degradation. To illustrate this, two indicators of importance to sustainable agriculture have been selected: nitrogen surplus and loss of soil organic carbon (SOC), shown in Figure 2.

Red areas in Figure 2 show the co-occurrence between intensive agricultural management and both nitrogen surplus and SOC loss. These are areas with large livestock systems in Germany, Ireland, the Netherlands, northern Italy, western Poland, northern France, Denmark, and some areas in Spain. Other areas shaded in green, yellow, pink and purple indicate where co-occurrence with one of the indicators is present, e.g., large areas of SOC loss in western France, Benelux, and Germany or nitrogen surplus in eastern Romania.

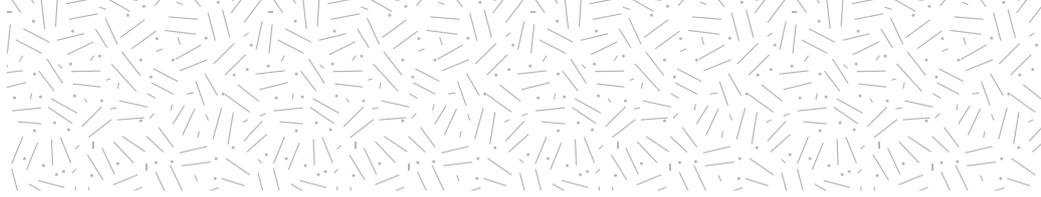
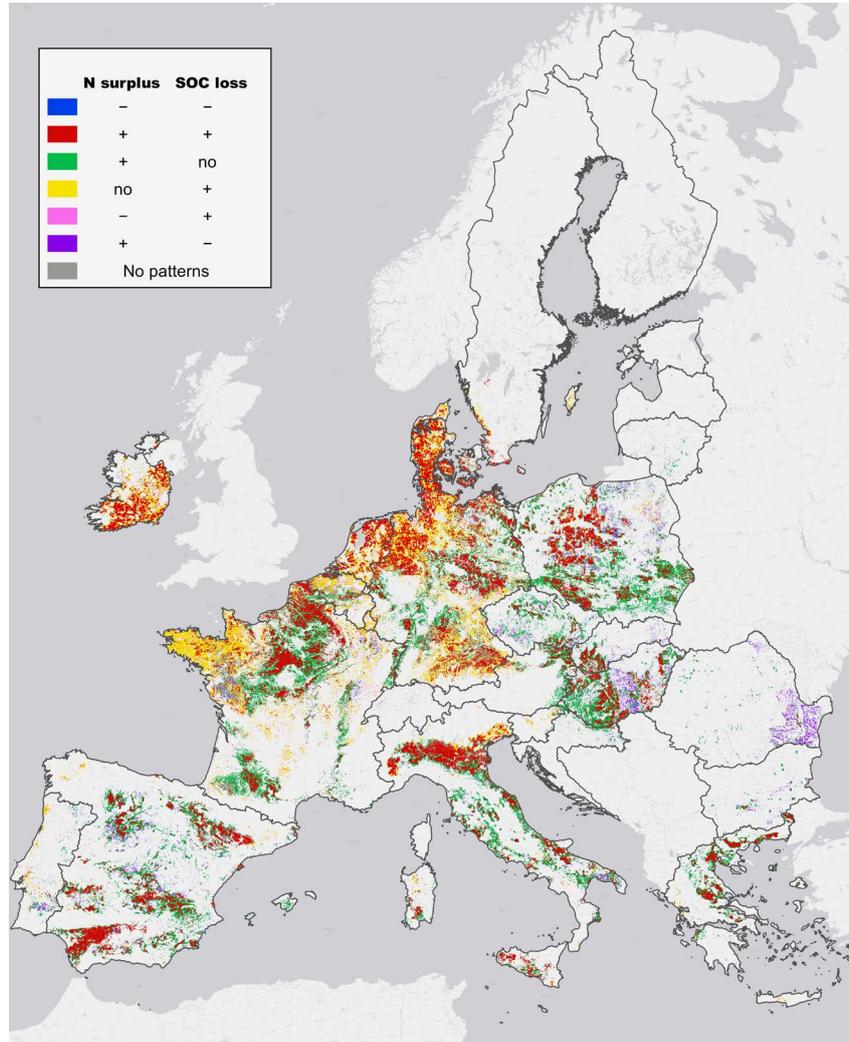


Figure 2. Hotspots of intensively managed land use and two soil degradation indicators: nitrogen surplus and soil organic carbon loss.

A positive sign in the legend refers to co-occurrence between intensive management and the indicator (hotspot), a negative sign is the opposite relationship (coldspot), and 'no' refers to no relationship.



These hotspot maps are a form of spatial-risk and opportunity identification, which could be used to target eco-schemes in areas with the highest combined risk. They could be used to create a composite risk index with tiered risk zones that could have different obligations or support levels. For example, high-risk zones could have higher compliance requirements than low-risk zones, where actions would be voluntary. Prevention zones could also be identified, i.e., those areas where intensive agriculture is present with no co-occurrence of soil degradation, since the cost of prevention is generally lower than remediation.

