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D4.6 Report on candidates for operational roll out – Final report

Work Package 4 - Operationalization

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Acronyms

Acronym	Description
Content	Content
AGB	Above-Ground Biomass
ALOS	Advanced Land Observing Satellite
CAP	Common Agricultural Policy
CCI	Climate Change Initiative
CDSE	Copernicus Data Space Ecosystem
CGLS	Copernicus Global Land Service
CLC	CORINE Land Cover
CLMS	Copernicus Land Monitoring Service
CGLOPS	Copernicus Global Land Operations Service
EO	Earth Observation
DEM	Digital Elevation Model
DL	Deep Learning
DSM	Digital Surface Model
EEA	European Environment Agency
ESA	European Space Agency
EU	European Union
EUDR	EU Deforestation Regulation
EWMA	Exponentially Weighted Moving Average
FCH	Forest Canopy Height
GEDI	Global Ecosystem Dynamics Investigation
GFMAP	General Framework for Mapping
GPP	Gross Primary Productivity
GSWE	Global Surface Water Explorer
HR	High Resolution
HRL	High Resolution Layer
IMD	Imperviousness Density
ISS	International Space Station
JRC	Joint Research Centre
LSC	Land Surface Categories
LPIS	Land Parcel Identification System
LR	Low Resolution
LUE	Light Use Efficiency
LULUCF	Land Use, Land Use Change and Forestry
ML	Machine Learning
N/A	Not Applicable
NISAR	NASA-ISRO Synthetic Aperture Radar
NFI	National Forest Inventory
NRT	Near Real Time
NVLCC	Non-vegetated Land Cover Characteristics
OSM	Open Street Map
PA	Producer Accuracy
PCA	Principle Component Analysis
RF	Random Forest
SAR	Synthetic Aperture Radar
SLF	Small Landscape Features
SWF	Small Woody Features
TBD	To Be Determine
TRL	Technology Readiness Level
UA	User Accuracy or Urban Atlas
VHR	Very High Resolution
VLCC	Vegetated Land Cover Characteristics
VPP	Vegetation Phenology and Productivity
WP	Work Package

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Applicable Documents

ID	Applicable document
[AD1]	D3.2 EvoLand Prototypes Report – Final version
[AD2]	D4.5 Report on candidates for operational roll out – interim version 2
[AD3]	D1.2 Service requirements report - final version
[AD4]	D4.2 Stakeholder consultation report – interim version 2

Executive Summary

The EvoLand project aims to develop and qualify future candidates for integration into the Copernicus Land Monitoring Service (CLMS) as part of Copernicus 3.0 and related ongoing activities. It should be noted, however, that if stakeholders such as the EEA and JRC deem it appropriate, certain results from EvoLand may be integrated into the CLMS earlier—before the official conclusion of the project.

This document presents the qualification exercise for operational rollout, designed to assess the capacity and readiness of each candidate for integration into the CLMS portfolio. The qualification process has been carried out in two phases, following the overall development strategy of the prototypes.

To this end, a series of criteria and associated evaluation tables have been defined (Chapter 2). Each candidate, described in chapter 3, has been assessed with respect to those criteria. The main trends and findings are analyzed and discussed in chapter 4. Finaly, chapter 5 presents an overview of potential use cases for each candidate, outlining how they may enhance or complement the existing CLMS portfolio.

Key findings indicate that most candidate services are well aligned with user requirements and exhibit strong potential for integration into future CLMS operations. Nonetheless, several challenges remain, particularly regarding the availability of training and validation data and constraints in Earth Observation data accessibility.

1. Introduction

1.1 Introduction to project and document

This document *D4.6 Report on Candidates for Operational Roll-out* – final version is the outcome of the Task 4.2 "Service roll-out analysis" of the EvoLand project, which aims to assess the obtained maturity of candidates developed in Work Package 3 for integration into the Copernicus Land Monitoring Service (CLMS).

The CLMS candidates were developed in two phases, and the assessment exercise followed the same structure. This document outlines the applied methodology and presents the results obtained at the conclusion of each phase.

The document is organized as follows with 5 more sections:

- Section 2, for presentation and exhaustive description of the 2 assessment tools used:
  - ✓ The first one entitled "Benchmarking" is an industrial process to objectively compare candidates in terms of predefined criteria, to assess whether they are fit for purpose.
  - ✓ The second one entitled the "Technology Readiness Level' assesses the prototype's maturity for operational roll-out, need for additional integration activities, or need to further research and development, possibly beyond the timeline and framework of the project to be considered for implementation within CLMS.
- Section 3, for presentation of each candidate and development results along phases.
- Section 4, for presentation and discussion of the assessment results, all in a table and candidate by candidate.
- Section 5, for presentation of main use cases per candidate.
- Section 6, final, one, for conclusion and an outlook on the evaluation at the end of the EvoLand project.

1.2 Terminology used

Method = EvoLand will develop algorithms and methods required for the candidate CLMS services using existing and novel Earth Observation (EO) data, in-situ data and infrastructure.

Prototype = EvoLand will develop eleven next-generation CLMS product candidates monitoring the status and changes of land use/land cover and various land surface characteristics at high resolution.

Candidate = The main result of EvoLand will be up to eleven operationally benchmarked and qualified candidate CLMS services with a TRL5-7, which will have the potential to be taken up and integrated into CLMS by the Entrusted Entities from 2026 onwards.

2. Assessment process

For the selection of assessment criteria, the project team revisited and updated the work performed in ECoLaSS (Evolution of Copernicus Land Services based on Sentinel data), an EU Horizon 2020 project that ran from 2017 to 2019, leading to the creation of a revised and enhanced list of criteria, better suited to the constraints of the EvoLand project.

These criteria are organized into three overarching categories, namely **Science and Standards**, **Impact and Relevance** and **Operational Feasibility**.

Additionally, an evaluation of the candidate service **Technical Readiness Level** (TRL) has also been performed. This was considered an important addition as TRLs are now routinely used in the field of Earth Observation and are a standard trans-disciplinary operational evaluation indicator.

2.1 Definition of benchmarking

Benchmarking is an industrial process to assess the capabilities of products or services, either by comparing them to an accepted standard or by comparing them to other existing products or services. These comparisons are implemented by clearly defining a set of criteria and a scoring methodology against which each service will be evaluated.

The criteria and scoring definitions must be adapted to the aim of the benchmarking and must enable a clear simple and impartial evaluation process.

In EvoLand, benchmarking must allow to assess not only how well a candidate service serves the relevance of adding it to the CLMS, either as a new service or as an improvement on an existing service but also provide an indication of the associated timeframe until operational roll-out is possible as some service may require future evolutions and development before being added.

The benchmarking process is broken down into 3 steps, namely the definition of the criteria and scoring methodology by the members of the consortium, the assessment by the industrial partners of each service and a final review of results.

A key aspect of the assessment is a good understanding of the complexities of the CLMS both in terms of service production, operational requirements, and user needs [AD.4]. The consortium partners VITO, CLS and GAF, with a long track record as CLMS service providers, as well as experience in various other related projects, more than fulfil this requirement.

2.2 Selection of benchmarking criteria

The 12 criteria and scoring scale used for this Benchmarking assessment tool are presented in table 1.

For clarity purposes, they have been grouped into 3 overarching groups, namely: -

- **Science & Standards,** which deals more with theoretical scientific aspects,

- **Impact & Relevance**, focusing on the users & stakeholders, CLMS and policy environment, and
- **Operational Feasibility,** which reflects more the technical characteristics and operational implementation of each candidate service.

There is a certain level of permeability between these 3 groups as criteria can often belong to more than one group.

There are 5 levels of evaluation, ++, +, o, -, --. Their signification is described below per benchmarking group, per criteria.

2.2.1 "Science & Standards" benchmarking

This benchmarking group aims to assess the candidates along **two criteria**: (1) "Level of Innovation" and (2) "Scientific acceptance". They are to some extent complementary as a very innovative approach or method can often still lack a wide scientific acceptance, simply due to being (still) novel. There is no change in criteria from previous version of the document.

Table 1. The five levels of evaluation for the "Science & Standard" benchmarking criteria.

Criteria \ Level	++	+	o	-	--
Level of innovation	**Highly Innovative**: A highly innovative service that brings significant improvements or entirely new capabilities compared to existing services. May rely on existing methods or features that haven't been used in this particular context.	**Innovative:** A service that incorporates original elements or substantial improvements to existing products or services.	**Moderately innovative**: Offers some improvements or adjustments compared to existing products or services, though without significant innovation.	**Low Innovation**: A service which provides only minor improvements to existing products or services and shows limited novelty.	**Not Innovative:** A service with minimal or no improvements, closely replicating existing products or services without adding noticeable value.
Scientific acceptance	**Widely use:** methods regarded as best-in-class by global scientific community.	**Well accepted:** methods are considered reliable, though not universally top choice.	**Mixed acceptance:** methods recognized in some studies, lack of consensus.	**Limited acceptance**: Methods not validated as best-in-class.	**Largely rejected:** or disregarded by the scientific community.

