LAMASUS
Land Management for Sustainability

D2.4 Updates to the Land Use Management (LUM) Geodatabase

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Abstract

Deliverable 2.4 is an update to the LUM Geodatabase as outlined in D2.1 *The LUM Geodatabase and Area Estimates of Land Use Change to 2018*. This report provides information on these updates and accompanies data made publicly available in the LAMASUS Data Explorer.

Keywords

Land cover and land use, land use management, spatially explicit data, high-resolution data

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Abbreviations

CLC	Corine Land Cover
EEA	European Environment Agency
EC	European Commission
ESA	European Space Agency
EU	European Union
JRC	Joint Research Centre
LUM	Land use management
VLCC	Copernicus High Resolution Vegetated Land Cover Characteristics

1. Introduction

Deliverable 2.4 is an update to the land use management (LUM) Geodatabase, delivered as a report (D2.1 The LUM Geodatabase and Area Estimates of Land Use Change to 2018), and uploaded to Zenodo at: https://zenodo.org/records/13254324 at the end of August 2024. A minor update in April 2025 was made to correct for a modification to the grassland management allocation rules (https://zenodo.org/records/15488011). The updated data set (now version 3.0) is available from Zenodo at: https://zenodo.org/uploads/19809788 and visualized and accessible through the LUM Data Explorer.

2. Updates to the LUM Geodatabase

Since the LUM Geodatabase was delivered in August 2024, new data sets have been released or made available that have been used in the latest update (version 3.0). These include:

- improved irrigation data from the European Space Agency (ESA)-funded WorldCereal project,
- new cropland and grassland layers from the Copernicus High Resolution Vegetated Land Cover Characteristics (VLCC) product (Wegscheider et al., 2024),
- new European Wetland Map (https://zenodo.org/records/14745285) from the EU-funded ALFAWetlands and WET HORIZONS projects.

A temporal update to 2024 was not done as the legacy Corine Land Cover (CLC) product and change layers (from 2018 to 2024) have not yet been released by the European Environment Agency (EEA).

The key features of this update include:

- modifications to the cropland management classes (i) to improve the arable and permanent irrigated cropland management class with better information on irrigation, and (ii) to refine the extensive arable cropland management class using the latest maps on temporary grassland, which indicate more extensive practices;
- the division of the four managed pasture and four managed grassland classes into two sub-classes each: one without mowing and one with mowing, thereby providing additional grassland management information;
- the addition of more accurate and up-to-date information on wetlands, which have been comprehensively mapped as part of the new European Wetland Map.

Each of these updates is described in more detail in the sections that follow.

2.1. UPDATES TO CROPLAND MANAGEMENT CLASSES

The cropland management classes were updated using two new datasets. Data and processing steps are described below:

- **A hybrid irrigation layer for 2021**: The ESA-funded WorldCereal project produced a global irrigation layer at a 10 m resolution, which is available on Google Earth Engine. As part of the LAMASUS LUM geodatabase updating procedure, this layer was first aggregated to the 100 m CLC grid to produce the percentage of irrigation in each pixel. This was then overlaid with the CLC classes **2.1.2 Permanently irrigated land** and **2.1.3 Rice fields**, to produce a hybrid map showing locations where irrigation is present in both or either of the two sources to capture as much irrigation as possible. This hybrid map is shown in Figure 1.
- **A temporary grassland layer for 2018 and 2022**: These are two derived layers that were produced by the Joint Research Centre of the European Commission (JRC, Ispra) as part of their role in validating and using products from the VLCC. Maps of temporary grassland were produced by combining the VLCC cropland and grassland layers to determine the location of temporary grassland, which is defined as grassland with a short-term agricultural cycle of 5 years or less. This may be fallow or uncultivated land, which indicates more extensive arable management practices. The original maps were at 10m resolution, so they were aggregated to the CLC 100 m grid to produce the percentage temporary grassland. A threshold of 50% was then chosen to remove noise (e.g., individual pixels) or the periphery of temporary grassland. Both layers were used to capture temporal management: if either layer contained temporary grassland, we assume the presence of more extensive arable cropland management except when there is irrigation, in which case the irrigation layer takes precedence.

