European Commission

JRC TECHNICAL REPORT

Deliverable 1: Methodology for identification and mapping of candidate peatlands and wetlands areas for LULUCF

JRC Project "Satellite based mapping and monitoring of European peatland and wetland for LULUCF and agriculture"

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Abstract

SEPLA stands for "Satellite based mapping and monitoring of European peatland and wetland for Land use, Land Use Change and Forestry (LULUCF) and agriculture". The main objective of the project is to ensure comprehensive inventory of wetlands and peatlands and to address the monitoring of their preservation and restoration, by remote sensing and regularly updated geo-datasets. The rationale of the project stems from the specific problems (different legislation for agriculture and LULUCF with no integrated target; gaps in reporting systems), their drivers (decrease of carbon removals in the land sector; implementation challenges), and the corresponding objectives of contribution of the LULUCF sector to the EU climate ambitions (climate neutral land sector by 2035; integrated and simplified climate policy framework) as in the European Climate Law.

This report, considered as the first deliverable of the project, summarizes the methodology for identification and mapping of "candidate" peatland/wetland areas for LULUCF. The work builds upon the extensive collaboration with a number of EU Member State experts. It takes into account the existing datasets and technological tools for data integration and gap filling from Earth Observation (EO) and in-situ data. It proposes a methodological framework for the elaboration of geospatial datasets to derive candidates of peatland and wetland on representative pilot areas.

The report starts with a description of the challenges and commonalities of the definitions, classification and key elements characterizing peatlands and wetlands in the EU. It offers a method for semantic assessment and mapping of the peatland and wetland types present in the EU Member States. It then defines the workflow and tools for data integration and identification of candidate peatlands/wetlands, categorized according to the Intergovernmental Panel on Climate Change (IPCC) sub-categories for LULUCF reporting on GHG. Finally, the report briefly describes the status of the work, the engagement of the Member States involved in SEPLA, and the work to be completed in the second phase of the project related to peatland monitoring, peatland management and potential restoration.

Reducing losses or increasing the carbon sink of peatlands/wetlands would be one of the most beneficial action for climate and environment, either as implemented through the specific Common Agricultural Policy (CAP) measures (eco-schemes and conditionality inside Integrated Administration and Control System-IACS) or as complementary policy instrument. The spatial components of these measures make them ideal candidates for assessing their performance through the future Area Monitoring System (AMS), thereby ensuring methodological synergies and reporting results for use in Member State GHG inventories. Bridging needs between CAP and LULUCF would help enhance the modelling capacity on climate action, to inform policy choices and foster the provision of climate services, as the SEPLA project strongly tries to contribute.

Foreword

This report presents some mid-term results of the project SEPLA (Satellite based mapping and monitoring of European peatland and wetland for LULUCF and agriculture), designed to help Member States to ensure a comprehensive inventory of wetlands and peatlands and to address the monitoring of their preservation and restoration using remote sensing and regularly updated geographically explicit datasets. The project is defined under the work programme signed between DG JRC and DG CLIMA, and implemented by the GTCAP team of JRC D5 Unit (Food Security). This report relates to Deliverable 1 "Report on the inventory of peatland/wetland - Methodology for identification and mapping of "candidate" peatland/wetland areas".

Acknowledgements

The authors wish to thank: the technical experts from BG, DK, IE, and LV engaged in SEPLA, for sharing their data and methodological experience, and for their active contribution; the colleagues from DG CLIMA and DG AGRI involved in the project for their valuable assistance; experts from Greifswald Mire Centre for the exchanged knowledge; the staff of GTCAP not explicitly mentioned as Authors.

1. Introduction

Land Use, Land Use Change and Forestry (LULUCF) is a key factor in global GHG emissions, as it offers strong potential as pool for CO_2 removal. At present, reported LULUCF greenhouse gas (GHG) flux represents around 11% removal of the EU's GHG emissions. By 2050, the Commission has proposed ([1]) to place the EU on a "realistic, and prudent pathway to climate neutrality by 2050" that balances remaining emissions in the economy by that date with removals, largely driven by LULUCF.

The role of the land use and land use change in agricultural areas is therefore expected to become more prominent, with increased sink needed in order for the EU to achieve climate neutrality by 2050. However, reversing the current decreasing sink trend requires significant short-term action, due to long lead times. While the focus has up to now be largely on forestry and sustainable afforestation, the restoration of wetlands, peatlands and degraded land in line with the Biodiversity Strategy ([2]) are also key to achieving this climate goal. This is all the more important, since emissions from organic soils across the EU make up the most significant component of emissions within the LULUCF sector, estimated by researchers ([3]) to perhaps exceed 140 $MtCO_2$/yr.

Additional efforts are needed at the EU level, therefore, to reduce GHG emissions from agricultural land management, and to increase the CO_2 removal capacity of these areas. Sustainable agricultural management practices applied on cropland (reduced tillage, presence of fallow land, rotations including leguminous crops) and on grassland (ban on ploughing, soil water management) could help preserve carbon already in the soil and increase (in area terms) the potential for carbon sink, and so enhance the EU's net sink. The intention of the Commission to raise the EU's climate ambition by 2030, will require that the action on land is more effective ([4]). This in turn requires further investigation into the potential of agricultural land area to reduce emissions and act as carbon sinks.

In this context, preserving agricultural land that already holds a high level of stored carbon and restoring depleted peatlands/ wetlands would further limit GHG emissions from the management of agricultural land uses. The GHG reduction commitments made by Member States in their climate plans and Common Agricultural Policy (CAP) strategic plans would be facilitated by exploring the full the potential of the EU policy information management systems - national ones, such as Integrated Administration and Control system (IACS) under EU CAP, together with Pan-European, such as e.g., Copernicus for Natura 2000 (COP4N2K) or Copernicus Land Monitoring Service. These may help record and handle up-to-date and geographically explicit (e.g. at individual field level) data and information on high organic soil land use, as well as land cover and land use change.

The scope of Integrated Administration and Control System (IACS) and data managed by the Land Parcel Identification System (LPIS) and the Geospatial Aid Application (GSAA), in particular, is at minimum targeting areas subject to EU CAP payments. This are mostly areas covered by arable land, permanent grasslands and permanent crops. However, due to the broad definition of grassland, which includes virtually any area suitable for forage and grazing, certain forested areas and environmentally sensitive natural areas qualified as wetlands are already included in the LPIS. Furthermore, JRC's IACS data sharing project, conducted in 2019, shows that EU countries usually do not regard the IACS as an isolated system in the strict CAP direct payment use case. Most of them use the LPIS in a broader scope, as a system for land management and administration, including LULUCF reporting. As a consequence, information handled by in IACS/LPIS often extends towards non-agricultural areas outside the CAP (as forests, scrubland, water bodies, wetlands) and could moreover in these cases offer historically pertinent data.

In all cases, the technical framework of satellite-based remote sensing, and in situ data from IACS and LPIS (being inherently scalable) or other sources would allow for easy extension of the data scope to include and comprise all the relevant peatlands and wetlands in the LPIS data management cycle.

At a technical level, the preservation and restoration of agricultural land containing or having contained a high level of stored carbon, such as peatland and wetland can be administered in the LPIS of all EU Member States, by integrating the related information at the level of the reference parcel. This integration can be achieved through an intelligent interaction of the different IACS spatial datasets, with other thematic information or raw data residing outside the IACS and LPIS, while taking into account the specific local conditions. JRC has developed a dedicated methodology ([5]) applied already for third-party thematic data, such as NATURA 2000. The usefulness of this approach is not restricted to agricultural land under CAP only; the methodology may also help build systems for the remuneration of land managers based on emission reductions or sink enhancement, under carbon removal certification initiatives or 'carbon farming' ([6]). This geo-localized information, developed using a synergistic methodology as to be applied by the CAP, would support policy planning purposes (e.g. identifying high risk areas where action is urgently needed, establishing the baseline etc.). At the same time, it should help move towards adequate monitoring, verification and reporting for either GHG inventories needed for climate policy compliance, and of the future GAEC2 and/or interventions in the CAP post-2020 (e.g. eco-schemes or agri-environment

([1]) Stepping up Europe's 2030 climate ambition, Investing in a climate-neutral future for the benefit of our people, COM(2020) 562 final

([2]) COM(2020) 380 final

([3]) Peatlands in the EU - Common Agricultural Policy (CAP) after 2020, Greifswald Mire Centre

([4]) COM(2020) 562 final, ibid

([5]) Technical guidance on Management of different layers in LPIS DS-CDP-2015-10

([6]) A Farm to Fork Strategy for a fair, healthy and environmentally-friendly food system COM(2020) 381 final commitments under Pillar 2 for carbon farming). Ensuring a close synergy between these policies is a clear gain in terms of efficiency and reducing burden on Member States.

The requirement for geographically-explicit land use conversion data ([7]) and the encouragement to apply Tier 3 methodology ([8]), require an advancement of the technology uptake in monitoring of the net climate impacts of and on land use, forestry and agricultural sectors. This advancement aligns with that of Earth observation programs like GEOSS and Copernicus. The relevant methodologies and achieved results could be tested against the large dataset of surface observations available at JRC (e.g. LUCAS and IACS) in order to quantify uncertainties. The benefits of the IACS in context of LULUCF could be further capitalized when engaged as in-situ data in the development of specific products, as well as in their validation based on Earth observation (as well as GNSS) technology.

Improving the carbon sink of peatlands/wetlands would be one of the practices beneficial for climate and environment, either as implemented through the specific CAP measures (eco-schemes and conditionality inside IACS) or as complementary policy instrument. The spatial components of these measures make them ideal candidates for assessing their performance through the future Area Monitoring System (AMS), thereby ensuring methodological synergies and reporting results for use in Member State GHG inventories. Bridging GHG inventory data needs between CAP and LULUCF would help enhance the modelling capacity on climate action, to inform policy choices and foster the provision of climate services.

([7]) As required for LULUCF monitoring across all land in Member States, see Regulation (EU) 2018/1999

([8]) Higher-order methods including models and inventory measurement systems tailored to address national circumstances

2. Project rationale, objective and expected outcomes

2.1 Technical specifications of the project

SEPLA stands for "Satellite based mapping and monitoring of European peatland and wetland for LULUCF and agriculture". The main objective of the project is to ensure **comprehensive inventory** of wetlands and peatlands and to address the **monitoring** of their preservation and restoration, by remote sensing and regularly updated geo-datasets. The targeted geographic scope comprises the EU countries, including also Iceland and Norway at later stage. SEPLA is a JRC.D5.GTCAP project in collaboration with DG CLIMA (within the 2021 work programme signed between the DG JRC and DG CLIMA) and technical experts of 10 paying agencies. DG AGRI is involved as (GAEC2) observer.

The rationale of the project stems from the **specific problems** (different legislation for agriculture and LULUCF with no integrated target; gaps in reporting systems), **their drivers** (decrease of carbon removals in the land sector; implementation challenges), and the **corresponding objectives** of contribution of the LULUCF sector to the EU climate ambitions (climate neutral land sector by 2035; integrated and simplified climate policy framework) ([9]), as in the European Climate Law ([10]) .

The project should provide further insight on how already **existing CAP-related spatially-explicit datasets (IACS**) may be used in combination with CAP satellite-based remote sensing systems in place, and how (where and when deemed necessary) additional data within IACS should be cost-efficiently collected to serve both needs of LULUCF Regulation 2018/841 and related objectives/indicators defined in the CAP Strategic Plans. This would include the improvement of the quality of Member States' LULUCF GHG inventories, assuring synergies and consistency between climate-related CAP outputs and LULUCF GHG inventories, and maximizing effectiveness of both policies. The work requires communication and networking with Member States, as well as implies the need of strategic vision and capacity of coordination among various JRC Units and DGs.

Among other things, the project assesses the usability of the types and methods for information extractions developed in the frame of the CAP Checks by Monitoring to capture and monitor the status and evolution of the peatlands and wetlands, considering the regional specificities and established local agronomic practices. It should then look to extend this approach outside the geographical scope of the CAP datasets and help compile the full territory inventories at the EU level. Nevertheless, a possible production of any pan-European datasets on peatland or soil organic carbon is out of the project scope.

Finally, the project should also advance the integration of Earth observation data into the relevant modelling platforms available at JRC. This will help enhance the assessment of climate mitigation and adaptation options in the EU agricultural sector, with tailored solutions at farm level. This could include assessment of the different options for spatial representation and ingestions of the EU and in-situ data into the models. The current efforts of ISO TC211 (WG7 - Information communities) to standardize the land cover and land use information concepts and enable interoperable use of the relevant data and services in machine readable manner, are also considered.

The expected projects outcomes are:

- Deliverable 1: Methodology for identification and mapping of "candidate" peatland/wetland areas for LULUCF;
- Deliverable 2: Technical report on methods and tools in support to the creation of "IACS carbon theme";
- Deliverable 3: Prototype and technical guidance for EO-based monitoring of peatland/wetland.

The expected timeline for the first two deliverables is the summer-autumn of 2022, while the third one is foreseen for the spring of 2023.

2.2 Further considerations from the project KO meeting

From CLIMA's perspective, the LULUCF accounting (i.e. towards a target) on wetlands should begin from 2026 onwards (Article 2 of Reg. 2018/841). In this respect, EU Member States should be able to collect and compile the relevant geographically-explicit data, required under the Governance Regulation Reg. 2018/1999 Annex V Part 3, well in advance. Since the focus falls on peatland and wetlands under agricultural management, the data inventory would naturally start with the geospatial information residing in IACS and LPIS, which covers the active agricultural land, subject to CAP-payments. However, the extension of the inventory towards the non-CAP and non-agricultural land should not be delayed, considering the possible data limitation in terms of coverage, thematic details and cartographic scale, outside the agricultural areas managed by EU CAP. Any relevant input from Greifswald Mire Centre & networks should be taken into account, as being one of the few sources of comprehensive analyses on peatlands at the EU level.