2.2.2 "Impact & Relevance" benchmarking

This benchmarking group aims to assess the candidates along **five criteria**: (3) "Answering user needs (including quality)", (4) "CLMS Portfolio complementarity", (5) "Future continuation potential", (6) "Backward compatibility potential" and (7) "Link to policy". The backward compatibility potential criteria is new compared to previous version of the document.

Table 2. The five levels of evaluation for the "Impact & relevance" benchmarking criteria.

Criteria \ Level	++	+	o	-	--
Answering user needs (incl. quality)	**Fully addressed:** user needs and stakeholder requirements (Tasks 1.1 & 4.1) are fully addressed	**Well addressed:** Responds well to user needs but may not be comprehensive.	**Partially addressed:** needs further alignment.	**Limited alignment**: lack of critical aspects.	**No alignment:** Does not meet user needs or align with Copernicus products / documentation.
CLMS Portfolio complementarity	**Substantial added value:** Provides substantial added value; unique or significantly enhanced products or service.	**Added value**: new or improved products or service.	**Complementary features:** Offers some complementary features; may overlap with existing products or services.	**Minimal new capabilities:** Largely duplicate existing products or services; minimal new capabilities.	**Redundant:** Entirely redundant with existing products or services.
Future continuation potential	**Strong assurance of long-term continuity**: Fully aligned with future Copernicus data missions, with guaranteed ongoing updates and compatibility. The service is expected to support seamless data streams well into the future.	**Good potential for future continuation:** Ongoing updates and compatibility are likely to be established.	**Some potential for future series:** Ongoing updates and compatibility might be established (including workarounds) but is not certain.	**Limited capacity for future time series:** Ongoing updates and compatibility are expected to be limited.	**No potential for integration:** with future data.
Backward compatibility potential	**Seamless backward compatibility**: Fully integrates with CLMS products or historical timeseries without any modifications.	**Strong backward compatibility**: Mostly compatible with historical products, requiring minor adjustments or data conversion.	**Moderate backward compatibility**: Partial compatibility with historical datasets. Significant adjustments are needed to align with legacy products.	**Limited backward compatibility:** Minimal integration with historical products	**No backward compatibility**: Incompatible with historical products

Link to policy	**Clear and direct link** to EU/member state & global policies & indicators; supports implementation.	**Supports specific policies:** on the topic, though impact may not be substantial. Policies are yet to be adopted.	**Supports general policies:** no specific one are targeted; relevance unclear.	**Minimal:** unclear alignment with policies; limited support.	**No identifiable link:** to any policies; irrelevant in this context.

2.2.3 "Operational feasibility" benchmarking

This benchmarking group aims to assess the candidates along **five criteria**: (8) "Adequate in situ / validation data", (9) "Adequate EO data", (10) "Level of automation", (11) "Timeliness", (12) "Scalability to EEA38 / global scale". There is no change in criteria from previous version of the document.

Table 3: The five levels of evaluation for the "Impact & relevance" benchmarking criteria

Criteria \ Level	++	+	o	-	--
Adequate in situ / validation data	**Full availability:** of in situ/validation data across EEA38 (or global) territory; comprehensive.	**Mostly available:** minor gaps may exist.	**Partial availability:** significant gaps affect implementation.	**Insufficient data**: for comprehensive implementation; key regions missing.	**No adequate:** in situ/validation data available; candidate cannot be implemented.
Adequate EO data	**Fully available and adequate**: supports seamless implementation.	**Mostly available and adequate**: minor gaps.	**Partially available**: significant gaps limit full deployment.	**Inadequate EO data:** affects candidate's accuracy.	**Lack of EO data:** deployment impossible.
Level of automation	**Fully automated:** no human intervention required.	**High automation**: occasional human oversight needed.	**Partial automation**: substantial human intervention required.	**Minimal automation:** heavily dependent on human operators.	**Not automatable:** full manual operation needed.
Timeliness	**Optimal timeliness**: minimal latency for operational use.	**Acceptable timeliness**: slight delays.	**Some delays:** may impact usability.	**Significant delays:** operational utility affected.	**Impractical:** Delivery timeline is impractical for timely use.
Scalability to EEA38 / global scale	**Full scalability:** across the entire EEA38 (or global) territory.	**Mostly scalable:** across EEA38 (or globe); minor limitations.	**Limited scalability**: restricted to certain regions.	**Highly restricted:** scalability; small coverage area.	**No scalability:** Cannot be scaled beyond limited area; utility severely restricted.

2.3 TRL presentation

The Technology Readiness Level (TRL) helps to manage the development process of space and other technologies, ensuring that each step is thoroughly vetted before moving to the next stage, thus minimizing risks and enhancing the chances of success in space missions.

The space agencies were the first one to define and use the TRLs. This scale is now used in many other areas such as the implementation of Earth Observation Services or Horizon Europe to position proposals and projects in the program. The TRL scale for Horizon Europe is defined in the general annexes and set the following scale ranging from 1 to 9 to assess the maturity of a particular technology:

TRL 1	**Basic principles observed and reported** *Scientific research has just started, and the first results are used to be translated into future research and development*	Basic Research
TRL 2	**Technology concept and/or application formulated** *Basic principles have been studied, and first experiments/tests are designed based on the initial findings. When results from experiments/tests support the initial idea, the technology concept is defined at this stage.*	
TRL 3	**Experimental proof-of-concept** *Active research and development (R&D) are initiated. This includes both analytical studies and laboratory studies to validate the analytical predictions of separate elements of the technology. A proof-of-concept model is constructed. Reaching to this point, one can conclude that the new technology is feasible from a scientific point of view, and the technology is ready to go to the development phases.*	Applied Research
TRL 4	**Technology validated in a laboratory environment** *The basic technological components are integrated to verify that they work together. Each component has been tested so at this point a laboratory prototype is available.*	
TRL 5	**Technology validated in a relevant environment** *The breadboard technology undergoes testing in a simulated or somewhat realistic environment (industrially relevant environment in the case of key enabling technologies).*	Technology Development
TRL 6	**Technology demonstrated in a relevant environment** *The prototype must be demonstrated in a relevant environment (industrially relevant environment in the case of key enabling technologies) to confirm the engineering is feasible*	
TRL 7	**System prototype demonstration in an operational environment** *The technology requires that the working model or the prototype developed to be demonstrated in an operational environment, typically under industrial conditions and timings.*	System Development

TRL 8	**System complete and qualified** The technology has been tested and proven to work in its final form and under the expected conditions. It is ready for implementation into an already existing technology or technology system.	
TRL 9	**Actual system proven and deployed in an operational environment** This is the final level of readiness, indicating that the technology has been proven to work in a real operational environment and has been deployed.	

3. Overview of candidate service to be benchmarked

The following chapter provides a summary of the EvoLand prototypes. A full description of the EvoLand prototypes can be found in D3.1 EvoLand prototypes report - interim version [AD.1].

There are six regions for assessment, the selection of them depends on candidates and phases (Figure 1).

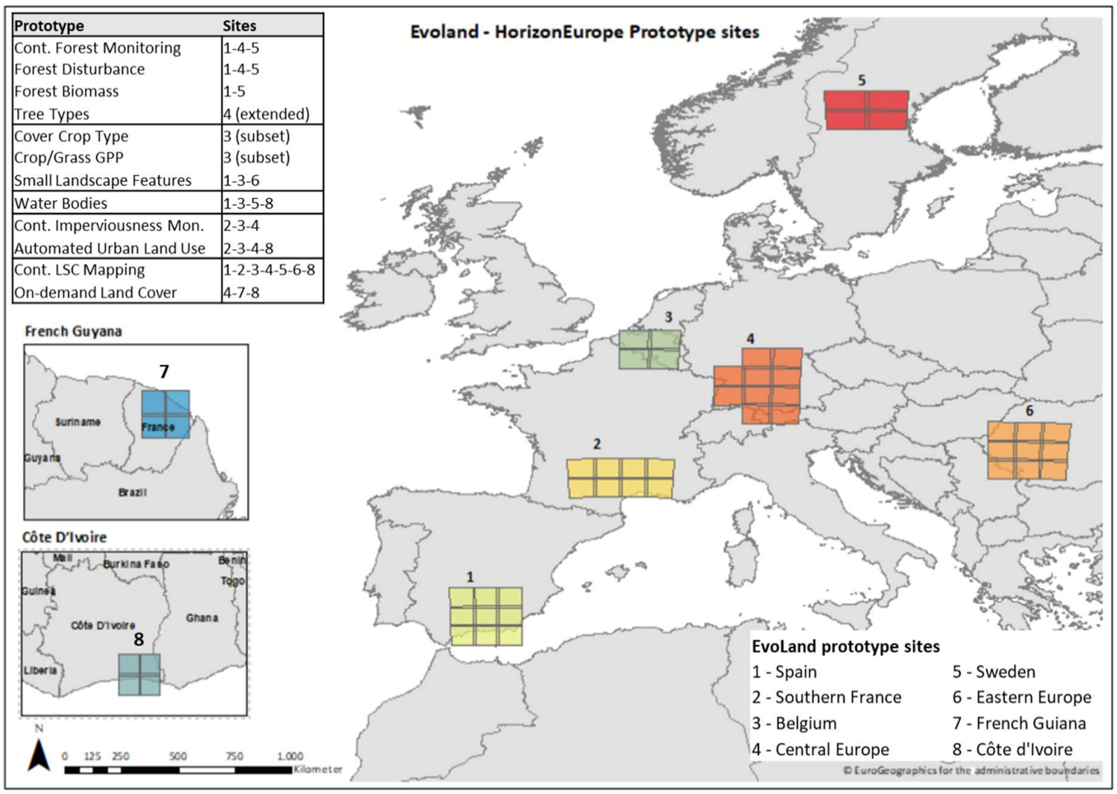

Figure 1: Identification of regions for assessment, selection of test cases depends on candidates and project phase

Note that due to its flexibility and independence of fixed datasets the C11 on-demand mapping prototype was excluded from this assessment.