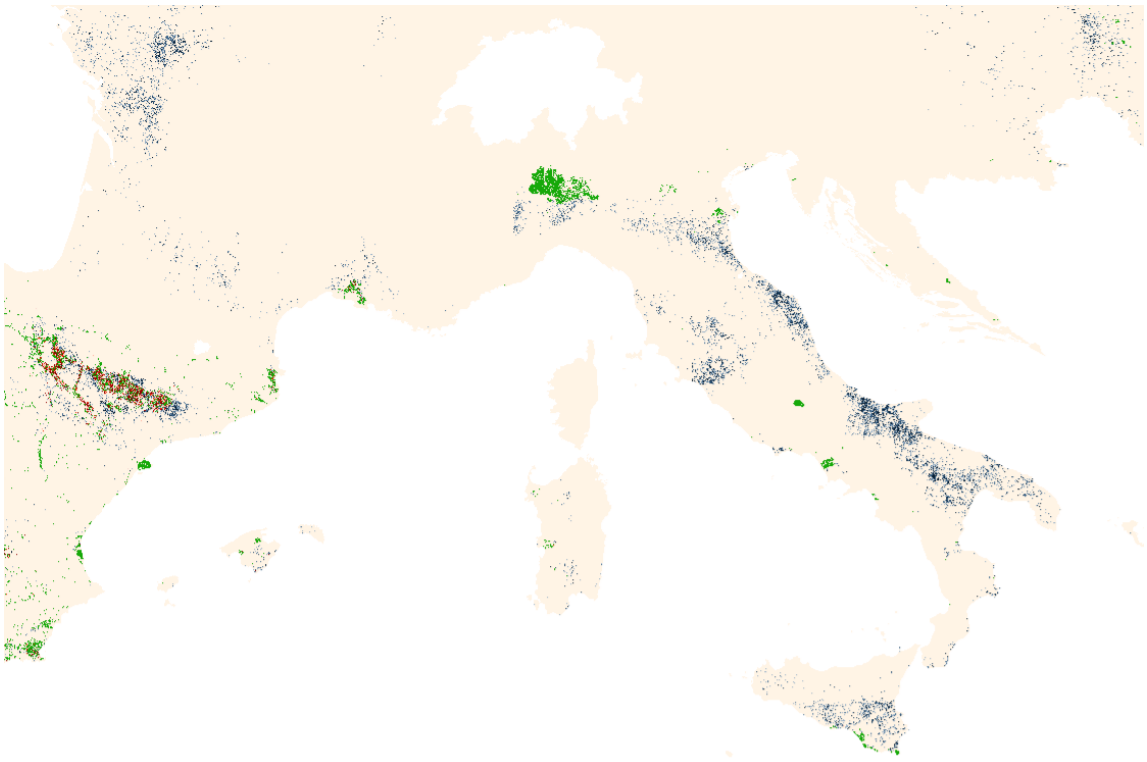

Figure 1: A zoomed-in section of the hybrid irrigation layer used to update the cropland management classes. Red areas indicate consensus between CLC and the WorldCereal layer, blue areas are the additional areas added by the WorldCereal layer, green areas are irrigated areas in CLC, and light pink areas are no irrigation.

Both layers were used to update the cropland management classes using the rules listed in Table 1, applied to the previous layers for 2018, 2010 and 2000, already fit to statistics. Although there is a temporal mismatch between these two layers and the older LUM Geodatabase layers (i.e., 2010 and 2000), the previously used irrigation layer was from 2010, and no information was available on temporary grassland, so we assume these patterns are not substantially changing over time. Although this is a limitation, the improved information content from these layers should partially compensate.

The rules in Table 1 assume the following:

- Irrigation has precedence over temporary grassland, so even if temporary grassland is present, the class remains irrigated.
- Temporary grassland is not relevant for permanent cropland classes, so this layer is not used in the rules. Similarly, there are no changes to Heterogeneous permanent cropland classes, so they are not listed in Table 1.
- Irrigation is not considered in heterogeneous arable classes, only temporary grassland, since these heterogeneous classes have grassland and semi-natural vegetation.