([9]) https://ec.europa.eu/clima/eu-action/forests-and-agriculture/land-use-and-forestry-regulation-2021-2030_en
([10]) https://eur-lex.europa.eu/eli/reg/2021/1119

From AGRI's perspective, the protection of carbon-rich soil as agricultural peatland and wetland within the scope of EU CAP, is an important GAEC standard that will enter into force a few years earlier than CLIMA's timeline. Some delay could be allowed based on MS justification but no longer than two claim years (at the latest January 2025). The objective of this GAEC is to stop further soil degradation through specific measures defined by the EU MSs themselves, such as ban of drainage, ban of ploughing-up, or extensive management of permanent grassland. For that reason, EU Member States should have by that time the carbon-related information, at reference parcel level, in the LPIS. This would ensure sufficiently precise identification of these areas, assist the farmer declarations and facilitate necessary cross-checks.

In order to frame the scope of the data inventory correctly, SEPLA should review the current peatland and wetland definitions applied, starting certainly with the IPCC approach used for the Greenhouse Gas reporting and inventories. Wetlands are complex phenomenon and ecosystems from bio-physical perspective and provide multiple functions in ecosystem service context. The initial review showed that most of the wetland mapping so far has been done by user communities other than the ones related to climate (as for example, the environmental community dealing with bio-diversity). The relevance of these datasets in the LULUCF context should be assessed. Plant populations/communities and the associated microorganisms (bacteria, fungi, algae), as well as their functions (such as carbon or methane storage/release; water quality regulations) are highly dependent on pH and temperature, thus relevant with respect to the restoration of the wetlands. In this respect, the project should consider the work done under MAES and keep contact with relevant projects and activities of DG ENV.

Despite the possible semantic ambiguities, IPCC provides a tangible starting point and offers the required flexibility. Due to the diversity of the national and local wetland definition, the aim of SEPLA is not to provide new definitions, but to identify the minimum set of characteristics (classifiers) that would qualify a given wetland for being in the scope of SEPLA, while accounting for the key characteristics required to report the presence of organic soils. It should account also for relations between the different wetland perceptions in the Climate Law and the GAEC 2 of the new CAP. The project should adopt the structured vocabulary of the Land Cover Meta Language (ISO 19144-2) to perform the semantic analysis, relying on the availability of ample and complete metadata of the peat/wetland datasets, subject to the inventory.

To further narrow down the initial work and advance faster, the project should focus on those wetlands/peatlands that are of critical concern. These are the areas where organic soils are drained and suffer a notable level of degradation, where prompt restoration (by rewetting) and protection (keeping C-rich soils wet) measures are needed.

3. Methodological steps

The project's sectoral scope spans over several application areas. It first deals with the climate and the related GHG emission accounting, where it explores the nature and availability of geographic-explicit data for more accurate and precise LULUCF reporting. It further incorporates the domain of new CAP, by trying to integrate this data into IACS to support the implementation of the GAECs in the adopted CAP conditionality. It does all this by using new technologies for capturing and monitoring the status of the observed land for climate and agriculture. This multi-sectoral aspect of SEPLA defines the key elements of the interactive cycle of the methodological framework: land definition -> data integration –> systematic observation.

In this respect, the methodology is organized around the following "work packages":

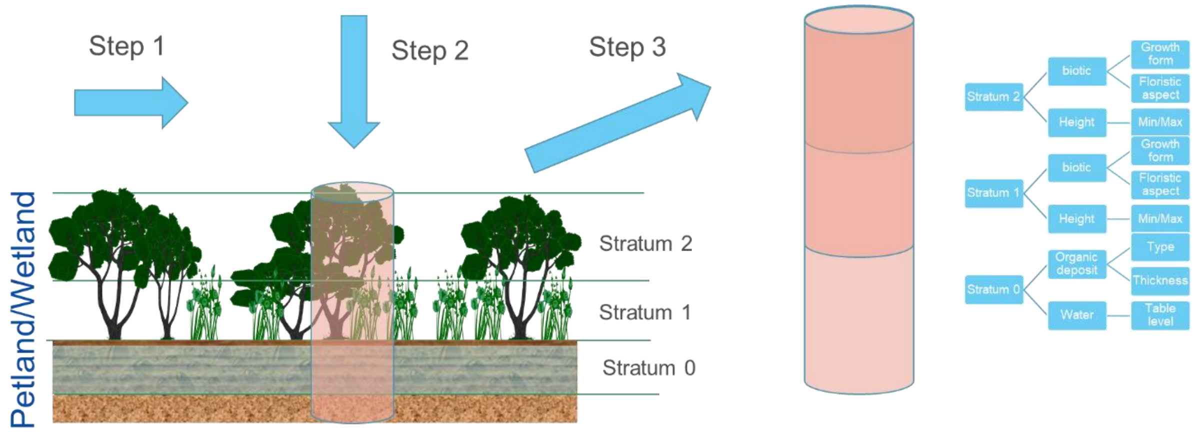
3.1 Definitions and classification

Scope: It deals with the perception and understanding of what peatlands and wetlands are, in the local (country/region) context, and studies their different typologies. It aims to identify the common bio-physical characteristics in the EU countries that define a land cover feature as peatland or wetland and to explore their "conceptualizations" in the available local geospatial products. It further investigates the applicable typologies reflecting the peatland/wetland management (for agriculture; for energy).

Method: The work package performs semantic assessment of the national/regional land-related classifications and associated nomenclatures, identified as holding data and information relevant to peatland and wetland. It also tackles the class instantiations in the given map products, by assessing the correspondent feature model. The semantic analysis uses a dedicated semantic meta-model, specifically designed for the purpose and based on common vocabulary of broadly accepted bio-physical characteristics, structured by semantic logic, The concept is shown in Figure 1.

Expected output: The results of this work will help EU Member States to assess whether the information content conveyed by their class definitions/feature catalogues is sufficient to implement the Wetland supplement definition of IPCC. Results could also tell whether the qualitative/quantitative information provided by the feature catalogues of the relevant datasets is sufficiently adequate and complete for the geographic-explicit LULUCF reporting and estimation of GHG emissions (tier-2).

Figure 1. Generic concept for semantic assessment of the local peatland/wetland class definitions: (Step 1) The assessor imagine him/herself being on the field to visit a wetland of a given class and locates the place with the most representative set of bio-physical components; (Step 2) He/she takes a virtual sample of both the land cover with all vegetation strata and the soil beneath; (Step 3) He/she describes what is in the sample (elements, characteristics) using structured semantic model (template).



The semantic "meta-model", designed in SEPLA, contains, in a hierarchical manner, the essential and commonly accepted bio-physical characteristics of the cropland, grassland and wetland, specifically located on organic soil (either wet or drained), using the Land Cover Meta Language (ISO 19144-2) as core standardized ontology, complemented with certain components of the EAGLE model (EIONET Action Group on Land monitoring in Europe). The design is further based on the 3-dimensional concept of tegon (Devos, 2015) and pedon (Milenov,2022) as elementary bodies of land cover and soil respectively, acting as a structural pair in the system "soil-plant-atmosphere".

It allows for documenting, in a standardized manner, the link between land cover and soil substrates. It also keeps the land cover and land use concepts separate, while retaining the semantic relation between them. The full semantic model and the instruction for its application are provided in a separate document (Milenov et al., 2022).

The purpose of this "meta-model" is to help EU Member States to document, in standardized manner, their local definitions applied for peatland and wetland, in order to:

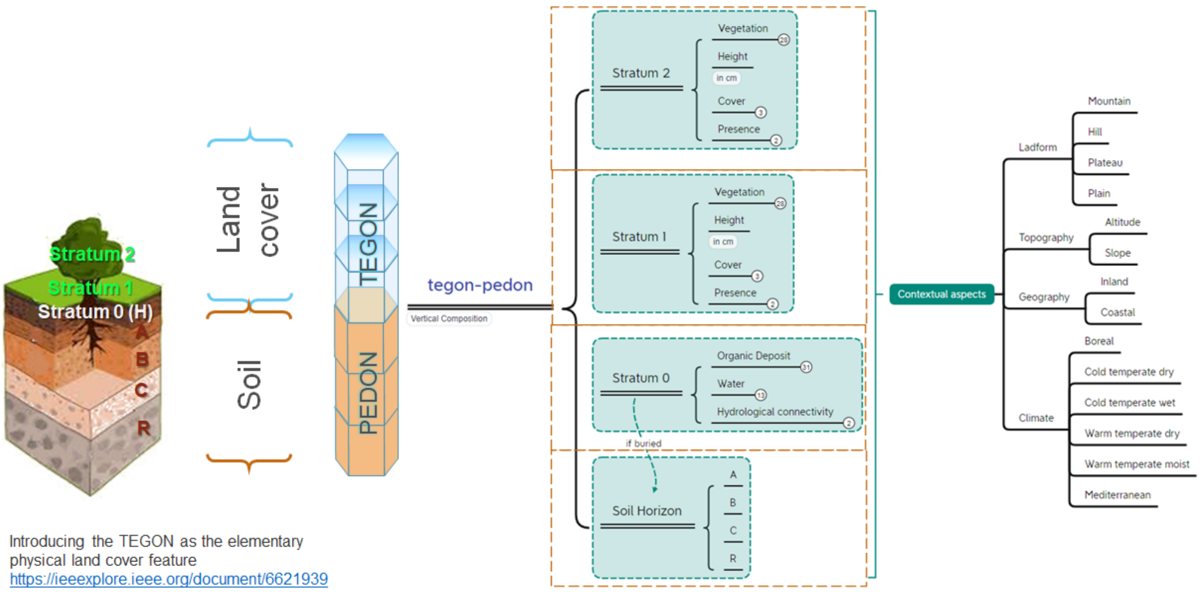
- identify similarities and differences between the national geographically explicit datasets based on these definitions;
- qualify the thematic data (classes and their mapped instances) that falls into the scope of SEPLA (according to IPCC definitions);
- compare it with international datasets, to be used when gaps in the national data are observed;
- help the setting up of the change detection approach (historic vs. recent data);
- select candidate bio-physical characteristics that can be monitored with Earth Observation (EO).

The SEPLA meta-model reflects only the bio-physical aspect of the IPCC sub-categories; land use (management) aspects are intentionally not included. However, the current set of characteristics should allow the description of land cover classes that reflect a transition or conversion between IPCC sub-categories, triggered by the type of management.

The semantic model comprises the (tentative) exhaustive set of terms, elements, and properties in a hierarchical structure. It characterizes the land cover and soil–related aspects of a wetland (Figure 2). In a typical case, a wetland is considered to have three vertical layers (strata). The topsoil stratum (numbered 0) corresponds to the uppermost (water saturated) soil horizon formed by organic deposits, in contact with vegetation and atmosphere. The strata 1 and 2 correspond to the layers of living vegetation above the soil (Stratum 0). Each of the strata represents the archetypical bio-physical elements and properties. Stratum 0 reflects the soil related characteristics; while Stratum 1 and 2 – the vegetation related at the intermediate and higher levels (typically covered by shrubs and trees respectively). The semantic meta-model has an additional set of characteristics, related to the local (ecotope) context (landform, topography, climate, etc.).

The model has been tested and adapted for land cover types associated with wetlands, which are examples of complex biophysical systems with high ecological value. Each of the elements present in the different strata of the "tegon-pedon" pair refers to a specific material that has a different behaviour and life cycle. The main assumption is that a sufficiently dense and uniformly spread set of observations will allow for comprehensive assessment of the relationship between soil characteristics and the behaviour of land cover feature above. The semantic model also accounts for the different meaning of the term "substrate" in the domains of tegon and of pedon.

Figure 2. The semantic meta-model and its link to the tegon/pedon.



The "**tegon**" is a three-dimensional elementary biophysical feature, acting as a building block of any material substrate on the Earth's surface. Tegon is the smallest measurable body that provides information about the nature and genesis of the land cover.
The "**pedon**" is a three-dimensional body of soil with lateral dimensions large enough to permit the study of horizon shapes and relations.

The semantic assessment, jointly performed by the SEPLA team and the EU MS experts, checks each of the relevant classes for presence of the following characteristics/classifiers:

- organic matter/soil organic carbon
- persistent water
- vegetation strata
- any contextual and land use-related aspects (e.g. hydrological connectivity)

It further assesses the semantic consistency of the classes and potential overlaps. It also conducts a visual verification of a sample of class instances, using up-to-date Sentinel 1 and 2 data, historic Landsat TM imagery, as well as information derived from the satellite signal (for example to assess the dynamics in the wetness of vegetation).

For each class, the assessment evaluates its potential role in the data integration process to derive the candidates for wetland and peatland under IPCC categories related to the land use (grassland, cropland, wetland), soil type (organic or mineral) and presence or absence of the water table (wet or drained).

3.1.1 Key characteristics of the peatland

In the semantic assessment, SEPLA deals with two aspects of wetland and peatland:

- what they represent in reality
- how they are mapped by the EU Member States

Regarding the first aspect, there is an agreement that wetland refers to ecosystems that are water saturated either permanently (for years or decades) or seasonally (for weeks or months) (Keddy, 2010). They encompass both mineral and organic soils. On the other hand, peatland refers to ecosystems where accumulation of organic deposit occurred in water saturated conditions. Thus, they could be considered as sub-types of wetlands. However, they can be in their natural status (wet) or drained as the case of agricultural utilisation.