3.1 C01 - Continuous Forest monitoring

Relevant CLMS thematic domain: Land cover and land use mapping: Forestry products

The monitoring of changes of the European Forests is a crucial input for many applications and steering processes. Timely updates are necessary to make well-based decisions regarding the protection and restoration of tree covered areas across Europe (and beyond). The information on where, when and to which extent tree cover is disturbed can be used to improve forest management and planning, support forest-related decision-making processes, or reporting on forest-relevant targets in EU policies.

Scope of this candidate: This prototype will expand and enhance the portfolio and scope of forestry products, particularly the current HRL Vegetated Land Cover Characteristics (VLCC) Forest products. The detailed specifications of the C01 prototype are outlined in Table 4. By increasing the update frequency of forest masks, it will capture dynamic changes within tree-covered areas and serve as an input for the forest disturbance agent classifier (C02).

Table 4. Technical and thematic specifications for the C01 candidate.

Candidate C01		
Candidate	C01 – Continuous Forest Monitoring	
Thematic specifications	Time of detection of tree cover canopy change	
Specificity per phase	Phase 1	Phase 2
Parameters/Classes	Month of the year in which a disturbance is detected	Month of the year in which a disturbance is detected
Test Sites	1 – Spain 4 – Central Europe	1 – Spain 4 – Central Europe 5 – Sweden
Test Period	1- Spain: 2020-2022 2- Central: 2019-2022	Spain, Sweden: 2020-2022 Central: 2019-2021
Temporal frequency	Monthly resolved yearly product	Monthly resolved yearly product
Spatial resolution	10 meters	10 meters
MMU	Pixel-based	Pixel-based
Envisaged accuracy	Not defined	Not defined

As result of phase 1, the prototype candidate C01 utilizes the EWMA method, which effectively captures subtle disturbances with small spectral magnitude; however, this sensitivity introduces a trade-off with false detections, potentially leading to commission errors, which are also connected to insufficient cloud screening. Notably, early spring months (e.g., March, April) show a tendency for elevated over-detection. The unsupervised EWMA approach does not require training data but does demand extensive Sentinel-2 time series data—spanning a minimum of three full years—before monthly analysis can commence. This requirement involves substantial pre-processing, including cloud masking. Nevertheless, the approach is robust as it is feasible to process large data amounts while still being computationally effective, and in addition it builds up on an open-source tool that has been recommended for forest monitoring applications. On top of the newly introduced monthly updates, compared to the existing 3-yearly forest change product within the VLCC portfolio, the C01 prototype demonstrates promising improvements towards potential yearly change products.

In Phase 2, the cloud masking has been improved utilizing a pre-trained deep learning model (Aybar, 2024[1]), which was trained on the CloudSEN12 dataset (Aybar et al., 2022[2]). In addition to that, a further prototype site in Sweden was rolled out. A tropical site in French Guiana was tested but the extreme cloud coverage throughout the whole year hampered the production of meaningful results with this approach based on optical S-2 imagery. Nevertheless, the improved cloud masking allowed for significant improvements in the European test sites, reducing the commission error for the Central and the Spanish demonstration site significantly. On the other hand, the omission of disturbance events especially towards the end of the monitoring period due to a delayed detection turned out to be a problem, which still needs to be addressed. More detailed information is provided in AD1.

3.2 C02 - Forest disturbance mapping

Relevant CLMS thematic domain: Land cover and land use mapping: Forestry products.

The forest disturbance mapping prototype is highly innovative, as it is not yet part of the CLMS portfolio. The derived information can be used to improve forest management and planning and support forest-related decision-making processes. Focusing on the driver behind forest disturbances, it enables adequate reactions and measures to different problems.

Scope of this candidate: The C02 Forest Disturbance Mapping candidate aims to identify the drivers behind forest disturbance events, specifically focusing on disturbances characterized by a decline in tree cover vitality or significant tree cover density loss. Unlike general tree cover change, disturbances here concentrate solely on tree cover loss (not on gain). Key disturbance agents, as defined by key stakeholders, include: (i) windthrow/storm damage, (ii) wildfire, (iii) insect infestations (e.g., bark beetle), and (iv) human-induced disturbances (e.g., forest clearing, clear-cutting, logging, and thinning activities). The detailed specifications of the C02 prototype are outlined in Table 5.

At the end of Phase 1, the C02 prototype provides continuous probability estimates of the likely causes of forest disturbances, using monthly forest change data from the C01 prototype as input. Phase 1 targets monthly updates, meeting the

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1 Aybar, C. (2024). cloudSEN12. https://huggingface.co/csaybar/cloudSEN12. https://doi.org/10.57967/hf/2291. Publisher: Hugging Face.

2 Aybar, C., Ysuhuaylas, L., Loja, J., Gonzales, K., Herrera, F., Bautista, L., Yali, R., Flores, A., Diaz, L., Cuenca, N., Espinoza, W., Prudencio, F., Llactayo, V., Montero, D., Sudmanns, M., Tiede, D., Mateo-García, G., & Gómez-Chova, L. (2022). CloudSEN12, a global dataset for semantic understanding of cloud and cloud shadow in Sentinel-2. *Scientific Data*, *9*(1), 782. https://doi.org/10.1038/s41597-022-01878-2

requirement for high-frequency products for event-specific monitoring. Due to limited reference data, drought effects are not included.

For Phase 2, an improvement of the algorithm was targeted, as well as improved regional calibration by collection of additional reference data, and the application in a third site (Sweden). Further, two additional classes have been introduced: Healthy tree cover and salvage logging (see AD1). The C02 prototype is delivered at 10m spatial resolution across European test sites. It is a consolidated yearly product, depicting the disturbance agent at the time of the disturbance detection. While human-induced activities like clear-cuts and logging are detected, distinguishing forest management from natural disturbance remains challenging without additional reference data. Besides the lack of adequate reference data, it turned out the another limiting factor is the delayed detection of disturbances, especially in case of slowly evolving disturbances, like bark beetle infestations. Timely clearing activities can obscure the actual cause of the disturbance in such cases.

Table 5. Technical and thematic specifications for the C02 candidate.

Candidate C02		
Candidate	C02 - Forest Disturbances	
Thematic specifications	Forest disturbance agent classification	
Specificity per phase	Phase 1	Phase 2
Parameters/Classes	1: wind throw/storm damage, 2: wildfire 3: insect infestation (e.g., bark beetle). 4: forest clearing, clear cut and logging/thinning.	1: bark beetle 2: clear cut/clearing 3: healthy trees 4: Salvage logging 5: wildfire 6: storm/windthrow
Test sites	1 – Spain 4 – Central Europe	1 – Spain 4 – Central Europe 5 – Sweden
Test period	Spain: 2020-2022 Central: 2019-2021	Spain, Sweden: 2020-2022 Central: 2019-2021
Temporal frequency	Yearly (monthly resolved)	Yearly (monthly resolved)
Spatial resolution	10 meters	10 meters
MMU	Pixel-based	Pixel-based
Envisaged accuracy	not defined	TBD

3.3 C03 - Forest biomass mapping

Relevant CLMS thematic domain: Land cover and land use mapping: Forestry products.

The forest biomass mapping prototype is highly innovative, as it is not yet available in the CLMS forest portfolio. While global biomass mapping is anticipated as a future addition, Tree or Forest Canopy Height is not yet included in the CLMS forest portfolio, despite ongoing scientific developments aimed at producing large-scale tree canopy height products. Forest biomass mapping is an important input for environmental monitoring, supports climate change studies and carbon stock assessment. Further, it supports sustainable forest management conservation efforts and policymaking for carbon credit programs, as well as assessing deforestation and forest degradation.

Scope of this candidate: The C03 Biomass candidate consists of two key products: Forest Canopy Height (FCH) and Above-Ground Biomass (AGB), both targeting woody biomass. FCH, also referred to as tree cover canopy height, enables the application of various forest definitions, providing users with flexibility in analysis and interpretation. Biomass mapping has been an active area of research for many years and is operationally conducted within the Climate Change Initiative (CCI) Biomass, though currently limited to a global spatial resolution of 100m or higher. The detailed specifications of the C03 prototype are outlined in Table 6.

Table 6. Technical and thematic specifications for the C3 candidate.