These types of maps could also be connected to water, climate and planning policies. For example, N surplus hotspots could be overlaid onto drinking water

catchments, wetlands, or eutrophication-prone waters to implement stronger measures in these areas. Areas with peat/organic soils or high-carbon mineral soils could be prioritised for SOC protection, or where SOC restoration potential is the highest, carbon programs could be targeted in these areas.

Hotspot maps of all the soil degradation indicators and intensively managed agricultural areas are available in the [LAMASUS Data Explorer](#).

Data and methods

The land use management geodatabase was created from many different data sets, integrated using rules developed by experts and with consultation across the forest and agricultural sectors. Table 1 lists the input data sets used to classify land-use management intensities in forests, arable and permanent cropland, grassland and urban areas.

Table 1. Input data layers used in the development of the land use management geodatabase (in addition to Corine Land Cover as a base layer)

AREA	INPUT DATA SETS USED TO DEFINE LAND USE MANAGEMENT
FORESTS	Forest loss and gain from 2000 to 2021 (Global Forest Watch) Maps of forest disturbance Database of primary forests in Europe & protected areas (Natura 2000) Forest age and evenness (Forest Navigator)
ARABLE AND PERMANENT CROPLAND	Irrigated areas and agricultural inputs expressed in terms of energy calculated by the CAPRI model from the JRC
GRASSLAND	Livestock density and probability layers of grazing livestock in managed grassland and semi-natural grassland Environmental zones across Europe (European Environment Agency)
URBAN AREAS	Urban Atlas and High Resolution Layers on soil sealing (Copernicus)

The European Soil Data Centre (ESDAC) at the JRC has published a number of spatially explicit soil degradation indicators in the EU, calculated from LUCAS data. These indicators were overlaid with the land use management geodatabase to determine hotspots where intensively managed cropland and grassland coincide with an indicator of soil degradation. Table 2 lists the full set of indicators considered in this analysis, but nitrogen surplus and loss of SOC were selected for this policy brief as they are key agricultural concerns from a policy perspective. Note that all hotspot maps can be viewed from the [LAMASUS Data Explorer](#).

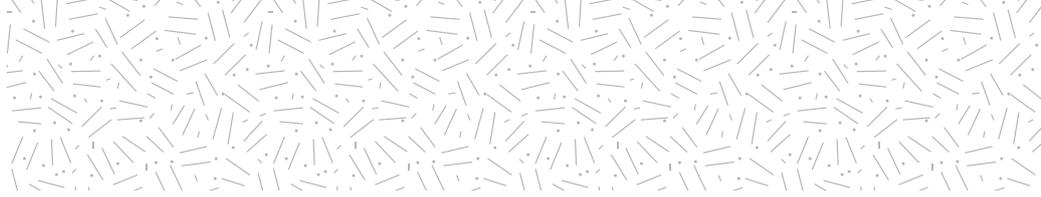


Table 2. Soil degradation indicators used in the hotspot analysis of intensive land use management

SOIL DEGRADATION INDICATOR	DESCRIPTION
NITROGEN SURPLUS	Agricultural areas where N surplus >50 kg/ha
PHOSPHORUS EXCESS	Agricultural areas where P >50 mg/kg
SOIL COMPACTION (PACKING DENSITY)	High packing density (>1.75 g/cm ³)
HARVEST EROSION	Erosion rate > 2 tonnes/ha/year
SECONDARY SALINISATION RISK	Areas in the Mediterranean biogeographical region where >30% is equipped for irrigation
LOSS OF SOIL BIODIVERSITY	A potential threat proxy identified as ≥Moderately high level of risk of potential threat to biological functions (microorganism, fauna, other functions), which was calculated based on 13 threats and their weights elicited from experts
LOSS OF SOIL ORGANIC CARBON (SOC)	Distance from 'maximum' SOC >60%, where the maximum SOC is a modelled 'medium-long term' attainable value reached if the location was kept as permanent grassland for 40 years with no tillage
TILLAGE EROSION	Erosion rate > 2 tonnes/ha/year
WATER EROSION	Erosion rate > 2 tonnes/ha/year
WIND EROSION	Erosion rate > 2 tonnes/ha/year
ALL SOIL DEGRADATION INDICATORS	The sum of the number of soil degradation indicators occurring at each location

Source: The indicators were downloaded from the European Soil Data Centre of the JRC (<https://esdac.jrc.ec.europa.eu/>).

Further information about the methodology used to develop the land use management geodatabase is available in [High Resolution LUM Geodatabase Requirements and Technical Specifications](#) and [The LUM Geodatabase and Area Estimates of Land Use Change to 2018](#).

The need for monitoring land use management over time

To date, much of the work on mapping land use management has been at a coarse spatial resolution (1 to 10 km), and the maps often only cover a single point in time. Yet there is a clear need to monitor changes in land use management, particularly for tracking the evolution of forest and farming practices in the EU towards the adoption of more sustainable approaches.