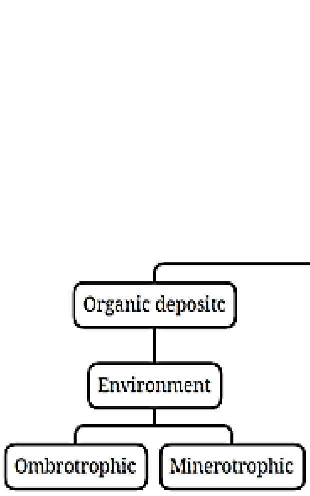
The assessment conducted on the national nomenclatures and datasets, and the knowledge exchange with "science-policy-practice" interface organizations, such has the Greifswald Mire Centre, **concluded that peatlands are complex systems consisting of both biotic and abiotic components, which are very regional/national specific. Although being quite distinct from wetlands, peatlands are considered part of the wetland category, due to origin and formation, which implies the persistent presence of water in the past. However, at present peatlands can be either still saturated by water or drained. In any case, they must have naturally accumulated layer of peat at the surface.**

Regarding the second aspect, SEPLA's guiding framework is IPCC, which divides wetlands according to specific criteria: presence of organic/mineral soil; wet/drain; and managed/unmanaged. Given that, the separation in subcategories like IPCC ones helps in understanding their status, and the best conservation actions.

From a morphological point of view, peatlands represent an intrinsic mix of vegetation and soil elements, involved in a process of material and energy exchange, each with its specific characteristics and properties, that could change in time. This change could be part of the natural cycle of the given set of elements or could be due to a long-term transitional process they are involved in. Certain characteristics and properties "manifest" on the surface, thus they are potentially observable.

Among the bio-physical elements/characteristics that define and describe a peatland, the ones considered fundamental are related to the: (1) type of organic deposit, (2) level of water table, (3) type of vegetation cover and (4) hydrological connectivity. They can be considered as the key components for each of the IPCC sub-categories in SEPLA scope (Figure 3).

Figure 3. Proposed key characteristics that unambiguously define/describe a peatland.



Source: IPCC, semantic meta-model, and associated guidance, as well as from the outcomes of semantic assessment; Greifswald reports and publications, IACS data interoperability pilot (IASC65); ISO TC211 group of LC and LU; EAGLE project

Due to the importance of hydrological connectivity in these systems, the local context of the eco-hydrological buffer zone should also be defined and monitored as a key element of the definition of each peatland (see Figure 3, bottom right).

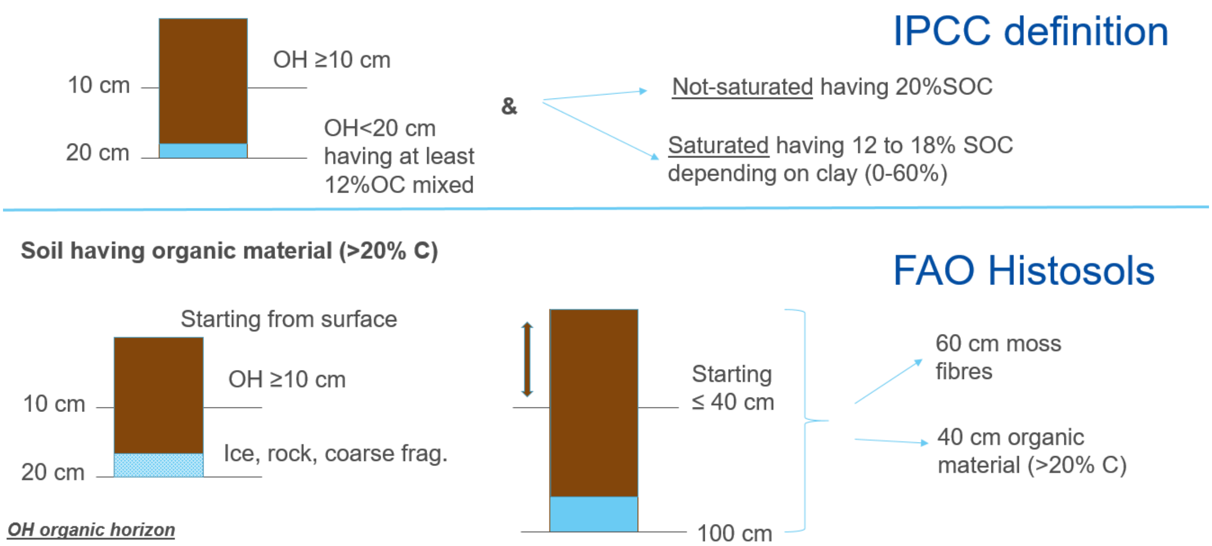
In this respect, the supply of water shapes the structure and evolution of peatland, which can be broadly classified in:

- Fens, primarily fed by groundwater that flows through mineral-rich soils or rock, or surface water flowing over land, resulting in a *minerotrophic* environment dominated by sedges and mosses;
- Bogs, which receive water from precipitation (*ombrotrophic*), leading to an acidic environment, low in nutrients and dominated by mosses (sphagnum).

3.1.2 Peatland definition under the IPCC 2013 Wetland supplement

Despite that Wetlands Supplement provides an extended guidance to identify and map "peatlands", it considers the **concept of peatland to be included in '(land with) organic soil'**. SEPLA reports here a graphical representation of the organic soil definition, according to the 2013 Wetland Supplement ([11]) and the updated FAO definition of Histosols ([12]) to facilitate the assimilation of different national sources and definition (Figure 4).

Figure 4. Graphical representation of a peat layer vertical distribution (in brown) within a soil profile according to IPCC (Wetland Supplement) and revised WRB definition of FAO Histosols. The blue horizon represents the mineral component, parent material or bed rock.



IPCC Wetland Supplement definition

Organic soils are identified on the basis of criteria 1 and 2, or 1 and 3 listed below:

1. Thickness of organic horizon greater than or equal to 10 cm. A horizon of less than 20 cm must have 12 percent or more organic carbon when mixed to a depth of 20 cm.

2. Soils that are never saturated with water for more than a few days must contain more than 20 percent organic carbon by weight (i.e., about 35 percent organic matter).

3. Soils are subject to water saturation episodes and has either:

a) at least 12 percent organic carbon by weight (i.e., about 20 percent organic matter) if the soil has no clay or;

b) at least 18 percent organic carbon by weight (i.e., about 30 percent organic matter) if the soil has 60% or more clay or;

c.) an intermediate proportional amount of organic carbon for intermediate amounts of clay.

Those criteria used by IPCC definition follow the WRB-FAO (2006) definition. However, **IPCC does not indicate a strict thickness criterion**, thus allowing often historically determined, country-specific definition of organic soils.

The World Reference Base (WRB) definition

The World Reference Base for soil resources 2014 (update 2015) revised and somewhat simplified the Histosols definition as soils **having organic material (i.e. at least having 20% of organic carbon):**

1. starting at the soil surface and having a thickness of ≥ 10 cm and directly overlying:

([11]) IPCC 2014, 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands, Hiraishi, T., Krug, T., Tanabe, K., Srivastava, N., Baasansuren, J., Fukuda, M. and Troxler, T.G. (eds). Published: IPCC, Switzerland.

([12]) IUSS Working Group WRB. 2015. World Reference Base for Soil Resources 2014, update 2015 International soil classification system for naming soils and creating legends for soil maps. World Soil Resources Reports No. 106. FAO, Rome.

a) ice, or b) continuous rock or technic hard material, or c) coarse fragments, the interstices of which are filled with organic material;

2. starting ≤ 40 cm from the soil surface and having within ≤ 100 cm of the soil surface a combined thickness of either: a) ≥ 60 cm, if ≥ 75% (by volume) of the material consists of moss fibres; or b) ≥ 40 cm in other materials.

In chapter 3 of "Mires and Peatlands in Europe" ([13]), peat is defined as sedentarily accumulated material consisting of at least 30% (dry mass) of dead organic material (corresponding rather to 20% of organic carbon).

In conclusion, while "peatland" does not have a universal definition (Lourenco et al., 2022) some prevailing criteria may be used to converge toward a common definition. An **accumulated material of at least 20% of organic carbon and a minimum depth of 20-30 cm** seem two criteria widely accepted at European level for mapping exercise (Tanneberger et al., 2017).

However, due to the ambitions of different EU policies to reduce emissions and protect peatlands, a minimum thickness lower than 20 cm should be encouraged as conservative criteria.

Since IPCC definition refers to **water saturation**, it further specifies that: "a **wet soil** is a soil that is inundated or saturated by water for all or part of the year to the extent that biota, adapted to anaerobic conditions, particularly soil microbes and rooted plants, control the quality and quantity of the net annual greenhouse gas emissions and removals. Every soil that is not a wet soil is in this supplement classified as a dry soil."

Since all organic soils are assumed to have originally formed in wet condition, a **dry organic** soil **is always** also a **drained organic** soil for the classification purpose.

3.2 Data Inventory

Scope: It deals with the inventory of the local datasets considered relevant in the context of the project. The work package assesses their territorial coverage and thematic scope, the lineage and product specifications (thematic concept, applications area, capturing method, temporal resolution, update cycle mapping scale, accuracy, etc.).

Method: The work package conducts a thorough review of the metadata and the feature catalogues, if made available, and compares the dataset specifications to the target expectations of IPCC and IACS. Together with the first work package, it identifies overlaps and gaps in the information provided by the local datasets and their class definitions. It also separates the datasets in two groups –thematic datasets with interpreted information, according to prior conceptualization (wetland types, land cover, soil types) and continuous coverages of a given measured or modelled physical characteristic (soil organic content, wetness, elevation). In such a way, it also selects the candidate bio-physical characteristics for EO monitoring.

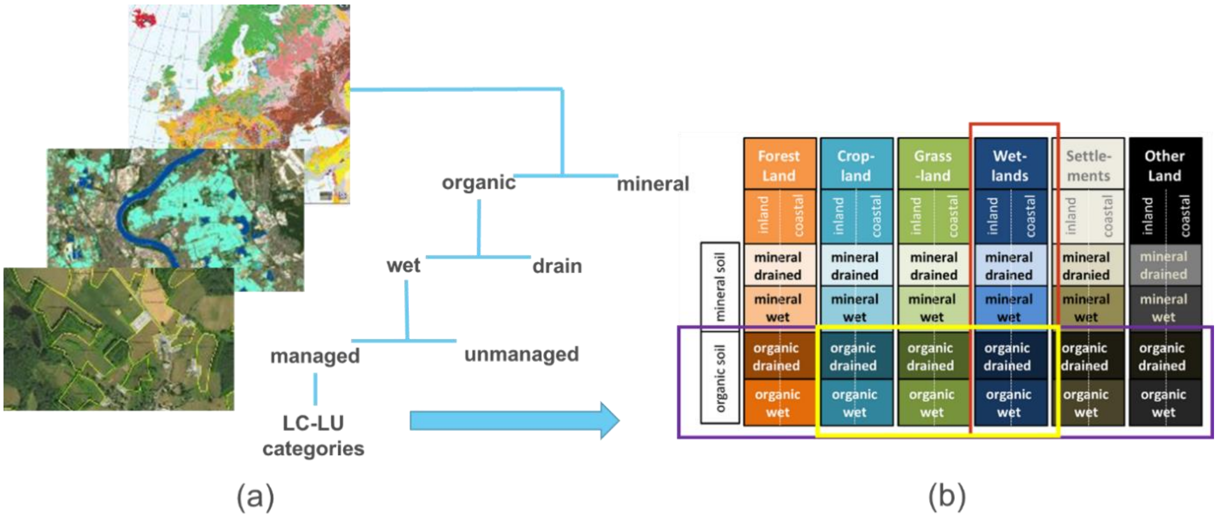
Expected output: The results of this work will help EU Member States to identify the critical datasets required for a meaningful wetland/peatland inventory in the context of LULUCF and IACS. It will provide information on data completeness and presence of possible gaps that should be filled in (through external datasets or EO data capturing). The results should be able to tell EU Member States how complete their datasets are in order to report in geographic explicit manner the areas of present peatland under agricultural and other management, and the areas of former peatlands converted to cropland and grassland ([14]). This comprises the following IPCC sub-categories (see Figure 5 below):

- On wetland: organic wet; organic drained
- On cropland: organic wet; organic drained
- On grassland: organic wet; organic drained

Furthermore, the outcomes of the inventory should inform whether the available data will allow the EU Members States to conduct the required historic analysis to come up with the four main groups of peatland/wetland of interest to the project from management and restoration perspective: (1) wet peatlands in natural state; (2) wet peatland at risk; (3) drained peatland for recovery; (3) drained peatland beyond recovery.

([13]) https://www.nhbs.com/mires-and-peatlands-in-europe-book
([14]) currently, areas covered with trees that qualify as Forest Land, according to the national definitions, are not in the scope of SEPLA.

Figure 5. (a) generic dichotomous approach for categorization of the available local data (soil, wetland, land cover, LPIS) and pan-European data (LUCAS soil, CLC, Copernicus HRLs) into the peatland/wetland categories; (b) the main IPCC reporting land (sub) categories in the scope of SEPLA (yellow box).



The inventory process requires the development of a methodology for **pre-identifying candidate areas which,** in addition to the above-mentioned aspects, should also account for:

- Proximity/access to rewetting, based on the available hydrological network
- “Socio-economic” factors: farm/land manager structure, land use zoning (flood risk to built-up areas)
- Restoration potential: reduction of GHG emissions, biodiversity, modified agricultural practice (e.g. paludiculture)
- Categorisation in terms of “protected zone” target potential

This would require an accounting in the characteristics regulating the processes in wetland/peatland, for the **spatial context and hydrogeology**. This is particularly relevant for those wetlands suffering loss of water and degradation of water quality, due to intensive agriculture near them (irrigation/ fertilizers (P/N mostly)/ and pesticides).