Candidate C03		
Candidate	C03 - Biomass Mapping	
Thematic specifications	Above-ground woody biomass (ABG) Forest canopy height (FCH) mapping	
Specificity per phase	Phase 1	Phase 2
Parameters/Classes	AGB mapped in t/ha FCH mapped in meters	AGB mapped in t/ha FCH mapped in meters
Test sites	1 – Spain 5 – Sweden	5 – Sweden
Test period	2021	2020 & 2022
Temporal frequency	Annual	Annual
Spatial resolution	10 meters	10 meters
MMU	Pixel-based (0.25ha and 0.5ha tested in WP2)	Pixel-based
Envisaged accuracy	Not defined	Not defined

As result of Phase 1, the derived models for both AGB and FCH utilized a combination of optical and SAR time series, DEM-based information, and GEDI LiDAR data, land cover structures visible in Very High Resolution (VHR) reference data could be effectively depicted. However, the methods tested and implemented so far are not yet operational, indicating significant room for improvement. The models tend to saturate at higher biomass and larger tree heights, leading to underestimation of AGB and FCH. Additionally, the AGB model appears to overestimate results at lower biomass values. These initial findings highlight the need for further analysis to assess the potential for a Europe-wide application in Phase 2.

Complementary to Phase 1 results, **in Phase 2,** two more reference years were rolled out for the Sweden test site, i.e. 2020 and 2022 with an adapted training model, using Sentinel-2 optical and Sentinel-2 SAR data as input. Further, two additional demonstration sites in French Guiana and Central Europe were tested. However, it turned out that the approach was not transferrable to those regions with a generally higher biomass and results were therefore discarded. Unfortunately, the NISAR mission, which was planned to be the primary data source for the Forest Biomass Mapping prototype, was launched too late, so the data could not be used in EvoLand. Without this or comparable data the experienced issues are to be expected, especially in areas with higher biomass. Nevertheless, the approach showed to deliver good results for areas with low or intermediate biomass, as found in the demonstration sites in Sweden and Spain, where saturation effects have less influence on the estimated biomass.

3.4 C04 - Cover crop type mapping

Relevant CLMS thematic domain: Land cover and land use mapping: Agriculture products.

Recognized as a key practice in sustainable agriculture by the Common Agricultural Policy (CAP), effective monitoring of cover crops is essential. Despite the establishment of various methods for mapping and monitoring main crop seasons, cover crop mapping remains less developed. Cover crops, also known as catch crops, are grown primarily to enhance and protect the soil rather than for harvest. They are typically planted between main crop cycles when the soil would otherwise remain bare. Common cover crops include grasses (e.g., rye, oats), legumes (e.g., clover, vetch), and brassicas (e.g., radishes, mustard). These crops offer numerous benefits, such as reducing soil erosion and nutrient leaching, increasing soil organic matter, providing natural fertilization, and enhancing biodiversity in agricultural systems.

Scope of this candidate: The objective of this prototype is to develop a service to map cover crop types at a 10-meter spatial resolution annually. This will be achieved using newly collected in-situ data and a hierarchical set of interconnected Deep Learning models based on Sentinel-1 and Sentinel-2 imagery. The detailed specifications of the C04 prototype are outlined in Table 7. Challenges include the scarcity of reliable reference data and the higher likelihood of clouds and snow during the secondary growing season, which complicates the use of optical imagery. Additionally, many cover crop seed mixes exhibit similar temporal patterns, making differentiation difficult.

Table 7. Technical and thematic specifications for the C04 candidate.

Candidate C04		
Candidate	C04 - Crop cover type mapping	
Thematic specifications	Map cover crop types at 10m resolution utilizing novel collected in-situ data on cover crop types as well as hierarchical set of inter-connected Deep Learning models based on Sentinel-1 & 2.	
Specificity per phase	Phase 1	Phase 2
Parameters/Classes	2 cover crop groups (“Grass-like” and “Leaf-rich & mix”)	3 cover crop groups (“Grass-like”, “Leaf-rich”, “Mix”
Test sites	3 – Belgium (subset)	3 – Belgium (subset)
Test Period	2021	2019-2021
Temporal frequency	Annual	Annual
Spatial resolution	10 meters	10 meters
MMU	1 pixel	1 pixel
Envisaged accuracy	not defined	not defined

As result of Phase 1, the focus was on a test site in Belgium during the 2021 growing season. The initial map distinguishes two main groups of cover crops and a winter cereal class, based on temporal features from Sentinel-2 and VLCC layers. While grass-like cover crops were relatively well separated from other winter covers, the accuracy did not yet meet the requirements. A significant limitation for cover crop mapping is the lack of reference data. LPIS datasets from Member

States rarely include cover crop information, and when they do, such as in the Flemish LPIS, the secondary crop declarations are often uncertain. This uncertainty hinders the development of a robust classification model. Additionally, defining a cover crop typology with clear separability is challenging. Currently, only two broad groups are differentiated. Cover crops often consist of seed mixes from multiple plant families, leading to confusion.

During **Phase 2,** the C04 prototype focused on strengthening the methodology and addressing earlier limitations. Efforts were made to refine classification, particularly improving the separation of crop families such as grass-like versus other winter covers. The phase also highlighted the persistent difficulty of handling mixed-class scenarios, confirming that further development is needed beyond broad groupings. In terms of validation, expanded confusion matrices and performance metrics were generated for the 2019 and 2020 Belgium cover crop maps, using LPIS as a reference. Due to limited availability of in-situ data, the demonstration scope remained restricted to a single site, meaning Phase 2 did not expand the geographic coverage but instead concentrated on deepening methodological validation (D3.2 EvoLand Prototypes Report).

3.5 C05 – Cropland/grassland GPP monitoring

Relevant CLMS thematic domain: Land cover and land use mapping: Agriculture products.

Information on the state and evolution of agricultural productivity is crucial for various applications, including crop yield estimation, assessing weather-related impacts on production, and measuring carbon fluxes. The current operational Copernicus CLMS Gross Primary Productivity (GPP) products at the European level rely on medium-resolution satellite images (e.g., Sentinel-3, MODIS), but are often insufficient for monitoring productivity dynamics at the field level. Additionally, the parameters and algorithms used are not specifically tailored to capture the productivity dynamics of agricultural lands such as cropland and grassland.

Scope of this candidate: Current operational products utilize the simplified Light Use Efficiency (LUE) to model GPP. To improve GPP estimations for grassland and cropland, the GPP model used for the GPP CLMS products is employed and adjusted to estimate GPP at a 10 m resolution. The detailed specifications of the C5 prototype are outlined in Table 8.

Table 8. Technical and thematic specifications for the C05 candidate.

Candidate C05		
Candidate	C05 - Grassland and Cropland GPP	
Thematic specifications	GPP estimation at 10 m resolution over cropland and grassland locations based on Sentinel-2	
Specificity per phase	Phase 1	Phase 2
Parameters/Classes	GPP for gras and cropland	GPP for gras and cropland
Test sites	3 – Belgium 4 – Central Europe 6 - Romania	3 – Belgium Entire tile: 31UFS
Test Period	2017-present *For information:* *2018 =dry year* *2021 =normal/wet year*	2018 and 2022-present
Temporal frequency	Decade	decade
Spatial resolution	10 meters	10 meters
MMU	1 pixel	1 pixel
Envisaged accuracy	not defined	not defined

At the end of Phase 1, the project demonstrated significant advancements in developing a high-resolution GPP product specific to cropland and grassland. The resolution was increased from 300m to 10m, allowing for observation of within-field GPP variations, meeting a key user requirement. The existing Light Use Efficiency (LUE) method was adjusted by calibrating the LUE factor specifically for crop and grassland locations, resulting in high precision, particularly for cropland. Methodological advancements were implemented in OpenEO to ensure scalability. The prototype's results were verified for consistency across 150 samples of crop and grassland spread across Europe, showing strong consistency and robustness. This consistency is crucial for the continuity of products in the CLMS portfolio.

In phase 2, the GPP model was further developed by (1) recalibrating with the most recent available in situ data (a pipeline to collect and clean the in-situ data was set up) and (2) assessing different methodologies to include water/drought stress directly in the model. The final model is a model where (i) the temperature stress term was adjusted to reduce the underestimation in the GPP in the spring and winter months (i.e. compared to the current operational CLMS GPP 300m product) and (ii) a drought stress term based on soil water content and evapotranspiration is included.

3.6 C06 - Small landscape features mapping

Relevant CLMS thematic domain: Land cover and land use mapping: Forest products.

Small Landscape Features (SLF) are stable landscape elements that provide ecological and socio-cultural functions, categorized into four main areas:

- Soil and Water Conservation: Features like grass margins, hedgerows, and ditches slow runoff, filtering pesticides and pollutants before they reach surface waters.

- Climate Protection and Adaptation: SLF play significant roles in flood and landslide mitigation, carbon storage, and sequestration.
- Biodiversity Support: SLF facilitate species movement between habitat patches, offering important habitats and ecosystem services.
- Cultural Identity: SLF structure rural landscapes, reflecting local agricultural history and providing diverse traditional landscapes across Europe, thus holding cultural value.