The LAMASUS land use management geodatabase represents the first attempt at developing a time series of land use management using existing European data assets. To extend the usefulness of this time series, the geodatabase needs to be updated as new data sets become available. In 2026, the new Corine Land

Cover for 2024 will be released, which will allow for temporal updating of the land use management geodatabase. The Protocol for Updating the Land Use Management Geodatabase is provided as a [supplement](#).

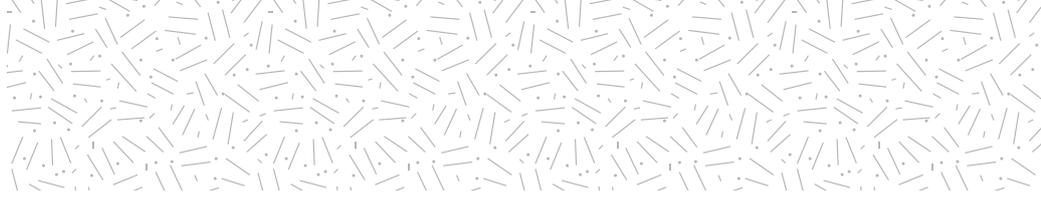
Making further advances in land use management mapping

In addition to updating the LAMASUS land use management geodatabase, new pan-European geographical data sets are now emerging that can be used to improve the way in which land use management is defined across the EU. For example, new Copernicus high-resolution layers on grassland have been released along with the latest LUCAS. Both data sets include additional information on grassland management that was not available previously, which can be used to improve the maps of intensively and extensively managed grassland and grazing systems.

Table 3 provides an overview of new data sets that have become available since the release of the [LAMASUS land use management geodatabase](#) in 2024 and how these can be utilised for improving the mapping of land use management across the EU.

Table 3. New spatially explicit data sources for land use management

DATA SET	DESCRIPTION AND UTILITY FOR LAND USE MANAGEMENT
CROP EXTENT AND CROP TYPES FROM THE COPERNICUS VEGETATED LAND COVER CHARACTERISTICS (VLCC)	<ul style="list-style-type: none"> ✓ Pan-European cropland extent and crop types have been produced annually for 2017 to 2023 at a 10 m resolution. ✓ Derived products include crop rotations, crop diversity and cover crops, which can improve the spatial distribution of cropland management intensities.
GRASSLAND EXTENT AND MOWING EVENT DATA FROM THE VLCC	<ul style="list-style-type: none"> ✓ The VLCC includes permanent grassland extent, the number of mowing events (up to 3) and the dates of the mowing events. ✓ Mowing event data can complement livestock data to define grassland management intensities.
GRIDDED AGRICULTURAL CENSUS DATA FOR 2020	<ul style="list-style-type: none"> ✓ Eurostat has released agricultural census data for 2020 on a multi-resolution grid, including the spatial distribution of livestock, organic farming and irrigable land. ✓ Additional products from the 2023 agricultural survey will include tillage and outdoor grazing as valuable inputs to cropland and grassland management.
GRIDDED LIVESTOCK DATA	<ul style="list-style-type: none"> ✓ New high-resolution time series on livestock distribution have been published, which could improve the characterisation of grassland management.
PESTICIDES	<ul style="list-style-type: none"> ✓ Spatial layers on pesticide use from the JRC can be an additional input to define intensively managed cropland and grassland.



Citizen-generated data through crowdsourcing and citizen science can provide another source of potential information on land use management. Funded by the European Environment Agency, citizen scientists will gather information on when mowing takes place across Europe to improve future Copernicus VLCC products on grassland. AI and computer vision will increasingly be used to recognise features from georeferenced photographs (e.g., from LUCAS) and high-resolution satellite imagery to produce new land use management data sets. Although still largely research-focused, operationalisation to a pan-European scale will be possible within the next decade and will add substantial value to the spatial and temporal characterisation of land-use management across Europe.

These future datasets on land use management will allow for better tracking of changes in intensive management as well as more specific targeting of locations where changes could be incentivised through policy instruments. Such advances might also contribute directly as data inputs to future CAP performance monitoring and evaluation indicators.

At the same time, spatially explicit information is still missing on management practices, which is hindering EU-wide mapping. For example, if farmer declarations to the Geo-Spatial Application (GSA) of the CAP were openly available for all EU countries and for multiple years, this would allow us to capture crop rotations as proxies for intensity. Standardising the types of information that are provided, e.g., inclusion of mowing information and organic farming, which are currently part of the GSA of Austria, would also enable better characterisation of management. Filling data gaps and opening up data related to land use management practices should be a key priority for the future.

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About

The LAMASUS consortium is built to deliver its overall ambition, and features world-leading interdisciplinary expertise in all domains necessary for the successful delivery of the project's objectives, including expertise in integrating knowledge across disciplines. The consortium harnesses the decades of experience in policy maker support on the science policy interface and has key expertise in econometrics, social sciences, and modelling of land-use, earth and climate systems, biodiversity, sectorial economics, and land management.

The LAMASUS consortium consists of 17 partners from 9 countries in Europe (Austria, Belgium, Germany, the Netherlands, France, Poland, Spain, Norway and Switzerland).

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