The process of defining peatland and wetland will be coherent and linked to the one that shall be carried out by the Member States to establish the areas for the implementation of the new **GAEC 2 “Appropriate protection of wetland and peatland”.**

In fact, in the new CAP, with the extension of the scope of the conditionality, a new GAEC standard on “Appropriate protection of wetland and peatland” (GAEC 2) has been introduced with the scope of protecting ”carbon-rich soils". The objective of this GAEC is to avoid degradation of areas considered as sensitive to further carbon depletion. The protection of these areas is very relevant not only in the context of climate mitigation and adaptation, but also because they represent very valuable ecosystems for biodiversity and contribute to habitat protection as well as to water and soil quality.

This GAEC 2 applies to all eligible agricultural land whatever the agricultural land use, whether arable land, permanent grassland, or permanent crops. In case the land is no longer used for production, the farmer has to keep a minimum activity to maintain land as eligible agricultural land.

To implement this GAEC 2, Member States authorities have to define wetlands and peatlands on which the GAEC 2 applies and map them on a specific cartographic layer or “IACS carbon theme”. Cooperation with DG AGRI has been initiated for the setting up of the criteria (definitions) to establish the areas to be classified as peatland/ wetland for the purpose of GAEC 2. According to Commission guidelines Member States are not obliged to differentiate between peatland and wetlands when defining these areas.

In their CAP Strategic Plans Member States may decide that the GAEC 2 will only be applicable as from claim year 2024 or 2025 and should provide justifications for this delay and a detailed planning of implementation. The decision of postponing the implementation of GAEC 2 was taken by most Member States in their CAP strategic plan.

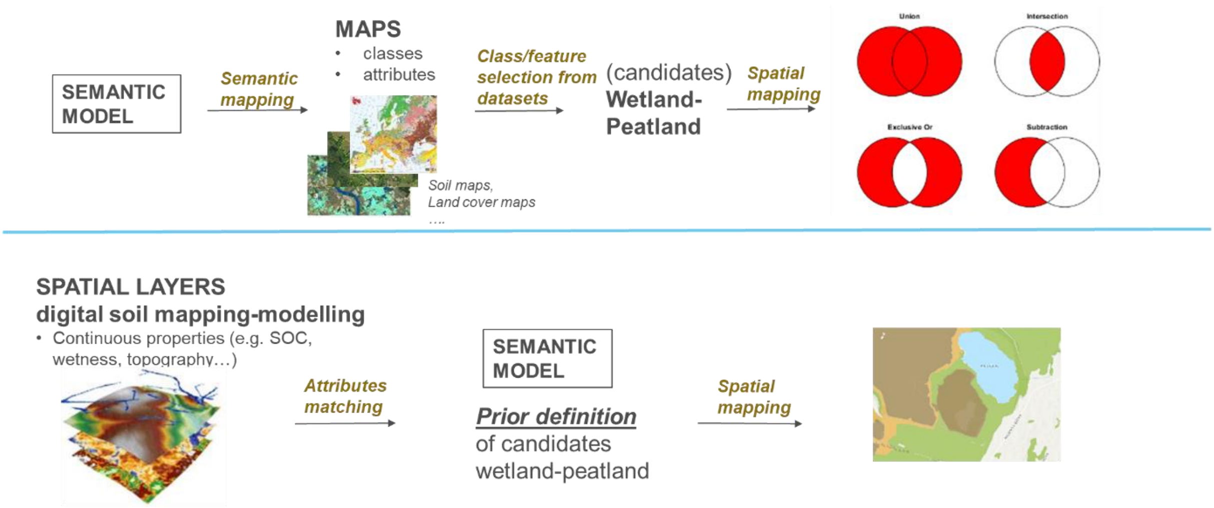
3.3 Data integration

Scope: This work package largely depends on the outcomes of the previous two. It deals with the approach and workflow for the integration and spatial processing of the input local datasets to produce the geospatial data for the reporting of the IPCC sub-categories given above. At a later stage, it should allow the reclassification of the allocated wetlands and peatlands into those at risk, recoverable and not recoverable, using the available historical data and contextual information. It also addresses the manner the resulted peatland/wetland data is brought in IACS and reflected at the level of the LPIS and GSAA parcels; more specifically, the business rules that apply to the spatial operations (intersections, topology) of peatland/wetland and IACS datasets, while maintaining the highest possible spatial resolution and positional accuracy of the outcome.

Method: The work package designs a dichotomous processing flow, following the logic of the Wetland Supplement of IPCC (IPCC, 2014) and the principles laid down in the Technical Guidance for Management of Layers in LPIS (Luketic et al., 2015). It tests the developed workflow with real data over pre-selected case-study areas, provided by the EU Member States, and adjusts interactively the flow of events and related parameters, depending on the results obtained. It also sets the ingestion sequence of the datasets in the workflow. The work package should foresee at least two application options for the "construction" of the peatland/wetland data, according to the types of local data available and the adopted national approaches (see Figure 6). The first option is based on thematic (interpreted) data, while the second one is based on continuous (measurement) data.

Expected output: The results of this work will help EU Member States to choose the implementation options to produce the geographic explicit data of peatland/wetland for IPCC and to integrate it into IACS. It should also tell whether the level of spatial disaggregation of the initial spatial data is sufficient. This is especially relevant for continuous (grid-based) dataset derived through modelling and spatial interpolation of discrete sample points, where the resulting grid cells indicate only the probability of a characteristic or value of being present. The work package should provide answers on the most viable option for the ingestion of the peatland/soil carbon information at the level of the LPIS/GSAA parcel, considering the diffuse character of the peatland and soil type boundaries and the way the spatial data is represented (point, polygon, or grid). Depending on the input conditions this can be done through either spatial overlay of the different "layers" or by recording the information as an attribute (or set of attributes) to the IACS spatial feature.

Figure 6 Application options for deriving candidates for peatland data. Option 1 (upper), when input datasets are predominantly thematic datasets with interpreted information – processing flow starts with semantic mapping of the class definitions against the pre-defined semantic meta-model. Option 2 (lower), when input datasets are predominantly continuous coverages of a given physical characteristic - processing flow starts with the mapping of these physical characteristics to the pre-defined set of characteristics reflecting peatland and wetland types, according to the semantic meta-model.



3.3.1 Workflow for identification of candidate peatlands/wetlands for IPCC based on thematic data and interpreted information

Figure 7 presents a data integration workflow that the project team elaborated based on all information, datasets and bilateral exchanges on specific case-study areas identified in collaboration with some MS under the SEPLA project.

This workflow uses a decision tree approach starting from three main entry-point datasets: **Wetland** (land cover), **Soil** and **LPIS/GSAA**. It should be stressed that, while the scheme is flexible enough to be applicable in different environmental contexts, some adaptations may be necessary according to the datasets available, expert knowledge and local conditions. Therefore, the aim of this exercise is to provide a generic methodology to facilitate wetlands inventory rather than a strict "universal" guideline.

The following points provide a brief explanation on how the decision tree may work to identify the main wetland subcategories (Figure 5 taken from Fig. 1.2 of 2013 IPCC Wetland Supplement), starting from the first entry point datasets:

Wetland (step1)
The areas recently mapped as wetland are considered, by definition, saturated by water (wet). Using the semantic meta-model applied to the thematic layers of the Wetland datasets, one could separate mineral wetlands from those having a peat layer (**organic-wet**).

Soil (step2)

From the soil map "Histosols" are considered, by definition, having a peat layer (organic). Other criteria may be used depending on definition (see section 3.1.1 and 3.1.2) and MS ambition to be more, or less conservative. Once the classes corresponding to organic soils categories are identified, one can further assess the water saturation condition by the semantic mapping previously done on soil classes. For instance, in a specific case-study, soils with a "gley" horizon are semantically mapped as being wet. Following the workflow, then, one can identify **organic wet** and **drained** areas based on soil information.

Depending on MS exigence, some non-Histosols may be further grouped in an organic-rich subcategory. While the upper threshold of 20% organic carbon can be accepted, the lower is less definable and related to MS ambition. As a first approximation organic-rich soils (i.e. having less than 20% organic carbon) can be considered as drained, since they were likely being peatland in their original wet status and then degraded and depleted in organic carbon.

Decision on layer intersection (step 3)

Since the entry datasets come from different scientific disciplines, are often made in different years, reflect different periods and have different spatial resolution and product specifications, the wetland-subcategories identified at this step of the decision tree may (or not) overlay with the soil data extracts. Therefore, one can define some rules based on the following conditions:

i) when the organic-wet areas identified from both the Wetland and Soil branch do not overlay, one can make their **UNION,** as considered having the minimum set of common criteria to be classified as **organic-wet;** when those areas overlay, one can dissolve them in a unique feature.

ii) when organic-wet areas from Wetland branch overlay with organic-drained ones from the Soil branch, one can take a decision how to reclassify one or another. This is done by accounting for the lineage, quality and up-to-datedness of data and by using expert knowledge or consulting remote sensing data (see Chapter 4). In the example depicted, the priority is given to the Wetland branch and a **SUBTRACTION** is performed of organic-drained areas by the overlaying organic-wet (in other words, organic-drained overlaying organic-wet areas are reclassified to the latter category). It should be pointed out that the subtraction may be done in the way around if the priority is given to the Soil dataset, especially if it is more recent and of adequate quality. This may happen, for instance, with old historical wetland maps, which identify wet areas that have been drained and cultivated.

LPIS/GSAA (step 4)

Following the steps 1 to 3, one can classify the areas as **organic-wet** and **organic-drained** (with a latter optional category representing **organic-rich-drained**). The following step requires an intersection with those categories and the LPIS and GSAA datasets, to delineate managed areas under **cropland** and **grassland**. The LPIS and GSAA has a priority over other land cover/land use datasets in defining the managed areas, since being with very high cartographic detail and up-to-date. The intersection could be done first with the LPIS, which reflects the stable agricultural land cover at cartographic scale of at least 1:5000 and allows the categorisation of the agricultural land into: arable land, permanent crop, permanent grassland and former agricultural areas converted to forests or wetlands. It could be fine-tuned with information from the GSAA, which reflect the annual farmer activities over the agricultural areas recorded in the LPIS.

All the remaining area not covered by the agricultural areas reflected in the LPIS-GSAA, can be classified in other IPCC categories (forestland, wetland, settlement and other land) either by:

i) the availability of stratum 1 and 2 in the wetland classes if evidenced by the semantic mapping (Par. 3.1), which will provide indications to the land cover class attribution;

ii) the use of other national or European dataset (i.e. Natura 2000, Ramsar sites, CLC+);

iii) remote sensing data and derived biophysical parameters (for example, from high-resolution sensors, such as Sentinel 1 or Sentinel 2).

Figure 8 reports an example of wetland sub-categories identified by the data workflow, based on the datasets provided by a MS on wetland (land cover), soil and LPIS-GSAA. This mapping exercise is solely based on the local data provided, however further refinements and identification of potentially candidates missing areas could be made by applying EO-based data capturing methods or third-party thematic datasets (see chapter 4).

Figure 7. Datasets integration workflow for mapping the different wetland-subcategories according to the IPCC guidelines from interpreted/thematic datasets.

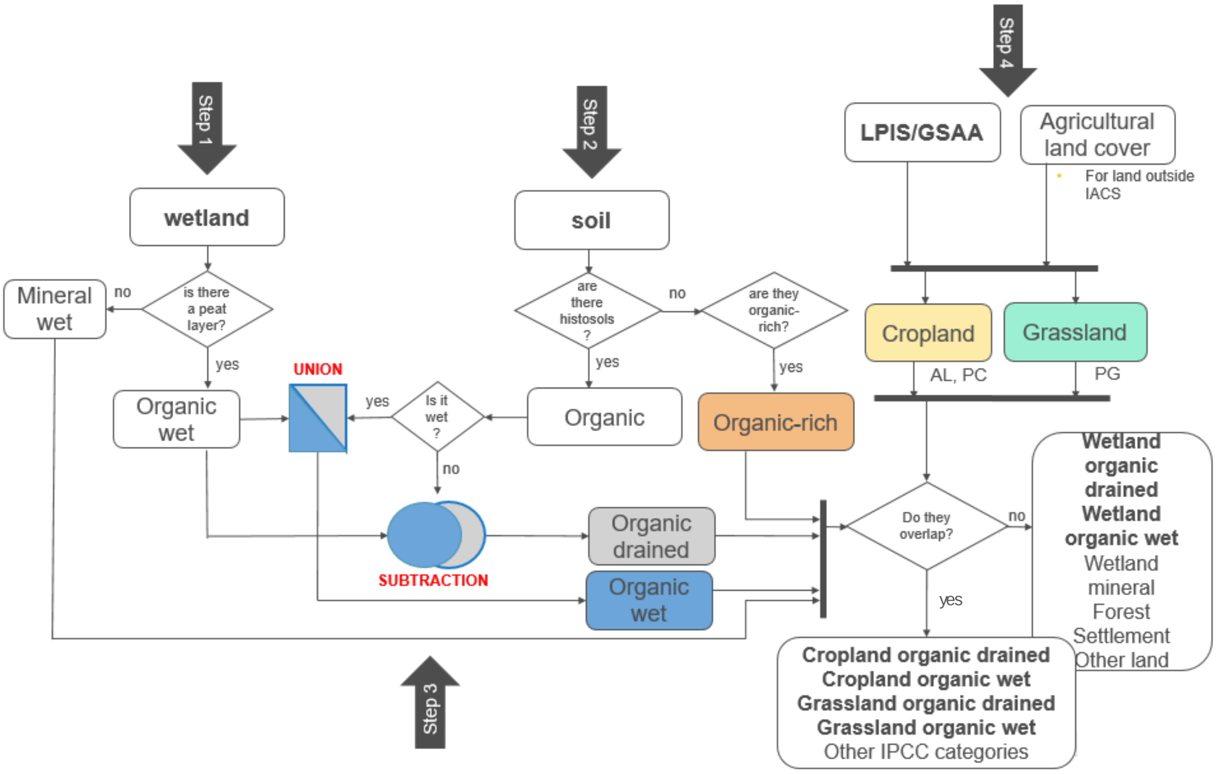
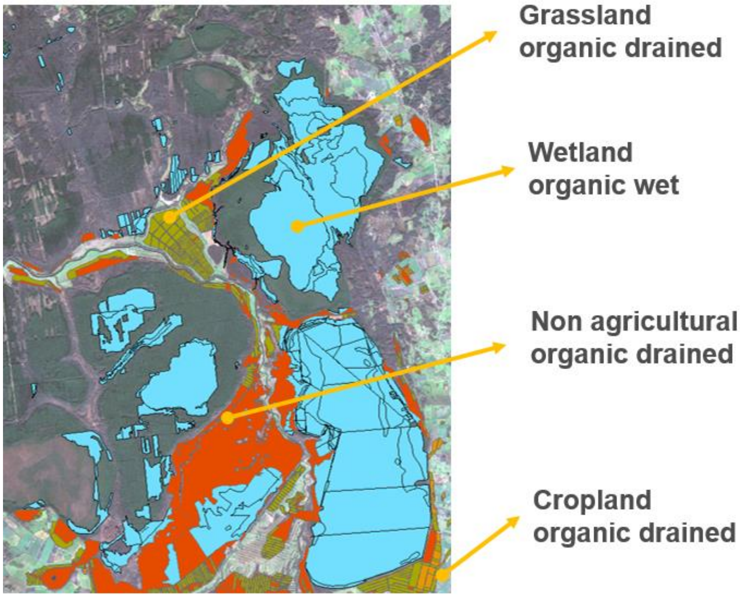


Figure 8. Result of the data integration flow from interpreted data: example of IPCC wetland sub-categories definition in a test area.