Scope of this candidate: C06 aims to enhance the existing CLMS product, Small Woody Features (SWF), which maps hedgerows and tree patches across Europe. This will be achieved by including additional feature classes through the analysis of new Earth Observation (EO) datasets. The detailed specifications of the C06 prototype are outlined in Table 9.

Table 9. Technical and thematic specifications for the C06 candidate.

Candidate C06		
Candidate	C06 Small Landscape Features	
Thematic specifications	Mapping of woody vegetated features outside forest and stable landscape features within agricultural areas (grass margin, stone walls, ditches)	
Specificity per phase	Phase 1	Phase 2
Parameters/Classes	Small Woody Features + generic class of "nonproductive agricultural features"	SWF + grass margin, ditches, stone walls, ponds
Test sites	Small subset of tiles 1 – Spain 3 – Belgium 6 – Eastern Europe	1 – Spain 3 – Belgium 6 – Eastern Europe
Test period	2022	2020-2022
Temporal frequency	Annual	Annual
Spatial resolution	2,5 meters	5m
MMU	50m²	
Envisaged accuracy	HRL SWF 2018 as basis: 80% UA/PA	HRL SWF 2018 as basis: 80% UA/PA

As a result for Phase 1, the Small Landscape Features prototype combines supervised and unsupervised approaches, incorporates new landscape feature classes, and does not rely on existing datasets or intensive in-situ data collection, making it easily transferable to other areas. It is also computationally efficient and leverages super-resolution Sentinel-2 data, making it suitable for mapping smaller landscape elements. The existing small woody features class has been successfully extracted at an improved spatial resolution using Pleiades imagery. However, the prototype has some limitations. The new class of features is generic and does not yet differentiate specific landscape features (e.g., grass margins, ditches, stone walls) and contains commission errors that need filtering. Detecting these features from Sentinel-2 super-resolution data is a significant achievement, it implies a maximum spatial resolution of 5m. Additionally, Sentinel-2 super-resolution is not available from standard data hubs like the Copernicus Data Space Ecosystem (CDSE), necessitating substantial pre-processing before extracting landscape features.

As a result for Phase 2, we focused on the identification and discrimination of the "non-productive agricultural features" class into different heights SLFs, plus small ponds were added to this category of landscape features and work on change detection for small landscape features was carried on. The studied areas were extended to the whole tiles to prove applicability of the workflow at larger scale.

3.7 C07 - Improved water bodies mapping

Relevant CLMS thematic domain: Land cover and land use mapping: Water products.

To better understand changes in global water surface area, the production of accurate, regular, and comprehensive water extent data is essential. Within the framework of CLMS, water area delineation is a key component. Near-real-time mapping of water bodies from satellite imagery plays a critical role in effective water management.

Scope of this candidate: The objective of the Improved water bodies mapping candidate (Table 10) is to enhance current CLMS products, such as the Copernicus High-Resolution Layer Water and Wetness and the Copernicus Global Land Monitoring Water Bodies. Based on the user requirements, solutions were developed starting from the existing products. The detailed specifications of the C07 prototype are outlined in Table 10.

Table 10. Technical and thematic specifications for the C07 Candidate.

Candidate C07		
Candidate	C07 Water Bodies extent	
Thematic specifications	Map water bodies extent and type of water bodies (permanent and temporary)	
Specificity per phase	Phase 1	Phase 2
Parameters/Classes	Water bodies	Distinguished permanent and temporal water bodies
Test sites	1 – Spain 3 – Belgium 5 – Sweden 8 – Ivory coast	1 – Spain 3 – Belgium 5 – Sweden 8 – Ivory coast
Test period	2022	2020-2022
Temporal frequency	2 dates per year -dry/humid season	Near Real Time
Spatial resolution	10 meters	10 meters
MMU	0.1 ha	0.1 ha
MMW	Not applicable	Not applicable
Envisaged accuracy	>95%	>95%

By the end of **Phase 1**, the methodological developments had led to several key advantages. The algorithm was nearing demonstration stage, fulfilling all major requirements with low computational cost. It preserved the Sentinel-2 native 10m resolution for water likelihood maps and supported flexible temporal aggregation—from daily acquisitions to monthly composites. It successfully detected new and ephemeral water bodies, using GSWE as a weighting factor rather than a spatial constraint. Accuracy across the four test sites exceeded 97%, and the potential coverage was nearly global, consistent with the Sentinel-2 footprint.

Despite these strengths, some limitations remained. The use of static thresholds for spectral indexes, while effective, required tuning to ensure global applicability.

Likelihood weighting using Copernicus GLO-30 DEM slope data helped reduce false positives in shadowed areas but introduced over-detections due to its coarser resolution compared to Sentinel-2's 10m data.

To improve operational efficiency and detection accuracy, **Phase 2** focused on refining the methodology and addressing these limitations. Significant efforts in Phase 2 focused on addressing the limitations identified during Phase 1. Several key enhancements were implemented to improve the overall performance of the methodology. The approach for combining spectral indexes and defining thresholds was refined to enhance detection accuracy. A dynamic shadow mask was introduced to replace the previous slope-based mask, allowing for more effective handling of terrain-induced shadows. Additionally, GSWE was removed as a weighting factor to increase the algorithm's sensitivity to ephemeral water bodies. Finally, a dedicated approach was developed to distinguish between permanent and ephemeral water bodies in the final product.

Regarding data frequency, a Near Real-Time (NRT) product was identified as the most suitable format for water resource monitoring. Based on this decision, water body maps were generated for four test sites between 2020 and 2022, following an NRT update schedule.

The changes introduced in Phase 2 led to a range of product accuracies—from 72.31% in the worst-case scenario (Ivory Coast) to 98.42% in the best-case scenario (Spain). Although the overall accuracy slightly decreased compared to Phase 1, the relevance and robustness of the results improved significantly. The updated algorithm is now capable of reliably detecting ephemeral and/or newly formed water bodies.

Remaining limitations include reduced performance in snow-covered areas, scenes with low sun zenith angles, shadowed regions, and challenges in accurately detecting cloud shadows. Despite these constraints, the algorithm is approaching operational readiness and could be deployed in a production environment to generate NRT or lower-frequency water masks.

3.8 C08 - Continuous imperviousness monitoring

Relevant CLMS thematic domain: Land cover and land use mapping: Imperviousness products.

The HRL Imperviousness product monitors soil sealing percentages and the spatial distribution of artificially sealed areas, updating every three years. While most CLMS products are updated annually, the current HRL Imperviousness layer is produced every three years.

Scope of this candidate: The main objective is to demonstrate the potential for continuous monitoring and incremental updates of imperviousness. The goal is to implement a candidate at a finer 5m spatial resolution with monthly updates. The detailed specifications of the C08 prototype are outlined in Table 11. During Phase 1 of the project, the focus was placed on consolidating and testing the algorithms, which led to implementing the prototype at six-month intervals instead. Although monthly updates were initially planned for Phase 2, feedback gathered during a user webinar held between the two phases revealed that users preferred a six-month update cycle. The algorithms aim to maintain the quality and thematic accuracy of the products over time, ensuring temporal consistency in the time series.

Table 11. Technical and thematic specifications for the C08 candidate.

Candidate C08		
Candidate	C08 Continuous Imperviousness Monitoring	
Thematic specifications	Monitors the percentage of soil sealing and captures the spatial distribution of artificially sealed areas including the level of sealing of the soil.	
Specificity per phase	Phase 1	Phase 2
Parameters/Classes	Percentage of soil sealing	Percentage of soil sealing and change areas
Test sites	2 – Southern France 3 – Belgium 6 – Central Europe	2 – Southern France 3 – Belgium 6 – Central Europe
Test Period	2020-2022	2020-2022
Temporal frequency	Every 6 months	Every 6 months
Spatial resolution	5 meters	5 meters (status/change layer)
MMU	1 pixel	1 pixel
Envisaged accuracy	HRL IMD 2018/HRL NVLCC 2021 as basis: min 90% UA/PA for urban/sealed classes	HRL IMD 2018/HRL NVLCC 2021 as basis: min 90% UA/PA for urban/sealed classes

At the end of Phase 1, the project successfully demonstrated that the developed processing chain can efficiently handle substantial volumes of input data while delivering high-quality classification results. The integration of Sentinel-2 super-resolution technology has shown significant promise, enhancing the precision and overall quality of the processed data. These advancements not only meet the initial project objectives but also lay a solid foundation for further progress in subsequent phases. Despite these successes, some issues need addressing. Regression and thematic accuracy results indicate an underestimation of the imperviousness degree and commission errors. Errors of omission and commission are balanced across the three test sites, but commission errors appear underestimated. Differentiating rocks or bare soils remains problematic and requires attention in Phase 2. Omission errors are mainly associated with roads and isolated or scattered built-up areas.

These issues need to be addressed in the current phase 2. The work done on the training sample selection and the time series classification should help to improve the results.

The timeliness of the service may be improved in phase 2 but feedback collected during webinars organized with the end/core users tends to show that the monthly interval is not mandatory and the 6-monthly basis is preferred. The 6-month window will also allow the integration of Sentinel-2 time series into the processing chain which will significantly improve the artificial sealed areas detection.