Table 1: Rules for updating the cropland management classes with irrigation and temporary grassland layers

OLD CLASS	IRRIGATION	TEMPORARY GRASSLAND	NEW CLASS	COMMENT
Irrigated arable cropland	Yes	-	No change	Irrigation has precedence over temporary grassland
	No	No	Rainfed intensive arable cropland	Remains intensive but not irrigated
	No	Yes	Rainfed extensive arable cropland	Changes to more extensive management
Rainfed intensive arable cropland	Yes	-	Irrigated arable cropland	Becomes irrigated
	No	No	No change	Remains intensive
	No	Yes	Rainfed extensive arable cropland	Changes to more extensive management
Rainfed extensive arable cropland	Yes	-	Irrigated arable cropland	Becomes irrigated
	No	-	No change	Remains extensive
Irrigated permanent cropland	Yes	-	No change	Remains irrigated
	No	-	Rainfed intensive permanent cropland	Remains intensive but not irrigated
Rainfed intensive permanent cropland	Yes	-	Irrigated permanent cropland	Becomes irrigated
	No	-	No change	Remains intensive but not irrigated

OLD CLASS	IRRIGATION	TEMPORARY GRASSLAND	NEW CLASS	COMMENT
Rainfed extensive permanent cropland	Yes	-	Irrigated permanent cropland	Becomes irrigated
	No	-	No change	Remains extensive but not irrigated
Intensive heterogeneous arable cropland	-	Yes	Extensive heterogeneous arable cropland	Changes to more extensive management
Extensive heterogeneous arable cropland	-	No	No change	Remains extensive

Source: LAMASUS WP 2

Once the rules were applied, the changes in classes were calculated, and the results are summarized in Table 2. As expected, the amount of irrigated arable land almost doubled with the new irrigation layer, while there was also a shift of around 3.2 million ha from rainfed intensive to extensive arable land with the use of the temporary grassland layer.

Table 2: Changes in cropland management classes after updating for the 2018 layer (in ha)

OLD CLASS	NEW LUM GEODATABASE CROPLAND MANAGEMENT CLASS							
	Irrigated arable cropland	Rainfed intensive arable cropland	Rainfed Extensive arable cropland	Irrigated Permanent cropland	Rainfed intensive permanent cropland	Rainfed extensive permanent cropland	Intensive hetergeneous arable cropland	Extensive hetergeneous arable cropland
Irrigated arable cropland	4,089,752	829,681	27,580	0	0	0	0	0
Rainfed intensive arable cropland	2,372,880	55,575,296	3,215,519	0	0	0	0	0
Rainfed extensive arable cropland	1,549,307	0	36,012,452	0	0	0	0	0
Irrigated permanent cropland	0	0	0	360,802	3,702,634	0	0	0
Rainfed intensive permanent cropland	0	0	0	216,695	3,164,715	0	0	0
Rainfed extensive permanent cropland	0	0	0	136,928	0	2,765,188	0	0
Intensive heterogeneous arable classes	0	0	0	0	0	0	914,657	85,362
Extensive heterogeneous arable classes	0	0	0	0	0	0	0	305,034

Source: LAMASUS WP 2

2.2. UPDATES TO GRASSLAND MANAGEMENT CLASSES

The grassland management classes were updated with mowing information, newly produced within the VLCC, and it is a clear indicator of management. In Europe, many grassland systems involve both mowing and grazing, which was missing previously. The separation of managed or grazed pastures (classes 1 to 4) from managed grassland (or grassland with largely indoor livestock, classes 5 to 8) was done by first allocating livestock to areas with high grazing probability and then allocating the remaining livestock to managed grassland.

In the updated LUM Geodatabase, we identified for each of the eight original grassland management classes whether mowing occurred or not for the period 2017 to 2021 using the new VLCC mowing event dataset, which indicates whether a 10 m pixel has been mowed once, twice or three times, or has not been mowed at all.

We first aggregated the 10 m data to the 100 m CLC, producing one layer per year for the period 2017 to 2021. If mowing was present in any of these five years (regardless of the number of times the pixel was mowed), new grassland management classes were created as outlined in Table 3. This process splits the eight main grassland classes from the LUM Geodatabase into sub-classes, one with mowing and one without.