3.3.2 Workflow for identification of candidate peatlands/wetlands for IPCC based on continuous measurement and/or modelled data

In case the thematic data are not available or outdated, an alternative way to identify IPCC wetland sub-categories can be based on **measured/modelled data**, reflecting the key peatland characteristics, according to the developed semantic meta-model and interpretation of IPCC guidelines. For example, the **soil organic carbon content (SOC)** and **ground water table level (GWT)** layers, obtained by digital soil mapping/modelling and providing continuous values to the whole territory, may be available.

In order to split the peatland/wetland candidates into wet and drained, one can use the ground water table level, identifying a proper **threshold that best represents the WET status** of the soil (see definition par. 3.1.1 and 3.1.2). As fens are by nature wet ecosystems and connected with ground water table, their GWT appears an adequate criteria to define the WET status. In the selected case study area, the ground water table depth was analysed within a sample of the Fen class polygons originating from archive maps, but carefully selected based on archive and contemporary remote sensing imagery (to eliminate the Fen class areas that have been modified since the dataset creation, i.e. by afforestation or soil sealing by buildings, roads and other infrastructure). The GWT statistics for 39 polygons carefully representing Fen in their natural condition have been computed using both winter and summer data (Table 1).

Table 1. Average values of the ground water table derived for selected 39 polygons within the Fen class.

GWT	Pixel count	Mean [cm]	Median [cm]	Stdev [cm]	q 0.75 [cm]
Summer	274	16	13	13	19
Winter	274	17	13	16	18

In the analysis, the threshold value was established as 0.75 quantile of GWT values of summer dataset, as a conservative condition of wetness when the evapotranspiration demand is higher. However, the very close distribution of data in winter and summer further confirm that Fens are saturated by water for all or part of the year.

All the land having GWT values below the established threshold value was classified as WET while, above the established threshold value, as DRAINED (Figure 9).

Special attention is needed to Bogs, as they are by nature WET but disconnected with the ground water table and therefore likely misclassified by this methodology due to their deeper water table (from 100 cm in winter to 270 cm in summer). In such a case, the archive data can be analysed and refined, as in the case of Fen class, and Bog could be moved to the WET category, as indicated in the data processing workflow below. The wetness of Bogs could be assessed also through the temporal evolution of a wet index derived from Sentinel-2 data in order to get evidence for persistent presence of sparse wet vegetation on their surface. This can be further confirmed by other data, e.g. pan-European datasets from Copernicus Land Services, such as the HRL on Wetness and the N2K.

Based on **thresholding of the soil organic content** data, the land can be divided into three categories: organic (e.g. for SOC >=20%), organic-rich (e.g. 20%>SOC >=6%) and mineral (e.g. for SOC<6%). While the 20% organic carbon content is a common accepted criteria to define organic soils (see par. 3.1.2), the lower limit of organic-rich soils (i.e. 6%) is more arbitrary but kept as indicated by the MS.

By application of raster thresholding, intersection and difference (Figure 9) on SOC and GTW datasets, the land was classified into the following classes: mineral wet, organic-rich drained and wet, organic drained and wet (see results in Figure 10). We would like to point out that, since the original SOC and GWT layers are derived from an extrapolation/modelling process, the final classification likely inherited some of the original uncertainty. For instance, organic-rich wet areas may be very degraded peatland successively rewetted or, more likely, an artefact related to the uncertainty of original layers intersected. Some fine tuning by EO data and local expert knowledge is then recommended.

Figure 9. Workflow for selection of candidate peatland/wetlands for IPCC based on raster datasets of ground water table level (GWT) and soil organic carbon (SOC) content. Classes of Fen and Bog from archive maps are used as well.

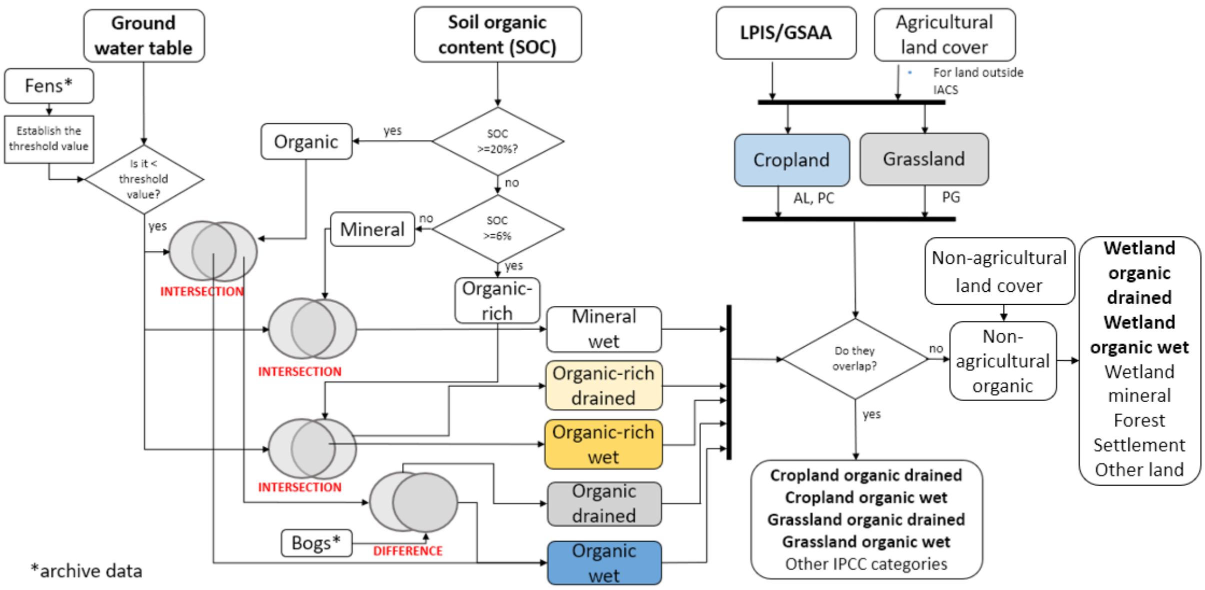
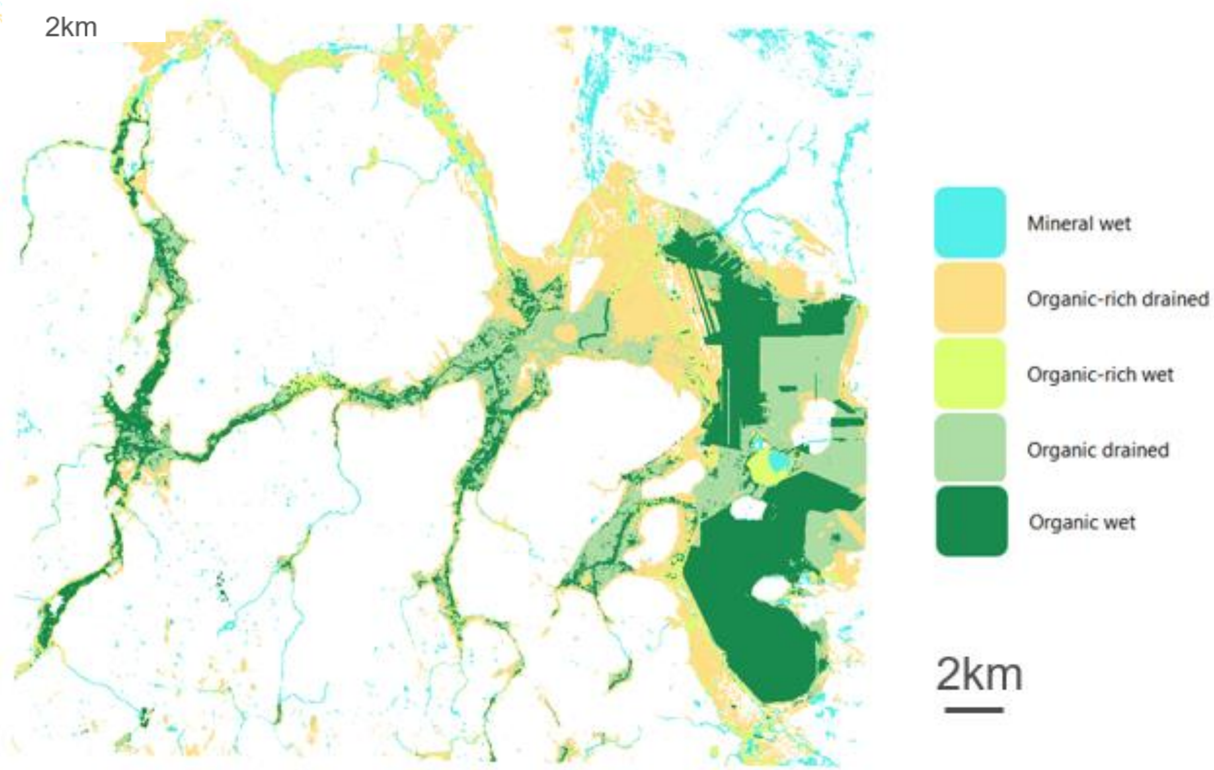
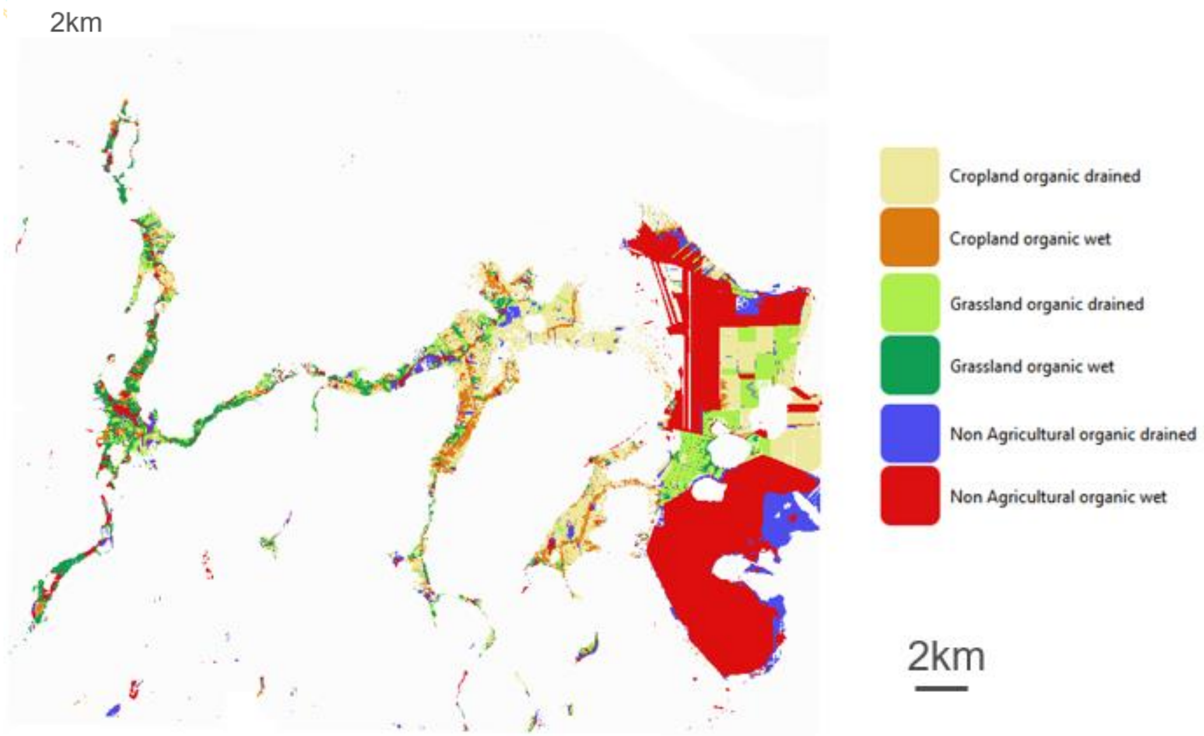


Figure 10. Results of the intersection of SOC and GWT layers for the definition of organic/organic-rich/mineral wet and drained areas.



In order to further divide the wetlands into relevant IPCC wetland sub-categories, information on the land cover/use is required. Relevant land cover categories declared in the LPIS can be used to distinguish between the agricultural sub-categories, i.e.: cropland and grasslands (as shown in Figure 11). Other data sources should be used to derive remaining IPCC sub-categories as indicated in the processing diagram in Figure 9.