For Phase 2, the project integrated the CLMS products from the current HRL Vegetated Land Cover Characteristics (VLCC) and Non-Vegetated Land Cover

Characteristics (NVLCC) 2021, including imperviousness, built-up areas, tree cover, crop types or grassland layers, in addition to the Open Street Map and the HRL Small Woody Features 2018 (2021 production not available). Due to the absence of in-situ or reference data on imperviousness, the Côte d'Ivoire test site could not be processed. Given the low priority assigned to global product coverage in the user requirements, efforts have been concentrated on the three European test sites. .

The derivation of the change layers, which includes the sealing and de-sealing information, was integrated in the processing chain in phase 2. Phase 2 also provided an opportunity to explore how the product could support the analysis of land loss or gain due to soil sealing. Although this aspect was not part of the technical specifications of the imperviousness products, potential synergies with the C09 prototype were examined. However, no conclusive results were obtained, primarily due to differences in the temporal coverage of the datasets. Change detection of urban features based on a 6-month period remains a challenge and is not fully mature.

Finally, the impact of a potential change in spatial resolution (upscaling from 10 to 5 meters spatial resolution) initially planned was not analysed in the phase 2.

3.9 C09 - Automated land use mapping of urban dynamics

Relevant CLMS thematic domain: Land cover and land use mapping: Urban atlas

The Urban Atlas Change Map allows monitoring of changes in urban areas. This map is updated every three years and is not automated at all. For a better monitoring of urban sprawl, urban renewal and renaturation, the interval needs to be reduced to 1 year thanks to an automated method.

Scope of this candidate: WP1 user requirements highlighted a strong desire for automated annual updates of land use products like the Urban Atlas, instead of the current three-year cycle. The candidate focuses on detecting urban dynamics using a nomenclature derived from the Urban Atlas, which includes various urban and rural classes. The detailed specifications of the C09 prototype are outlined in Table 12. The final layer produced by the prototype is a stand-alone layer of potential changes, and not an update from an existing layer. The minimum mapping units adhere to Urban Atlas rules: 0.25 ha.

Table 12. Technical and thematic specifications for the C09 candidate.

Candidate C09		
Candidate	C09: Automated land use mapping of urban dynamics	
Thematic specifications	Monitor the changes by detecting and characterizing them automatically	
Specificity per phase	Phase 1	Phase 2
Parameters/Classes	Delineation of changes + high level characterization of these changes (urban/natural)	Delineation of changes + detailed characterization of these changes (construction/landfill, sealed, natural/agricultural, woody, water)

Test sites	2 – Southern France 3 – Belgium 4 – Central Europe	2 – Southern France 3 – Belgium 4 – Central Europe 8 – Ivory Coast
Test Period	2020-2021	2020-2021 + 2021-2022
Temporal frequency	Annual	Annual
Spatial resolution	10 meters	5 meters
MMU	0.25ha	0.25ha
Envisaged accuracy	85%	85%

As result of Phase 1, the project has developed the first version of the prototype. Automating a process previously done by visual analysis was a significant challenge. Initially, we chose Sentinel-2 Level 2A data for the prototype, applying super-resolution to achieve precise delineations of change polygons in areas lacking in-situ data. However, Sentinel-2 L3A data later proved more suitable, particularly for eliminating clouds that could be mistaken for false changes, making super-resolution unnecessary. The processing, based on regularly available Sentinel-2 data, allows for annual updates with a latency of no more than one year. Since the product is not based on any existing product, it can be produced wherever L3A data is available, potentially covering all cities, towns, and suburbs.

For Phase 2, the main objective was to improve the characterisation of changes by going deeper in the nomenclature (more precise land cover classes), another point is to improve the detection by correcting the commissions and omissions. The "WP2 Method - Improved Resolution" was used to obtain the input EO Data Sentinel-2 L3A at 5m resolution and thus the output product at 5m resolution. The main challenge was to apply the processing chain to the Côte d'Ivoire test site, due to the lack of in-situ data and the landscape differences with Europe. Due to this lack of CLC data to train the classification model, data from Worldcover 2020 and 2021 were used as substitutes, but 2022 is not available. Therefore, the output layer for this Ivorian site is limited to the 2020–2021 period.

3.10 C10 - Continuous mapping of land surface characteristics

Relevant CLMS thematic domain: Land cover and land use mapping: land cover products

Most operational global land cover datasets, such as the Copernicus Global Land Service (CGLS) Land Cover product, NASA's MCD12Q1 dataset, and the ESA Climate Change Initiative (CCI) land cover dataset, classify the Earth's surface annually. While invaluable for various applications, their fixed legend systems and yearly updates do not support near-real-time monitoring of rapid or seasonal changes, such as forest loss or cropland rotations. Timely land cover information is crucial for understanding anthropogenic pressures, ecosystem states, and their evolution. Near-real-time mapping of basic, independent diagnostic categories, known as Land Surface Categories (LSC), can complement yearly land cover maps. Continuous LSC information can capture land cover dynamics and seasonal changes, supporting downstream applications like land cover and land cover change products. Other applications include mapping dynamics (e.g., snow, water, vegetation cycles) and generating user-defined classification systems (e.g., ephemeral vs. persistent water bodies).

Scope of this candidate: The scope of the C10 candidate is to develop a methodology to map near real time Land Surface Categories. User requirements indicated that the service should be used worldwide, the outputs should be used as inputs to other services, should support the mapping of water, wetlands, and detection of harvesting and emergence events. It should further provide data at 10m resolution, with a cadence of 3-10 days, minimum latency and have an accuracy of at least 85%. The detailed specifications of the C9 prototype are outlined in Table 13.

As a result of phase 1, we developed an initial methodology for near-real-time (NRT) mapping of Land Surface Categories (LSC). Visual inspection and evaluation on the test set indicated that the LSC captured the classes with reasonable accuracy, successfully detecting changes such as alternations between bare and herbaceous vegetation and forest loss. However, there are some challenges. The probability of the woody vegetation class over sparsely vegetated areas tends to show seasonal fluctuations, and there is confusion between the built-up and bare classes. Additionally, some artifacts, such as the prediction of water over topographic shadows, are still present.

During **Phase 2,** the C10 prototype for Continuous Mapping of Land Surface Categories (LSC) was further developed and tested across multiple sites, with the workflow implemented in the openEO environment to ensure scalability. The focus was on refining the continuous mapping methodology, assessing improvements in spatial, temporal, and spectral resolution, and integrating new in-situ training data. Evaluations confirmed that the system could capture dynamic surface changes such as transitions between bare soil and herbaceous vegetation as well as forest loss. However, several challenges remained: seasonal fluctuations in the woody vegetation class over sparsely vegetated areas, confusion between built-up and bare soil, and artefacts such as false water predictions in topographic shadows. Despite these limitations, Phase 2 demonstrated the feasibility of near-real-time monitoring of LSC, marking an important step toward operational use, while also highlighting the need for further refinements in data handling and classification.

Table 13. Technical and thematic specifications for the C10 candidate.

Candidate C10		
candidate	Continuous Mapping of Land Surface Characteristics	
Thematic specifications	Land Surface Categories (LSC) are basic, independent diagnostic categories and characteristics describing the properties of the Earth's surface. This deliverable describes the LSC prototype maps, produced at 10m resolution for single scenes over the test tiles	
Specificity per phase	Phase 1	Phase 2
Parameters / Classes	Woody vegetation, Herbaceous vegetation, Bare, Not vegetated, Snow and ice, Water, Clouds and shadows	Shrub, Herbaceous vegetation, Bare,, Snow/ice, Water, Built-up, Clouds, Shadows and No data
Test sites	Phase I: Belgium (3), Sweden (5) Phase II: Spain (1), Southern France (2), Belgium (3), Central Europe (4), Sweden (5), Eastern Europe (6), Cote d'Ivoire (8)	
Test Period	2020-2022	2020-2022

Temporal frequency	Single scenes (one scene per month for the year 2020)
Spatial resolution	10 meters
MMU	1 pixel
Envisaged accuracy	TBD

3.11 C12 - Tree Types Mapping

Relevant CLMS thematic domain: Land cover and land use mapping: Forestry products.

Mapping tree types is an essential step for understanding forest composition, monitoring forest health, and supporting biodiversity assessments.

Scope of this candidate: The focus of the C12 Tree Types prototype is the extension of the current CLMS Tree Cover & Forest portfolio to provide further information on the dominant tree species or genus (i.e. tree types). Therefore, the objective was to develop and test a methodology for mapping tree types in the Central European demonstration site, which was extended northwards, covering 25 Sentinel-2 tiles, in this case. The primary aim was to assess the potential of deep learning approaches, specifically the TempCNN model, to classify dominant tree species groups using Sentinel-2 time series, combined with in-situ reference data from the Global Biodiversity Information Facility (GBIF) and the state-wide forest inventory data for the state of Lower Saxony, Germany.