Table 3: Rules for updating the grassland management classes with mowing event layers from the Copernicus High Resolution Vegetated Land Cover Characteristics

OLD CLASS	OLD CLASS DESCRIPTION	MOWING EVENTS	NEW CLASS	NEW CLASS DESCRIPTION
1	Very high density managed pasture system (> 2 LSU/ha)	No	1a	Very high density managed pasture system (> 2 LSU/ha), no mowing
		Yes	1b	Very high density managed pasture system (> 2 LSU/ha), with mowing
2	High density managed pasture system (1 to 2 LSU/ha)	No	2a	High density managed pasture system (1 to 2 LSU/ha), no mowing
		Yes	2b	High density managed pasture system (1 to 2 LSU/ha), with mowing
3	Moderate density managed pasture system (0.5 to 1.0 LSU/ha)	No	3a	Moderate density managed pasture system (0.5 to 1.0 LSU/ha), no mowing
		Yes	3b	Moderate density managed pasture system (0.5 to 1.0 LSU/ha), with mowing
4	Low density managed pasture system (<0.5 LSU/ha)	No	4a	Low density managed pasture system (<0.5 LSU/ha), no mowing
		Yes	4b	Low density managed pasture system (<0.5 LSU/ha), with mowing
5	Very high density managed grassland (> 2 LSU/ha)	No	5a	Very high density managed grassland (> 2 LSU/ha), no mowing
		Yes	5b	Very high density managed grassland (> 2 LSU/ha), with mowing
6	High density managed grassland (1 to 2 LSU/ha)	No	6a	High density managed grassland (1 to 2 LSU/ha), no mowing

OLD CLASS	OLD CLASS DESCRIPTION	MOWING EVENTS	NEW CLASS	NEW CLASS DESCRIPTION
		Yes	6b	High density managed grassland (1 to 2 LSU/ha), with mowing
7	Moderate density managed grassland (0.5 to 1.0 LSU/ha)	No	7a	Moderate density managed grassland (0.5 to 1.0 LSU/ha), no mowing
		Yes	7b	Moderate density managed grassland (0.5 to 1.0 LSU/ha), with mowing
8	Low density managed grassland (<0.5 LSU/ha)	No	8a	Low density managed grassland (<0.5 LSU/ha), no mowing
		Yes	8b	Low density managed grassland (<0.5 LSU/ha), with mowing

Source: LAMASUS WP 2

Once the rules were applied, we compared the previous LUM Geodatabase for 2018 with the updated version, and we then calculated the split of each original class into non-mowed and mowed versions of the class, summarized in Table 4. The results show that grazing and mowing take place in the same fields in the majority of classes, regardless of whether they are managed pastures or managed grasslands. However, in the case of managed grasslands (classes 5 to 8), there is a stronger shift to classes with mowing events, which is expected since these classes are proxies for indoor livestock, fed with silage from mowed fields or supplementary feed.

The only exception is class 1, which is the most intensively managed pasture class with the highest livestock densities, which may also need supplementary feed in addition to grazing. These additional classes now avoid the need to artificially separate the grassland management classes into either grazing or mowing.

Table 4: New LUM Geodatabase grassland management class statistics (in ha and shares) after updating for the 2018 layer

TYPE	OLD CLASS	NEW SUB-CLASS WITHOUT MOWING (HA)	NEW SUB-CLASS WITH MOWING (HA)	NEW SUB-CLASS WITHOUT MOWING (%)	NEW SUB-CLASS WITH MOWING (%)
Managed pastures	1	252,787	1,732,186	12.7	87.3
	2	1,911,606	3,901,253	32.9	67.1
	3	2,556,578	3,887,482	39.7	60.3
	4	2,750,272	4,767,717	36.6	63.4

TYPE	OLD CLASS	NEW SUB-CLASS WITHOUT MOWING (HA)	NEW SUB-CLASS WITH MOWING (HA)	NEW SUB-CLASS WITHOUT MOWING (%)	NEW SUB-CLASS WITH MOWING (%)
Managed grasslands	5	89,066	1,035,814	7.9	92.1
	6	138,259	2,454,094	5.3	94.7
	7	446,554	3,496,150	11.3	88.7
	8	1,678,427	8,590,681	16.3	83.7

Source: LAMASUS WP 2

2.3. UPDATES TO WETLAND CLASSES

Using the new European Wetland Map, we have improved the characterization of wetlands in the LUM Geodatabase by taking information from this map and adding it, where possible, to the LUM layers. The European Wetland Map has ten classes, some of which map directly onto CLC classes, as shown in Table 5. The floodplains are not relevant, as these can be different types of CLC classes, where the majority overlap with arable cropland. The remaining classes have a 1-to-1 correspondence.