Figure 11. Result of the data integration flow from continuous data: example of IPCC wetland sub-categories definition in a test area.



4. EO-based monitoring

Scope: This work package should be able to define, develop and document the processing methods and techniques, based on Copernicus Sentinel data, that could:

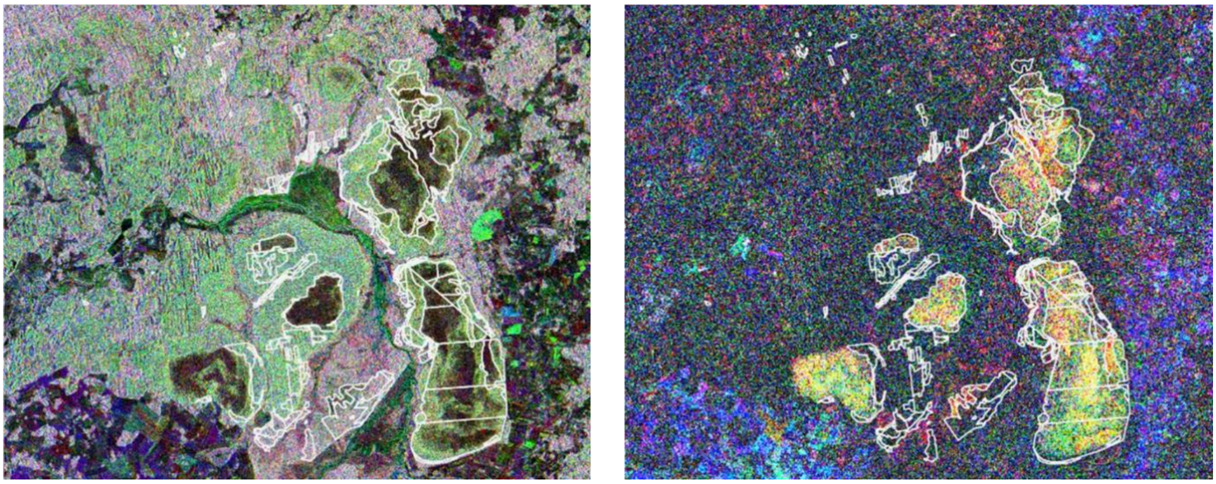
- complement and fill data gaps in the existing input datasets, related to wetland/peatland;
- effectively and efficiently provide information of the status and change of status of the peatland/wetlands from the bio-physical point of view;
- quantify the impact of the natural processes and anthropogenic events (ex. farming activities) on their state and conditions (ex. organic content), and
- monitor the effect of the defined sustainable management practices and conducted restoration activities. It also should be able to identify any technological obstacles hindering the uptake of the monitoring approach (based on Copernicus Sentinel data) in relation to peatlands and wetlands, and to assess the feasibility of using alternative observation methods and technologies, such as geo-tagged photos.

Method: The work package deals first with the identification of those bio-physical characteristics of the peatland/wetland and agricultural land on organic soil that are observable, and therefore monitorable, through remote sen sing (either Earth Observation or in situ/close-range). It also identifies the observable types of anthropogenic events and natural processes that affect or happen on peatlands and wetlands and changes their conditions. This will include any local natural disturbances, such as droughts and fires. It assigns to the proper types of information extraction, the relevant EO data/in-situ data required to derive that information and the associated automated processing options. As most of the anthropogenic events are farming-related, the work package will try to re-use observation methods and capturing techniques already developed and applied in the CAP Checks by Monitoring (CbM), by designing the relevant peatland related scenario and selection of the proper signals and markers (Figure 12).

Expected output: The results of this work will help EU Member States to design their own locally tailored solution for data gap filling, monitoring of the preservation and restoration of peatland/wetland, depending on the Sentinel data availability and the viability of alternative data sources. It will allow them to test the feasibility and re-use prototypes and tools, developed by JRC in the scope of CbM-related projects, such as the CbM Outreach. It will also indicate potential limitations and pitfalls in the monitoring approach and identify potential "proxy methods" to address the tracking of the implementation and effectiveness of the preservation and restoration measures, in the local context.

SEPLA already started to assess the potential of the EO data as a source to complement possible gaps in the peatland and wetland datasets, by developing prototypes for data capturing and land cover mapping. The work includes also an assessment of the usability of the existing Copernicus Land Monitoring products, such as High-Resolution Layers (Wetness, Grassland), High Resolution Vegetation Phenology and Productivity, N2K, Corine Land Cover, etc.). A full exploitation of this methodology will be assessed in the second year of the project.

Figure 12. Role of Sentinel 1 in peatland mapping/monitoring; example from Latvia. Peatlands indicated with white polygons are shown on top of Sentinel 1 false colour composites (three dates in 2020). Left image: SAR backscatter; dark area within peatlands could indicate persistent water saturation. Right image: SAR coherence; bright areas within peatland could be indicative for persistent lack of vegetation. Note: Copernicus Application Ready Data provided by the JRC CbM outreach project.



Regarding the geotagged photos, we could define the following potential uses:

- Geotagged photos, if collected using standardized protocol, could be an important source of ground truth for: (1) identification of change in ecosystems status (e.g. rewetting, vegetation change); (2) use in the analysis of the bio-physical characteristics that could be observed from space, by linking the EO observation with the ground truth; (3) quality checks of results derived by the machine-learning based image classification algorithms.
- The standardized tools for geotagged photo capturing to be used by EU Member States can facilitate and improve the efficiency of their already existing in-situ data collection campaigns. SEPLA will check the feasibility of the geotagged photo app, EGNSS4CAP, developed by EUSPA in SEPLA context.

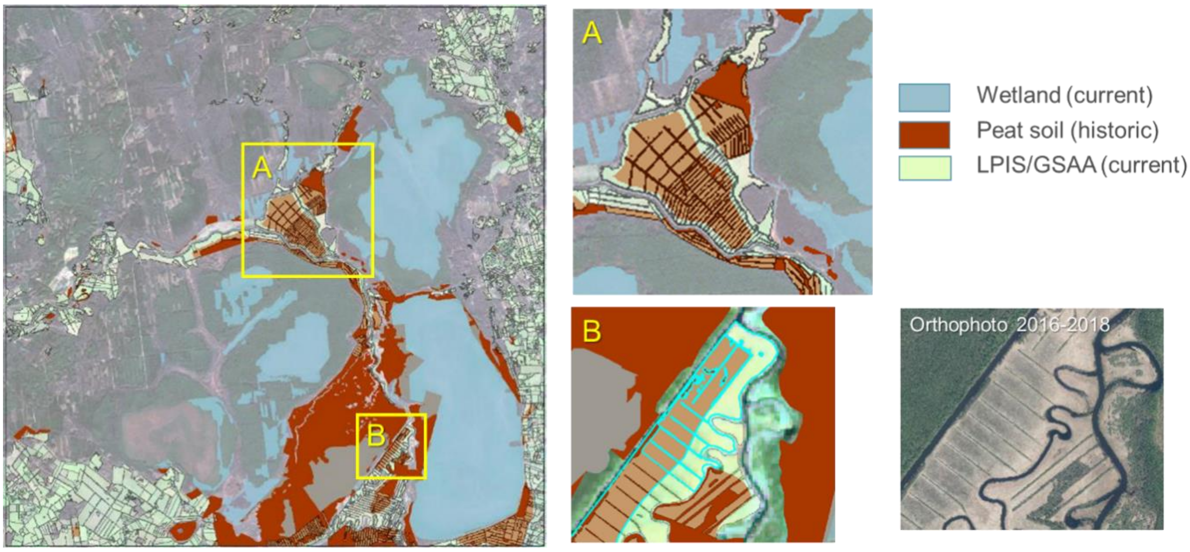
5. Peatland management

The scope of this work package will be to address the management aspect of peatlands and wetlands, taking into account the results from the data integration (Figure 13). It should consider the local context related factors and pressures influencing their status and restoration potential, as well as the organic content of the soil. The elements to account for this target will be: (1) proximity/access to rewetting, based on the available hydrological network; (2) "socio-economic" factors, related to farm/land management structure and land use zoning; (3) restoration potential, through modified agricultural practice (e.g. paludiculture), historic background, and GHG and biodiversity information; (4) protection status (ex. N2000). Those elements should be set integrating the local and regional specificities whenever possible.

Method: The work package will be built based on experience from conducted and ongoing research projects (Interreg DESIRE, DIONE, LIFE), addressing peatland preservation and restoration. It will also include active collaboration with science-policy-practice interface organizations (as the Greifswald Mire Centre) and the national agricultural administration, dealing with the design and implementation of CAP Strategic Plans. It will imply also a communication with DG AGRI on the criteria (definitions) used by the EU Member States to establish the areas to be classified as peatland/ wetland for the purpose of CAP conditionality (GAEC 2) and the additional targeted CAP aid support, foreseen in the eco-schemes and RD measures (e.g. carbon farming). The same principles mentioned in the first paragraph should inspire wetland/peatland restoration of land beyond CAP support.

Expected output: The results of this work will help EU Member States to establish the interlink between type of land use and processes driving peatland degradation and its "performance" in climate and environmental contexts (related GHG, status of ecosystems). It should provide them with more clarity with respect to the possible scenarios of future management (for example by peatland rewetting, paludiculture, potential impacts of land use changes in the buffer contextual zone, etc), applicable at the local conditions, as well as of their impact on biodiversity conservation and other key ecosystem services beyond carbon sequestration (as water quality or flood regulation). It should also provide input to certain technical concerns in relation to water management, such as the spatial-temporal character of water dynamics and the cross-border aspect of hydrological connectivity.

Figure 13. Integration of IACS and Wetland data to identify the areas under agricultural management - example from Latvia



5.1 Landscape and ecological context

Wetlands, including peatlands, are key ecosystems for climatic and environmental targets. Many of those are located under Natura 2000 sites, though others are part of a much broader spectrum of the EU territory. A portion of those is at the same time dedicated to agriculture (as grasslands for livestock or rice fields) or forestry production. In all the cases, the management of the land, within the wetlands itself or in the buffer zone surrounding each wetland will impact some key ecosystem services linked to GHG and their potential to buffer other climate change impacts such as flooding or drought regulations, which are expected to increase in frequency due to climate change. More importantly, depending on the agricultural (or not agricultural) management these ecosystems can release or capture carbon and other GHG, but also impact other biogeochemical cycles and environmental ecological processes.

For the restoration of an adequate functioning and services of these relevant ecosystems, the spatial, historical and socio-economic context where they are located is crucial. Furthermore, the management aspects (i.e. land uses) should account for the biologic and bio-geochemical factors regulating the processes in wetlands and peatlands, including the spatial context and hydrogeology for each specific wetland (or at least for group of wetlands with similar contextual characteristics). This is particularly relevant for those wetlands suffering seasonal changes in the presence and availability of water (i.e. water quantity) or changes in the quality of the water, due to agriculture practices in their contextual area of influence (for example due to irrigation, the use of fertilizers (N and P mostly) and/or other products used in agriculture, as pesticides). Those agricultural practices might influence the biological processes regulating GHG and, therefore, should be taken also into consideration for the design of management and monitoring of the wetlands and peatlands, as well as their potential restoration planning.

5.2 Land use typologies in relation to wetland/peatland management

Land use planning, categories and the relevant spatial data are largely driven by national and regional legislation. Therefore, the associated requirements and approaches for the management will be necessarily quite different from one country or region to another. Inside a country there might also be different land use classifications in operation, serving different domain-specific administrative and management purposes for the same wetland or peatland (part of the area is under agriculture use, while other part is protected and under conservation use). Similarly, to the approach used for land cover and in line with the IPCC methodology, instead of harmonising the local land use definitions to create a commonly applicable one, SEPLA would identify a set of meta-language elements (classifiers) to describe in standardised manner the relevant land use nomenclatures and lists of management practices, without replacing them, to allow for their interoperable use (cross-domain and cross-country comparison; data up-scaling for LULUCF reporting).

In relation to the semantic framework, SEPLA will rely on standardised ontologies, such as the Land Use Meta Language (ISO 19144-3) currently under development. In the context of SEPLA, this offers some key advantages:

- No predefined fixed list of land use classes exists, but it allows an almost unlimited possibility of combination of well-defined attributes. Each land use class is characterised by a specific set of meta-language elements, described in Unified Modelling Language (UML).
- The semantic framework allows for the documentation and representation of ecosystems with complex land dynamics and multiple ecosystem services, as the ones of interest to SEPLA. It also maintains the conceptual separation of land cover and land use.
- It provides the mechanism to define the relationship between the biophysical aspects of the wetland/peatland (defined through land cover), the allowed human footprint (expressed through the anthropogenic activities and their impacts) and its function in ecosystem service context.

In the second phase of the project, SEPLA will focus on defining and documenting, in collaboration with Member States, the interlink between: (1) the type of land use and the processes driving peatland degradation, and (2) the potentialities for restoration, considering them together with the related GHG emissions and LULUCF reporting. Below, the key concepts and elements of the foreseen work are briefly outlined:

<u>Land use categories</u>

In the context of SEPLA, the land use assessment will focus on the following possible management categories with relevance for the LULUCF GHG reporting (as shown in Figure 5):

- Agriculture (including also Livestock/ Grazing)
- Peat Mining
- Nature Conservation
- Forestry

<u>Activities</u>

The semantic assessment of the wetlands in terms of land cover (check chapter 3.1) will be further complemented with the land use aspects, which will account for the associated activities and corresponding functions.