This prototype was introduced in **Phase 2** of the EvoLand project, as a direct reaction to evolving stakeholder requirements. The pixel-based results are provided at 10m spatial resolution for the reference year 2021.

Table 14. Technical and thematic specifications for the C12 candidate.

Candidate C12		
Candidate	C12 – Tree Types Mapping	
Thematic specifications	Mapping of European tree types on genus and species level, with 13 different classes.	
Specificity per phase	Phase 1	Phase 1
Parameters/Classes	N/A	0: No tree cover 21: Fagus 22: Quercus 23: Betula 24: Alnus 25: Populus 26: Other Broadleaved 31: Picea 32: Pinus 33: Other Coniferous
Test sites	N/A	4 - Central, extended to 25 S-2 tiles
Test period	N/A	2021
Temporal frequency	N/A	Three-yearly
Spatial resolution	N/A	10 meters
MMU	N/A	pixel based
Envisaged accuracy	N/A	Not defined

4. Evaluation of candidates

4.1 Benchmarking results

4.1.1 Summary table

The results of assessment after phase 1 of the EvoLand project are presented in subsections along overarching groups while the Table 15 below gives an overall overview of the benchmarking exercise.

The benchmarking method relies on three overarching groups to assess:

- **Science & Standards** to address theoretical scientific aspects,
- **Impact & Relevance**, to focus on answering to users & stakeholders, CLMS and policy environment needs
- **Operational Feasibility** to address the technical characteristics and operational implementation of each candidate.

Note that only candidates C01 through to C10 and C12 are benchmarked. Indeed, C11, which is an on-demand service, is not adapted to operationalization and has thus been removed from the evaluation process.

The full definition of benchmarking criteria and notation is given in section 2. The signification of the 5 levels of evaluation, ++, +, o, -, --. is recalled for each criterion (see relevant section). It is important to note that the scoring is qualitative, and an evaluation such as "–" should not be interpreted as negative. The best example is for the criteria 2, "Scientific acceptance", where "-" means "Novel" or "state-of-the-art" thus the method has not yet been described extensively in literature and ++ indicate an abundance of scientific work related to the methodology.

Table 15. Summary of assessment - all Benchmarking criteria.

Criteria	C01	C02	C03	C04	C05	C06	C07	C08	C09	C10	C12
Science & Standards											
Level of innovation	++	++	o	+	+	+	+	o/+	o	++	+
Scientific acceptance	+	-/o	-/o	o	+	o	+	o/+	-	o/+	+
Impact & Relevance											
Answering user needs	o/+	o/+	o	+	+	+	+	+/++	+	+	+
Portfolio complementarity	++	++	+/++	+	++	++	+	+/++	+	++	++
Future continuation potential	++	+ /++	o	o	+ /++	+	++	+/++	++	++	++
Backward compatibility potential	n/a	n/a	n/a	+	+	o	+	+/o	+	+	+
Link to policy	++	+	++	++	+/++	++	+/++	+	+/++	+	+
Operational Feasibility											
Adequate in situ data	+	-/o	o	-	o	-/o	o/+	+/o	o	o/+	-
Adequate EO data	+ /++	+	-/o	o/+	+	o	+/++	++	+	+/++	++
Level of automation	++	o/+	+	o/+	+/++	+	++	++	+/++	++	+
Timeliness	++	+	+/++	+	+	o	+/++	+	++	++	++
Scalability to EE38 / global scale	++	o	o/+	o	+	o/+	++	++	+	++	o/+

4.1.2 Detailed criteria analysis

4.1.2.1 "Science & Standards" benchmarking

For Science & Standards, we have analyzed that the scientific acceptance criterion is the most problematic. This is not in itself detrimental as many candidates are novel and the methods have yet to be published and disseminated within the community. Novel methods and workflows/approaches therefore have a lower rating (i.e. -/0 or o). This highlights where the efforts need to be targeted by the teams to establish and publish new methodologies and workflows, to ensure that each candidate is accepted and compliant with the CLMS requirements.

(1) Level of innovation

Table 16. Scoring description for the criteria "Level of innovation".

++	+	0	-	--
Highly Innovative**:** **A highly innovative service that brings significant improvements or entirely new capabilities compared to existing services. May rely on existing methods or features that haven't been used in this particular context.**	**Innovative:** A service that incorporates original elements or substantial improvements to existing products or services.	**Moderately innovative**: Offers some improvements or adjustments compared to existing products or services, though without significant innovation.	**Low Innovation**: A service which provides only minor improvements to existing products or services and shows limited novelty.	**Not Innovative:** A service with minimal or no improvements, closely replicating existing products or services without adding noticeable value.

Table 17. Evaluation of the candidates for the criteria "Level of innovation".

		Score	Comment
C01	**Continuous forest monitoring**	++	The algorithm 'Exponentially Weighted Moving Average' (EWMA) has been published and updated previously; hence it is not so novel anymore. It is tailored to forest monitoring, and the novelty lies in its implementation and Europe-wide application.
C02	**Forest disturbance mapping**	++	The algorithm (LightGBM classifier) can count as published/notonovel, but has not been used for this purpose of forest disturbances.
C03	**Forest biomass mapping**	o	The method as Random Forest (RF) is published and widely applied, but not so much for AGB or FCH. It is not novel itself. The use of GEDI for biomass mapping is a rather new development.

C04	**Cover crop type mapping**	+	The cover crop type mapping algorithm is a novel approach built on the well-established CatBoost machine learning framework. This candidate enhances and expands the existing "secondary crop" layer within the VLCC (Vegetation and Land Cover Characterization) suite, adding new capabilities for detailed identification and classification of cover crop types.
C05	**Cropland/grassland GPP monitoring**	+	The method is implemented at medium resolution in CGLOPS (e.g., Sentinel-3, Modis). The novelty is the implementation at a 10m spatial resolution and the inclusion of a drought indicator.
C06	**Small landscape features mapping**	+	The production is a combination of supervised and non-supervised classification. It is innovative for a CLMS products, even though it has not been published in a Scientific journal.
C07	**Improved water bodies mapping**	+	The new algorithm development improves accuracy and optimization of existing technology. The innovation resides also in the selection of the indices and the threshold for classifications, as well as ephemeral / permanent water bodies discrimination.
C08	**Continuous imperviousness monitoring**	o/+	Existing, well known and established algorithms and parameters (Machine learning and Random Forest and Pantex index) but new technologies with the super resolution techniques not yet used for such product that bring spatial resolution improvements compared to existing products. No innovative algorithm used (DeepLearning for example). For change detection, core algorithm is well-published (PCA).
C09	**Automated land use mapping of urban dynamics**	o	The processing chain is new and custom built. They are no peer reviewed yet. The core of the algorithm is already largely published (PCA).
C10	**Continuous mapping of land surface categories**	++	The LSC candidates use a new algorithm, which combines state-of-the-art deep learning (U-NET) and pixel-based (CatBoost) approaches. The continuous and near real time aspects make this prototype highly innovative.
C12	**Tree Types mapping**	+	The algorithm (TempCNN) is published, well known and well proven for LC classification tasks, based on time series data. The novelty is a large scale mapping of tree types on genus and species level and the prototype closes a gap in the CLMS portfolio.

This assessment highlights a range of innovative methods and tools used for environmental monitoring and land use applications, emphasizing advancements in spatial resolution, algorithmic design, and real-time processing, as well as implementation and verification of already existing methods that were previously only applied at research scales or in different domains.

All candidates have neutral or positive scores which are coherent in a project that aims to explore new approaches and solutions:

- C10 achieves the highest score, introducing a new algorithm with continuous and near real-time capabilities, marking a significant innovation.
- C01 and C02, while based on existing algorithms, are highly innovative in their respective fields of application.
- C04, C05, C06, C07, C08 and C12 are broadly new implementations of existing technologies that improve existing products without being groundbreaking.
- Finally, C03 and C09 are based on well-established algorithms and only offer some improvements to existing CLMS products.

(2) Scientific acceptance

Table 18. Scoring description for the criteria "Scientific acceptance".

++	+	0	-	--
Widely use: **methods regarded as best-in-class by global scientific community.**	**Well accepted:** methods are considered reliable, though not universally top choice.	**Mixed acceptance:** methods recognized in some studies, lack of consensus.	**Limited acceptance**: Methods not validated as best-in-class.	**Largely rejected:** or disregarded by the scientific community.

Table 19. Evaluation of the candidates for the criteria "Scientific acceptance".