Table 5: Classes in the European Wetland Map and their mapping onto Corine Land Cover wetland classes

EWM CLASS #	EWM CLASS NAME	CORINE LAND COVER CLASS
1	Floodplain, maximum extent	Not relevant
2	Floodplain, potential floodplain extent	Not relevant
3	Floodplain, actual floodplain extent	Not relevant
4	Coastal wetland, (inter-) tidal flats	423 Intertidal flats
5	Coastal wetland, estuaries	522 Estuaries (rivers)
6	Coastal wetland, lagoon	521 Coastal lagoons
7	Coastal wetland, salt marsh	421 Salt marshes
8	Coastal wetland, saline	422 Salines
9	Other wetland, most likely mineral wetland	411 Inland marshes
10	Peatland	412 Peat bogs

Source: LAMASUS WP 2

The European Wetland Map was first overlaid onto the 2018 CLC accounting layer to assess: a) the level of discrepancy between existing wetland classes, and b) how much wetland is missing from the CLC. Missing wetlands are primarily due to small patches that fall below the CLC minimum mapping unit of 25 ha, as well as the more detailed information available in the European Wetland Map, which has been compiled from national datasets and mosaicked together.

Table 6 shows the match between the European Wetland Map classes and CLC wetland classes in areas where they overlap. According to Corine, the total wetland area is 4,417,160 ha. The diagonal values in Table 6 represent direct class matches, amounting to 3,530,103 ha (79.92%). The remaining area reflects mismatches between classes, with the greatest confusion occurring between '9 Other wetland/411 Inland marshes' and '10 Peatland/412 Peat bogs'. In the updated version of the LUM geodatabase, these mismatches were corrected using information from the European Wetland Map by simply replacing wetland classes from Corine with those from the European Wetland Map.

Table 6: Comparison of the European Wetland Map (EWM) with wetland classes in Corine Land Cover for the twenty-one countries covered by both the EWM and the LUM geodatabase (in ha)

EUROPEAN WETLAND MAP CLASS	CORINE LAND COVER CLASS						
	411 Inland marshes	423 Intertidal flats	522 Estuaries (rivers)	521 Coastal lagoons	421 Salt marshes	422 Salines	412 Peat bogs
9 Other wetland	**173,067**	709	1,379	3,334	52,672	1,580	417,929
4 Coastal wetland, (inter-) tidal flats	373	**38,166**	8,590	1,176	4,102	267	5
5 Coastal wetland, estuaries	29	2,499	**24,055**	1,043	109	228	0
6 Coastal wetland, lagoon	1,718	365	83	**105,475**	4,202	2,568	1
7 Coastal wetland, salt marsh	9,468	6,294	3,683	10,267	**176,287**	8,517	5
8 Coastal wetland, saline	1,399	61	78	985	1,113	**30,715**	0
10 Peatland	287,727	1,339	671	3,577	44,793	2,119	**2,982,338**

Source: LAMASUS WP 2

Across the subset of countries considered, the European Wetland Map identifies a total of 15,049,810 ha of wetlands. This indicates that CLC captures only 29.35% of wetland areas. Of the remaining 70.65% not represented in the CLC, 1.3% corresponds to coastal wetland classes, 29.13% to '9 Other wetland/411 Inland marshes' and the largest share (69.56% or approximately 10,469,386 ha) to peatland.

It is important to note that the CLC 'Peat bog' class represents only a subset of the European Wetland Map "Peatland" class. While peat bogs are defined as a land cover type, peatland refers to a soil ecosystem and can occur simultaneously in areas of forest, cropland, and grassland. Therefore, this large omission is expected and reflects the broader scope of the European Wetland Map, particularly its usefulness for identifying areas suitable for peatland restoration.

Figure 2 shows the percentage of missing peatland, inland wetland, and coastal wetland present in the European Wetland Map but absent from the CLC. In more than half of the countries shown, over 50% of the missing wetland area is classified as peatland, largely representing peat soils beneath other land cover classes like forest, cropland and grassland.