Within agricultural land, apart from rewetting, some other monitorable agricultural practices (activities) will have an impact on wetland bio-physical characteristics and on GHG emissions. For the purpose of simplifying, SEPLA will consider only some identified agricultural practices that can be monitored through remote sensing with Satellites (Sentinel-based). In this line, SEPLA will benefit from previous experiences from the team in monitoring grazing, mowing; shallow tillage; ploughing; parcel-irrigation; or presence of green-cover/bare soil on agricultural land. It should be noted, however, that the monitorability through EO of those in the case of peatlands and wetlands is still on research state on particular study cases, as further studies and literature review are needed for this particular type of ecosystems.

Functions

In relation to the functions of the land, SEPLA will consider them in ecosystem service context related to GHG and key services under climate change scenarios. For that, the following Functions will be considered in SEPLA:

Production: the process of growing, harvesting or making goods. It refers both to the growing of plants or animals and the process and methods used to transform tangible raw materials into goods.

Provision: the action/process of providing or supplying of intangible products for other business or consumers; it refers to the provision of services, utilities, transport, or logistics. Ecosystem services. Including adaptation and mitigation of CC through carbon and other GHG reduction.

Regulative: an area under specific normative rules (controlling, directing or managing) or principles including both conservation/protection of environmental areas, conservation/protection archaeological sites, restriction rules to access particular areas. For the purposes and context of SEPLA they will incorporate conservation/protection of environmental areas and regulation of water regime including quality and quantity, and its relationship with biogeochemical cycles with an impact on GHG.

6. Engagement of the EU Member States

The objective of SEPLA is to support the EU Member States in improving their LULUCF reporting of peatland/wetland and the implementation of EU CAP measures related to the protection of organic soil. It relies on the experience of those EU Member States with a notable share of peatland areas that have already advanced in the mapping and monitoring of wetlands and organic soil in general. In this respect, the project applies purely multi-actor and bottom-up approaches, relying on the local expertise to upscale prominent national solutions into a common methodological framework applicable at the EU level.

The EU Member States participating in SEPLA were chosen based on:

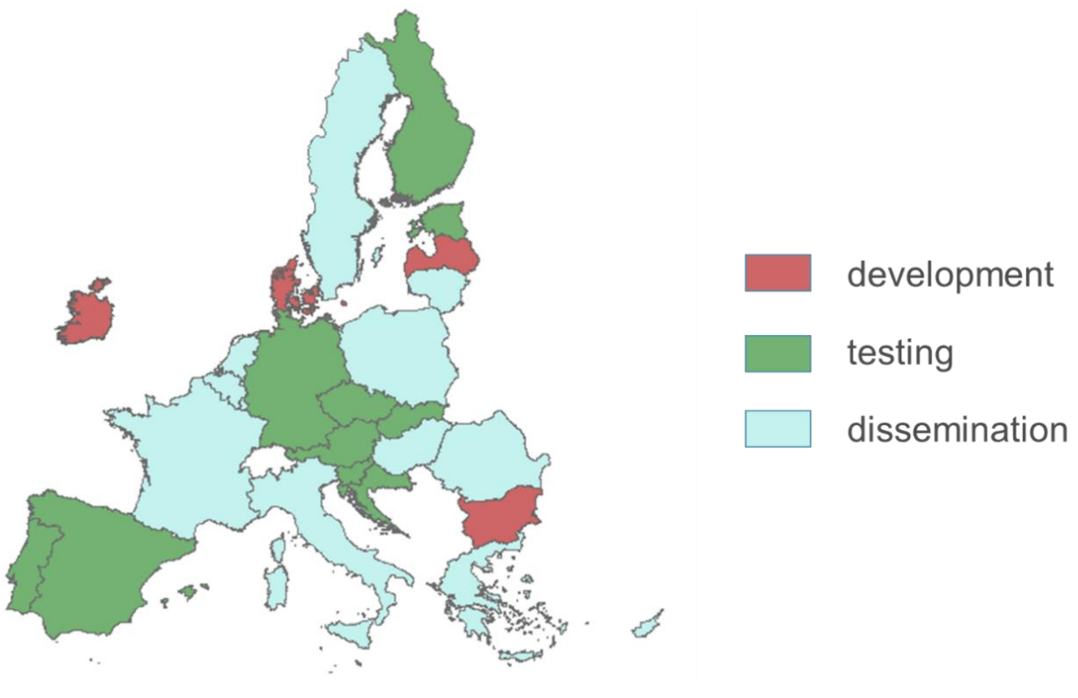
- their LULUCF/GAEC 2 needs and expressed interest in the project;
- coverage of particular (bio)geographic region;
- existing collaboration with JRC (CbM, data interoperability).

They were divided in two groups:

- "*Precursors*": These are the EU countries participating in the development of the methodologies, based on their best practices, approaches. They also share geographic-explicit data for testbed setting (organic soils and associated land cover types; historic data related to drained peatlands and wetlands). Four countries participate in this group: Bulgaria, Denmark, Ireland and Latvia.
- "*Users*": These are the EU countries participating in the feasibility testing of drafted common procedures and techniques. They should analyse the potential challenges and obstacles in the implementation of the methods in their conditions and propose solutions. Several countries expressed interest to participate, and their number is growing: Austria, Czech Republic, Finland, Portugal, Slovakia, Slovenia, Sweden, etc.

Due to the technical character of the project, SEPLA doesn't work directly with the national administration, but with a selected number of local technical experts, covering different professional areas. Currently, there are more than 60 experts involved in the project, covering a broad range of competences (soil and land cover mapping, hydrology, wetland assessment, LULUCF, IACS management, CbM implementation) and affiliations (agricultural administrations, mapping and data supply agencies, research agencies, Copernicus contact points). In the course of the project, SEPLA stays in touch also with other potential stakeholders (DG ENV, JRC Soil Unit) and research bodies (Greifswald) for possible synergies with existing research and available datasets (e.g. LUCAS Soil) and ongoing projects at the EU or national level (e.g. Interreg DESIRE, DG CLIMA-funded LIFE projects). Essentially, SEPLA aims to offer a collaborative environment to share and exchange know-how between EU Member States, address challenges and fill data gaps at national level.

Figure 14. Map of Member States whose experts in SEPLA project in the different phases.



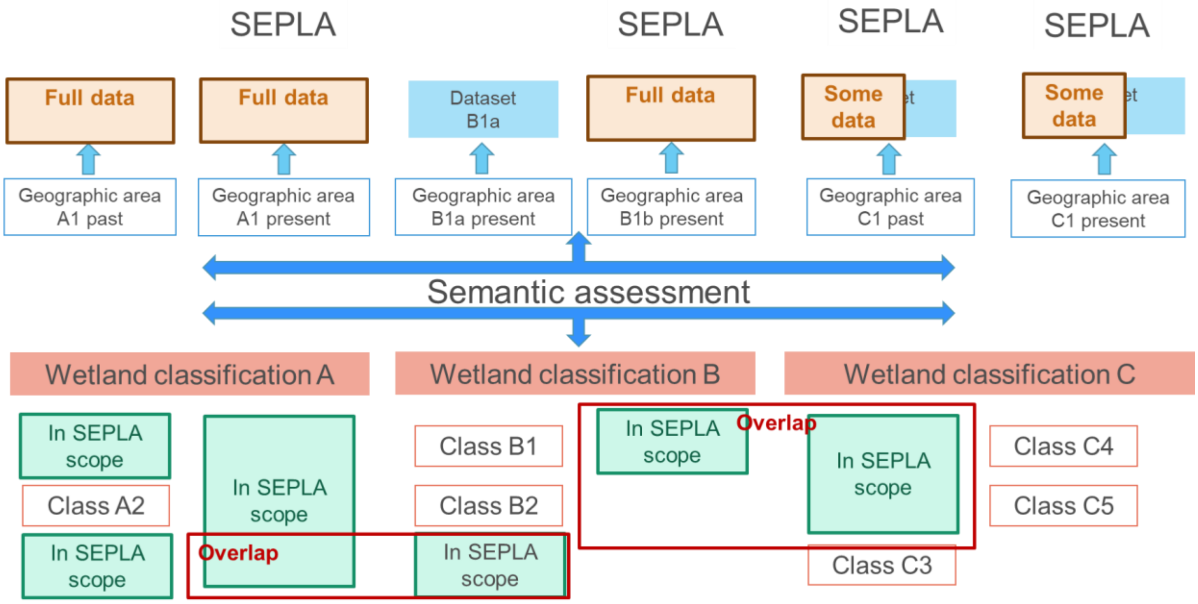
7. Status of the work, first results and user feedback

In 2021, the project invested in bringing up the necessary technical experts from the EU MS, selected as "precursors", and ensured that the required competences and knowledge is available. SEPLA team of GTCAP relied on the excellent network with EU MS agricultural administration built for the last 20 years to map and engage the relevant experts from the other domains (soil, wetland, N2000). The collaboration with the four selected EU MSs (BG, DK, IE and LV) proved to be very fruitful and intensive. There were six bilateral meetings on average with each EU Member State in the first ten months of the project. Their purpose was:

- administrative: to inform experts of the project scope, status and streamline the information exchange flow;
- technical: to conduct the semantic assessment and discuss the result, to design the methodology for data integration, and test some EO-based approaches for filling data gaps.

Much effort was put in understanding the nature of the peatland/wetland, and the associated definitions applied at national level. It became clear that geographic information on peatland and wetland is collected in different periods, by various user groups and for different purposes. The situation was further complicated by the fact that in the IPCC guidance, the definition of wetland is very broad, and there is no explicit definition of peatland. Thus, the definitions vary, and correspondent classes are neither harmonized, nor interoperable. This urged SEPLA to adopt a semantic meta-model to "map" the various peatland/wetland definitions, corresponding feature catalogues to assess the relevance of the given spatial data in SEPLA thematic context (Figure 15).

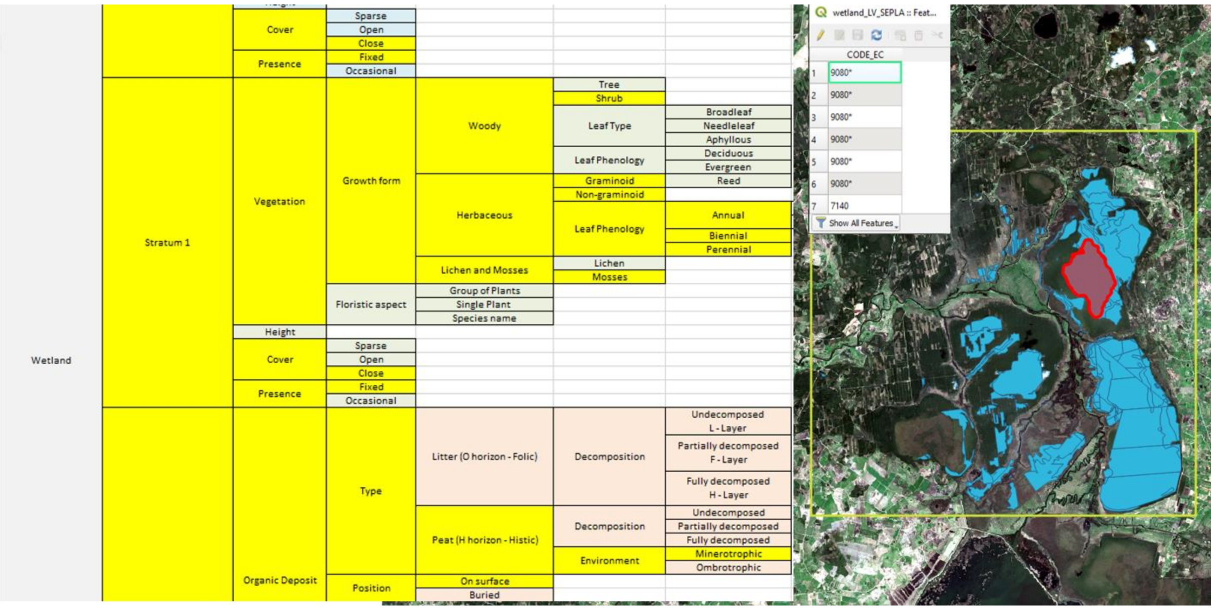
Figure 15. Schematic representation of the role of the semantic assessment to identify the national wetland datasets relevant to SEPLA. Red boxes encompass classes in different classifications systems that are semantically similar (are referring to the same land cover type).



The designed semantic meta-model was based on commonly accepted and observable bio-physical characteristics, taken from standardized meta-languages as ISO Land Cover Meta Language (LCML) and EAGLE. It used the tegon concepts for 3-dimensional representation of the land cover, further extended it with the pedon concept to allow the link between land cover and soil, while retaining the relationship with land use (indented or conducted activity). The semantic meta-model and the instructions for its use were published in a dedicated technical report (Milenov et al., 2021).

Experts from the EU Member States greatly appreciated the semantic meta-model as a method to identify and "map" the geospatial data, relevant for the peatland/wetland inventory. For each of the national peatland/wetland class (and associated feature catalogue), a specific "passport" was created, holding in structural way all bio-physical characteristics and properties of the class and its feature instances aim to convey. In other words, the passport provides, in a standardized and structural manner, information on the key characteristics and properties of the land cover and underlying soil, associated with this class. The resulting "passports" helped MS experts to allocate and channel the classes and associated instances through the appropriate data integration workflows (Figure 7 and Figure 9). Most of the experts found it easy to perform the semantic mapping on the nomenclatures and datasets by themselves (Figure 16). Some asked for additional support from JRC. The work is still ongoing with some EU Member States.

Figure 16. Example of semantic passport of wetland types in Latvia. There were 12 passports of wetland biotopes created for the entire country.



Both JRC and EU MS started assessing the class "passports" in relation to:

- their correspondence to IPCC needs/requirements;
- semantic gaps and overlaps (and possible data to fill in);
- role of the class/dataset in the dichotomous data integration approach;
- identification of peatlands at risk or degraded.