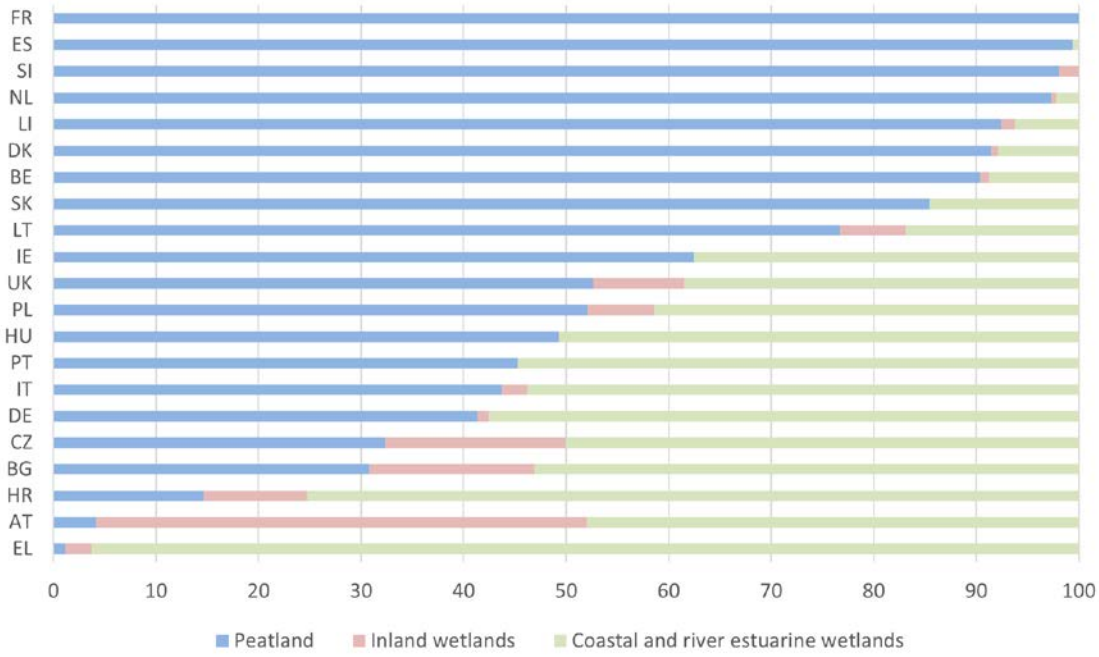

Figure 2: The percentage of missing peatland, inland wetlands and coastal/river estuarine wetlands in the Corine Land Cover compared to the European Wetland Map for the twenty-one countries covered by both the EWM and the LUM geodatabase.

By incorporating information from the European Wetland Map into the LUM geodatabase, we have attempted to improve the representation of wetlands where possible. However, we have not updated peatland areas that overlap with forest, cropland or grassland. There are two reasons for this:

- For the purpose of the LUM geodatabase, the importance is the management of forest, cropland and grassland, and the presence of peatland is secondary. The only way to include peatland would be to create sub-classes of management with the presence of peatland, but this would result in a doubling of the number of classes. Instead, for those interested in peatland restoration, we recommend combining the European Wetland Map with the LUM geodatabase as a separate exercise.
- Secondly, the LUM geodatabase is fit to official statistics, so the amount of forest, cropland and grassland cannot change, and hence we cannot overwrite these classes

with peatland. In addition, we would argue that peatland in this case is a soil system underneath these classes and not a land cover class like peat bogs.

Therefore, the main changes are the correction of wetland classes where the European Wetland Map overlaps with Corine wetland classes and the change of non-forest, cropland and grassland LUM classes to wetland classes from the European Wetland map to improve the representation of wetland more generally.

After applying these replacements for the years 2000, 2010, and 2018, Table 7 summarizes the changes in wetland extent (in hectares). Positive values indicate areas of wetland gain (i.e., newly captured wetlands), while negative values represent losses in the 2018 LUM layer. The updated total wetland area is 4,748,442 ha, corresponding to a net increase of 264,983 ha (5.66%). Note that the reason for wetland losses in some countries is a result of the procedure used to fit forest, cropland and grassland statistics to the LUM layers. There are situations where the forest, cropland and grassland probability layers place these land cover types in areas of Corine wetland because of Corine's 25 ha minimum mapping unit while the probability layers are at a much higher resolution (i.e., 1 ha). In these situations, the pixels are allocated to forest, cropland, and grassland instead, meaning that they would not be allocated to wetland during this updating process. We chose one country (Spain) with wetland losses and confirmed that this was the case.