The assessment of the class "passports" was based on the assumption that the initial selection of the "candidate" datasets made by EU MS is adequate. It was also made from a purely bio-physical perspective, since any land use, contextual and socio-economic information is not yet accounted for. SEPLA plans to extend the semantic meta-model with management and land use impact aspects.

In parallel, the EU Member States provided detailed metadata and specifications of the local datasets, together with an abundant number of scientific publications, explaining the various methods for data production. They also provided much of the dataset extracts for the test sites identified. See Table 2 for more detailed information.

Table 2. Status of EU MS interaction (December 2021).

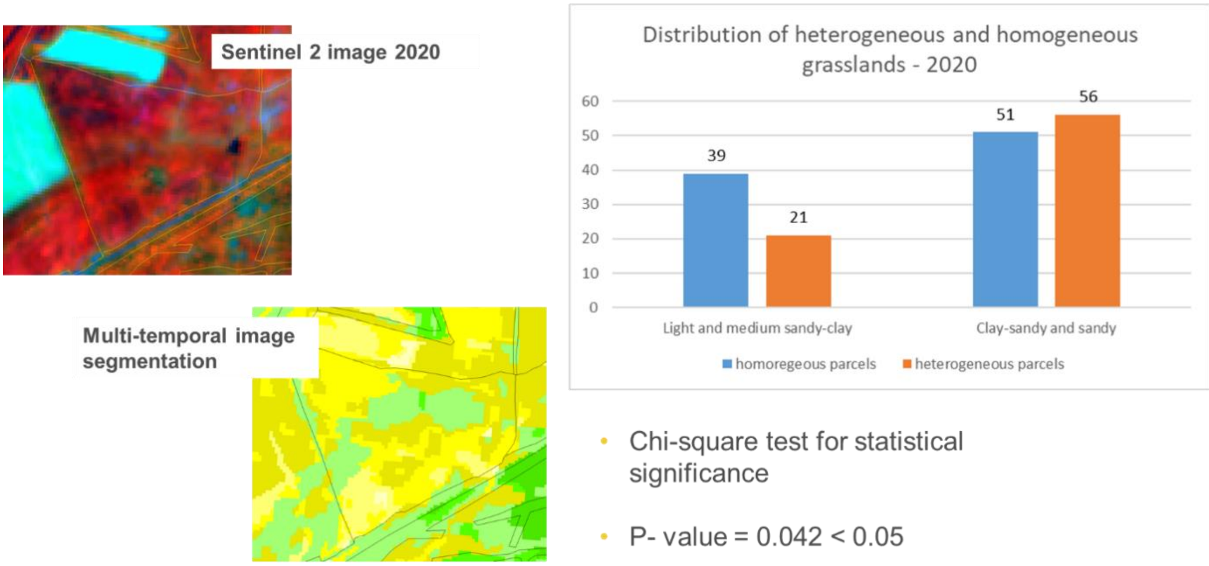
EU MSs	Number of bilateral and individual technical meetings conducted	Number of experts involved (from initial four EU MS only)	Test site definition and data provision	Provision of product metadata	Semantic mapping	Data integration
BG	5	8	YES (7064 km2)	YES (>10 datasets)	ongoing	ongoing
DK	10	13	YES (646 km2)	YES (>10 datasets)	completed	completed

IE	6	16	YES (325 km2)	YES (5-10 datasets)	ongoing	ongoing
LV	4	16	YES (400 km2)	YES (5-10 datasets)	completed	completed

So far, EU MS experts show high commitment and interest in SEPLA. They appreciate the synergies with other JRC activities, such as the CbM outreach and IACS65 work on data interoperability. The project gradually reveals the key elements that define a land cover as peatland - organic soil, water level, type of management, protection status – and accelerates the use of common semantics for mapping local definitions, the same way it was done in the LPIS quality assurance framework. Still, the abundance of wetland typologies, as well as the fact that much of the soil related data is derived through spatial modelling of limited sampled points, remains a major methodological challenge.

SEPLA team of GTCAP made it clear that the project is about methodological development, not data collection/creation. The aim is to use the national data and expert knowledge to build the semantic bridge between LULUCF and CAP (GAEC 2). SEPLA team also acknowledges the complex and holistic character of the project and the difficulty in bridging different expert communities. EU MSs appreciate that SEPLA tries to keep the project simple, incremental, and collaborative, with the focus on finding practical solutions, rather than dealing in detail with all research-relevant aspects. The synergies with the other JRC activities made it possible to already start exploring monitorable aspects of the peatlands and testing the Copernicus Application Ready Data to track certain characteristics, such as vegetation heterogeneity and soil texture (Figure 17).

Figure 17. Use of Feature of Interest (FOI) assessment tools to evaluate the possible relation between the soil texture and vegetation heterogeneity – example from Bulgaria (Source: PhD thesis in collaboration with JRC).



Conclusions

The first year of the project managed to unlock and expose the involved EU Member States to a wealth of knowledge and know-how, shared in an interoperable manner. The project offered to the project participants, a set of practical solutions - relation to semantics modelling, use of existing GIS technology, and data integration - to "navigate through" and make sense of the vast amount of information available on wetland and organic soils. The active collaboration with multiple stakeholders was maintained with regular online meetings with prompt replies to emails and queries. EU MS experts expressed their positive experience with the participatory approach adopted and the knowledge sharing that offered them the opportunity to scale up their local know-how to the required policy implementation level.

The project insights also revealed the main challenges, related to the local specificities of the landscape and socio-economic context, the variety of non-harmonized and non-interoperable data, and the lack of integration among the different "expert communities" dealing with wetlands and peatlands. In this respect, SEPLA helps with the clarification and standardization of the underlying concepts and the adoption of common methods to ease area identification and spatial data management. The project further tries to alleviate the apparent complexity of the implementation through the promotion of incremental, modular, and practical solutions. EU MS experts point out some further opportunities for enhancement, such as the more intensive interaction with project teams from other members states, the sharing of lessons learned and knowledge from related projects, and the support to the EU MS's advancements in relevant technologies (inSAR, LIDAR, machine learning, geotagged photos, etc.).

References

19144-2:2012, I. (2012). ISO 19144-2:2012 Geographic information - Classification systems — Part 2: Land Cover Meta Language (LCML). Switzerland: ISO TC211.

Devos, W., Milenov, P., Land Use and Land Cover Semantics - Principles, Best practices and prospects (Vols. applying tegon, the elementary physical land cover feature, for data interoperability). CRC Press, Boca Raton, USA, 2015, ISBN:978-1-138-74799-9

Devos W., Lemoine G., Milenov P., Fasbender D.: Technical guidance on the decision to go for substitution of OTSC with checks by monitoring. Document DS/CDP/2018/17, EUR 29370 EN. Publications Office of the European Union, Ispra, 2018b, doi: 10.2760/693101

Devos W., Sima A. and Milenov P., 2021. Conceptual basis of checks by monitoring, JRC127678.

IPCC 2014, 2013 Supplement to the 2006 IPCC Guidelines for national greenhouse gas inventories: wetlands, Hiraishi, T., Krug, T., Tanabe, K., Srivastava, N., Baasansuren, J., Fukuda, M. and Troxler, T.G. (eds). Published: IPCC, Switzerland.

IUSS Working Group WRB. 2015. World Reference Base for Soil Resources 2014, update 2015 International soil classification system for naming soils and creating legends for soil maps. World Soil Resources Reports No. 106. FAO, Rome.

Keddy, P.A. (2010). Wetland ecology: principles and conservation (2nd ed.). New York: Cambridge University Press. ISBN 978-0521519403.

Lourenco, M., Fitchett, J. M., & Woodborne, S. (2022). Peat definitions: A critical review. Progress in Physical Geography: Earth and Environment, 0(0). https://doi.org/10.1177/03091333221118353

Luketic N., Milenov P., Devos W., Technical guidance on management of layers in LPIS, European Commission, Joint Research Centre, Italy 2015

Milenov, P., Lugato, E., Puerta Pinero, C., Angileri, V., Sima, A. and Devos, W., Semantic assessment of land cover types and feature classes, European Commission, 2021, JRC128087 [https://marswiki.jrc.ec.europa.eu/wikicap/images/e/ec/JRC128087_jrc128087_semantic_assessment_sepla_pubsy_jrc128087_v51.pdf]

Milenov, P, Assessment of the status of agricultural land with Remote Sensing, Bulgarian Agricultural Academy, Institute of Soil Science, Bulgaria, 2022 [http://www.issapp-pushkarov.org/sites/default/files/pictures/avtoreferat_p.milenov_en.pdf].

List of abbreviations and definitions

BG	Bulgaria
CAP	Common Agricultural Policy
CbM	Checks by Monitoring
DG AGRI	Directorate-General for Agriculture and Rural Development
DG CLIMA	Directorate-General for Climate Action
DG ENV	Directorate-General for Environment
DGs	Directorate-Generals
DK	Denmark
EAGLE	EIONET Action Group on Land monitoring in Europe
EC	European Commission
EO	Earth Observation
EU	European Union
GAEC	(Standards for) Good agricultural and environmental condition of land
GAEC2	Good agricultural and environmental conditions (of land)
GHG	Green House Gases
GSAA	Geospatial Aid Application
GSAA	Geospatial Aid Application
GTCAP	Guidance and Tools for CAP
GWT	Ground water table level
IACS	Integrated Administration and Control System
IE	Ireland
IPCC	Intergovernmental Panel on Climate Change
JRC	Directorate-General Joint Research Centre of the European Commission
LCML	Land Cover Meta Language
LPIS	Land parcel Identification System
LUCAS SOIL	Land Use and Coverage Area frame Survey on top Soil
LULUCF	Land use, land-use change and forestry
LUML	Land Use Meta Language
LV	Latvia
MS	Member State
P/N	Phosphorous/ Nitrogen
PA	Paying Agency
RS	Remote Sensing
SOC	Soil organic carbon content
UML	Unified Modelling Language

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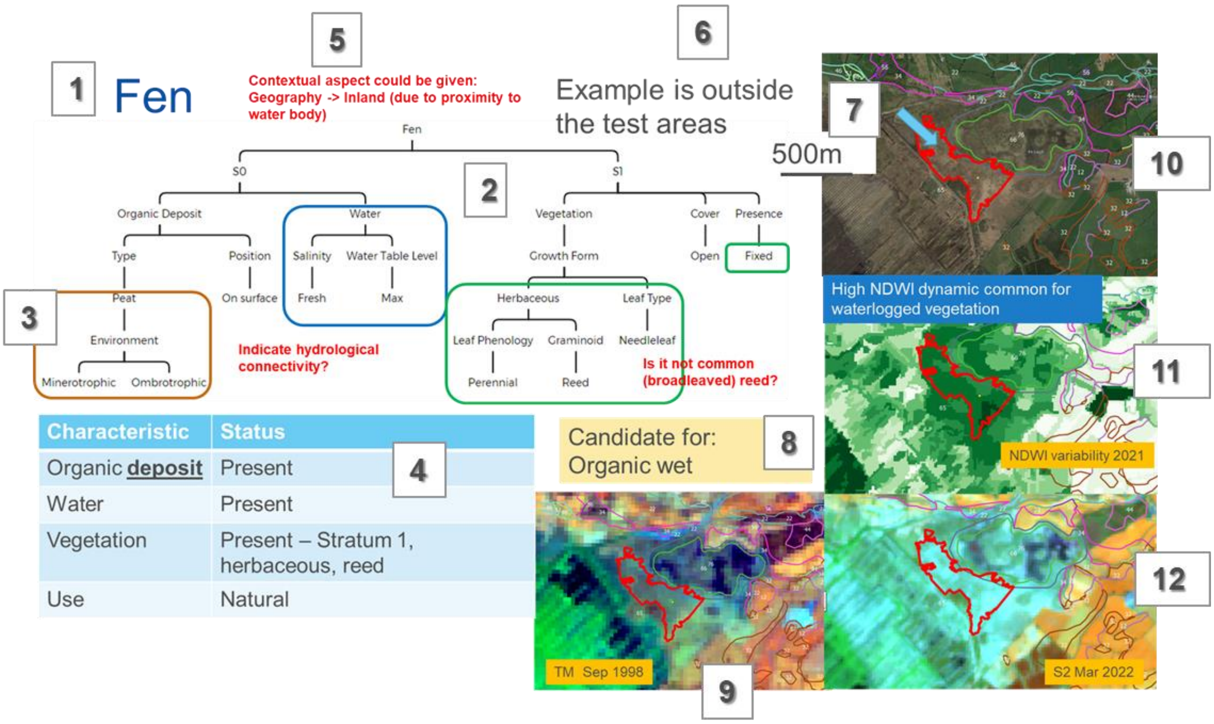
Annexes

Annex 1. Example of the common template for exchanging the outcomes from the semantic assessment with EU MS experts



1. Class name, as defined in the national/local class nomenclature
2. Simplified UML representation of the resulted semantic passport
3. Boxes highlighting the most important classifiers that define the class (brown box for soil classifiers; blue box for water classifiers; green box for vegetation classifiers)
4. Table with summary of the findings from the passport (based of the key classifiers identified)
5. Editorial recommendations regarding the passport correctness (with reference to the excel table with the passports provided by the EU MS experts)
6. Other comments
7. Visual scale of the imagettes
8. Proposed role of the class in the data integration process and the outcome foreseen
9. Class instance (polygon feature) overlaid on archive Landsat TM image in false colour composite (NIR, SWIR, RED)
10. Class instance (polygon feature) overlaid on Google maps with some of the vector layers shown (Soil, LPIS, others)
11. Class instance (polygon feature) overlaid on thematic raster showing the annual variability of NDWI, derived from multi-temporal segmentation
12. Class instance (polygon feature) overlaid on up-to-date Sentinel-2 Image in false colour composite (NIR, SWIR 1, RED)

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