Table 7: Country-level gain (positive) and loss (negative, bold) in wetland classes (in ha) after applying the European Wetland Map to the LUM Geodatabase 2018 layer for the twenty-one countries covered by both the EWM and the LUM geodatabase

COUNTRY	COASTAL AND RIVER ESTUARINE WETLANDS	INLAND WETLANDS	PEATLAND
AT	**-3**	23,749	30,015
BE	49	18,648	27,289
BG	1,149	**-866**	1,314
CZ	0	2,017	**-573**
DE	**-6,331**	13,357	259,307
DK	**-252**	9,557	45,690
EL	2,975	**-110**	142
ES	**-12,242**	1,599	**-22,406**
FR	**-17,746**	22,634	**-8,811**
HR	685	6,225	6,148
HU	0	10,398	140,463
IE	5,910	**-60,557**	**-159,898**
IT	2,395	153,964	665

COUNTRY	COASTAL AND RIVER ESTUARINE WETLANDS	INLAND WETLANDS	PEATLAND
LI	0	3	510
LT	137	11	133,902
NL	3,641	22	126,902
PL	33,022	1,050,514	252,486
PT	284	1,518	**-255**
SI	30	**-1,236**	993
SK	84	628	122
UK	8,513	**-207,601**	**-1,635,725**

Source: LAMASUS WP 2

2.4. AGGREGATION TO 1 KM AND NUTS2 SHARES

The updated 100 m LUM Geodatabase for 2000, 2010, and 2018 was aggregated to produce shares at 1 km and NUTS2 resolutions and uploaded to Zenodo as version 3 of the LUM geodatabase at: https://zenodo.org/uploads/19809788. The 100 m layers are available from the LAMASUS Data Explorer.

3. The Future of the LUM Geodatabase

When the 2024 version of CLC is released, the LUM geodatabase can be updated as outlined in D2.3 Protocol for Updating the Land Use Management (LUM) Geodatabase. At the same time, new datasets that have emerged (and continue to emerge) could be used to improve the specification of the land use management classes. Areas where improvements could be made, where we anticipate new data layers in the upcoming year, include:

- **Forest management:** New maps of high-resolution tree heights and species (produced by Meta and PlantNet) could be used to improve the rules for allocating forest management as well as other layers emerging from projects like Forest Navigator and Path Finder (e.g., new maps of forest management, products derived by combining National Forest Inventory data with remote sensing, etc.).
- **Cropland management:** New layers of cropland intensity based on crop rotations from the VLCC (being developed by the JRC) could be used as one additional input to determine intensity. Furthermore, new pesticide layers produced by the JRC could be incorporated, as well as gridded agricultural survey data on tillage (to be produced in the future by Eurostat in collaboration with the JRC). Disaggregated CAPRI data could also be integrated into rules for management intensity.

- **Grassland management:** Data from the LUCAS grassland module on intensive and extensive grassland could be used in the Bayesian modelling approach to produce more accurate maps of grazing probability. Gridded agricultural survey data on the number of months that livestock are grazed (still to be produced by Eurostat/JRC) could be another useful input to the modelling framework.
- **Urban intensity:** The latest high-resolution land cover maps (World Cover, Dynamic World, ESRI Land Cover) can be used to delineate urban areas more accurately.
- **Wetlands:** The European Wetland Map can be fully integrated with the CLC 2024 before translating the CLC classes into the LUM classes and fitting the map to the statistics. This will be more accurate than updating the LUM geodatabase that is already fitted with statistics.
- **Fitting to statistics:** The new high-resolution VLCC layers for forest, cropland and grassland and the latest high-resolution land cover maps (World Cover, Dynamic World, Esri Land Cover) could be used to update the probability maps for fitting the areas to statistics more accurately.

However, one of the key features that is missing and would allow for a model-based approach rather than a rule-based approach (as undertaken in LAMASUS) is field-based information on intensity. It would be possible to gather some of this information from very high resolution satellite imagery, looking for proxies that indicate levels of intensity (e.g., size of farm infrastructure, presence of hay bales, size of agricultural fields, etc.), which could then be combined with other layers to fit a predictive model of management intensity, or an independent field-based survey could be undertaken, funded through another European project or another source.

4. References

Wegscheider, S., Stumpf, A., Siegert, C., Acar, E., De Roo, B., Gasber, T., Faucqueur, L., 2024. Copernicus Land Monitoring Service – High Resolution Layer - Vegetated Land Cover Characteristics. D1.12 HRL VLCC Product User Manual. European Environment Agency, Denmark, Copenhagen.