		Score	Comment
C01	**Continuous forest monitoring**	+	The method is recommended by the JRC and is implemented alongside a few other methods in the JRC NRT tool). All those methods were developed for forest monitoring purposes, but the best in class is not evaluated, neither among the different methods in the JRC NRT tool, nor in comparison with other methods.
C02	**Forest disturbance mapping**	-/o	It has not been tested or published for that purpose of forest disturbances, and was tested against other algorithms during phase 2.
C03	**Forest biomass mapping**	-/o	Other approaches (e.g. SAR-based physical modelling) would be accepted by the scientific community (e.g., UT3 method).
C04	**Cover crop type mapping**	o	Although Catboost is generally considered one of the best & robust ML frameworks, there is no scientifically accepted method for mapping cover crop types
C05	**Cropland/grassland GPP monitoring**	+	The method has been published and validated using medium resolution input datasets (e.g., Sentinel-3, Modis)
C06	**Small landscape features mapping**	o	There is no real reference to assess these criteria. It is difficult to say whether it is accepted or not, because this a fully exploratory approach.
C07	**Improved water bodies mapping**	+	There is no reference because such candidate has not yet been validated. However, validation criteria are already good, based on widely used approaches
C08	**Continuous imperviousness monitoring**	o/+	The model uses recognized Machine Learning algorithms, the Pantex index is used and highlighted by the JRC in the detection of frames for example.
C09	**Automated land use mapping of urban dynamics**	-	Normally Deep Learning is used in literature, but there is a lack of sufficient reference data sets to train the model. PCA (Principal Component Analysis) is favored as it assures repeatability
C10	**Continuous mapping of land surface categories**	o/+	Few studies have been done on this topic. However, the state-of-the-art deep learning and pixel-based approaches applied for the candidate have been validated and published.
C12	**Tree Types mapping**	+	Recent studies have shown the potential of time-series analyses for tree species mapping at national to continental scales.

This evaluation examines the scientific acceptance of methods used in environmental and land monitoring candidates, focusing on the level of consensus among the scientific community regarding their reliability and efficacy. None of the candidates score very highly, which is to be expected as most approaches are either new or novel in their method, approach or application and have yet to be disseminated within the community. This is very much the purpose of this project, to try new methods and find out if they are beneficial to the user.

- C01, C05, C07 and C12 score the highest as they are based on existing algorithms which are well-known to the scientific community and their successful application is shown in several scientific publications. Within EvoLand, the algorithms have been applied slightly differently in a novel context (i.e. at higher resolution or within a Europe-wide scope).
- C02, C03, C08 and C10 are part of the lower scoring candidates, since they are either innovative and explorative approaches that are not widely used or are not tested or compared to other methods for these specific purposes and are hence novel in terms of their application.
- C09 score is low because it uses an accepted method which is not best-in-class.

4.1.2.2 “Impact & Relevance” benchmarking

In terms of **Impact & Relevance**, the analysis results show clearly that all the candidates are aiming to respond to the user needs and are impactful and adapted to the current CLMS portfolio, as well as to policy needs. There are some issues with future continuation potential, but this is not unexpected when working with new products where past data may not be available, or reference data existence or availability cannot be guaranteed in the future.

(3) Answering user needs

Table 20. Scoring description for the criteria “Answering User needs”.

++	+	0	-	--
Fully addressed: **user needs and stakeholder requirements are fully addressed**	**Well addressed:** Responds well to user needs but may not be comprehensive.	**Partially addressed:** needs further alignment.	**Limited alignment**: lack of critical aspects.	**No alignment:** Does not meet user needs or align with Copernicus products / documentation.

Table 21. Evaluation of the candidates for the criteria “Answering User needs”.

		Score	Comment
C01	**Continuous forest monitoring**	++	Fulfills all needs and offers closer temporal intervals as required, i.e., monthly updates then the desired yearly updates, hence provides additional on top of requirements. Moreover, an improved change detection even for yearly products results from this approach.
C02	**Forest disturbance mapping**	o/+	Fulfils the user needs but with some restrictions (i.e. exclusion of 1-2 drivers, merging of drivers are too difficult to be distinguished, reduction of temporal interval, reduced accuracy)
C03	**Forest biomass mapping**	o	Europe-wide 10m spatial resolution was required but likely cannot be done at desired quality (there is the CCI biomass 100m product), and not with the desired data (e.g. L-band or P-band SAR). The user requirement on forest canopy roughness is not addressed.
C04	**Cover crop type mapping**	+	Addresses the user requirement to provide information on cover crops at 10m spatial resolution.

C05	**Cropland/grassland GPP monitoring**	+	Answer well to the user's needs, the candidate (i) has a resolution of 10m, (ii) has the highest possible precision, (iii) is updated every 10 days and (iv) can be generated for the entire EU territory.
C06	**Small landscape features mapping**	+	The candidate is partially addressing users' needs. Not all classes are discriminated, there is a need for improvement. There is also a need for height data (Lidar) and more time series indices at a spatial resolution of at least at 5m.
C07	**Improved water bodies mapping**	+	The candidate is well answering to the user's needs. The new prototype can capture ponds under 1ha. It is at a resolution of 10m at the global level and can be produced on an NRT basis (better than at least monthly). New or ephemeral water bodies are considered and discrimination between permanent and temporal water bodies still needs validation..
C08	**Continuous imperviousness monitoring**	+/++	User's needs are partially addressed. The change detection has been done in phase 2 but does not address all the user requirements.
C09	**Automated land use mapping of urban dynamics**	+	The candidate partially addresses the users' needs. More frequent production (1 year) is ensured. The CLMS change of UA already exists on a 3-year basis.
C10	**Continuous mapping of land surface categories**	+	The candidate meets the 10m spatial resolution and near-real-time (NRT) cadence user requirement. The selected LSC classes are designed for flexibility in downstream applications, such as water dynamics mapping. Woody and herbaceous vegetation classes support the detection of harvesting and emergence events, although woody vegetation probability fluctuates seasonally, especially in dry areas. The prototype currently achieves an 82% overall accuracy.
C12	**Tree Types mapping**	+	C12 answers user needs as the information on tree species is a critical component for effective forest management, biodiversity conservation, and climate change research.

For this criterion, the candidates are evaluated regarding their ability to fulfill the user needs, which is a logical step when developing a concept into an actual product. Indeed, during this development phase, the development teams encountered many challenges that may impact the prototype's ability to meet the user requirements [AD1].

- We see that the limitations often come from insufficient spatial resolution, frequency or coverage of the EO input data as well as in situ data (C03, C04).
- For some candidates, at the end of phase 2, the user needs are fulfilled with some restrictions. (C02, C06, C07, C08, C09).
- Finally, a few prototypes already mostly to fully meet the user requirements (C01, C07, C10, C12)

(4) CLMS portfolio complementarity

Table 22. Scoring description for the criteria "CLMS Portfolio complementarity".

++	+	o	-	--
Substantial added value: **Provides substantial added value; unique or significantly**	**Added value**: new or improved products or service.	**Complementary features:** Offers some complementary features; may overlap with	**Minimal new capabilities:** Largely duplicate existing products or services;	**Redundant:** Entirely redundant with existing products or services.

enhanced prod-ucts or service.		existing products or services.	minimal new ca-pabilities.	

Table 23. Evaluation of the candidates for the criteria "CLMS Portfolio complementarity".

		Score	Comment
C01	**Continuous forest monitoring**	++	This product doesn't exist yet, so indeed it provides added value and fits well in portfolio
C02	**Forest disturbance mapping**	++	This product doesn't exist yet, so indeed it provides added value and fits well in portfolio
C03	**Forest biomass mapping**	+/++	This product doesn't exist yet, so indeed it provides added value, however, it is not sure where it fits into the portfolio.
C04	**Cover crop type mapping**	+	The Cover Crop candidate is novel and can potentially be in-tegrated within the HR VLCC to complement the existing secondary crop layer.
C05	**Cropland/grassland GPP monitoring**	++	The candidate Cropland/Grassland GPP monitoring proto-type at 10m is a new service, but exists in a similar form at low resolution, and is complementary to the HR VPP service.
C06	**Small landscape features mapping**	++	The ditches are new, all classes are new. So yes, indeed it pro-vides added value.to the existing portfolio.
C07	**Improved water bodies mapping**	+	This product already exists but at a coarse resolution. With a finer resolution of 10 m (possibility to be produced at 5m in phase 2), it enables distinction of permanent and ephemeral water bodies and NRT dynamic. This product provides an improvement that fits already in the portfolio.
C08	**Continuous imper-viousness monitoring**	+/++	The candidate already exists in the portfolio, but this proto-type provides added value thanks to the improved frequency and spatial resolution at 5m
C09	**Automated land use mapping of ur-ban dynamics**	+	The candidate urban atlas already exist in the portfolio, in-cluding a change layer between 2 periods. This product overlaps with the change layers, but as it is automatized and no longer a manual processing, it is complementarity, add-ing value with a more frequent update, a continuous process concept.
C10	**Continuous map-ping of land surface categories**	++	The LSC candidate is a unique new service, offering unique analysis ready datasets for several downstream service
C12	**Tree Types map-ping**	++	Yes. It does not exist yet and provides added value, while it fits into portfolio and is compatible with the existing CLMS Tree Cover & Forests products.

This criterion evaluates how well the candidates align with the existing CLMS portfolio, and how they would fit into the portfolio as complementary products. Unsurprisingly, there is generally good complementarity between the EvoLand prototypes and current CLMS products, indicating that the requirement identification process was conducted diligently.

- Several prototypes would be novel products which, however, fit well within the thematic scope and outline for desired developments, or would provide complementary products to already existing ones.
- Only C04, C07 and C09 do not score highly, with C09 being an automation of an existing product, which is currently produced manually.
- Regarding C07 and C08, a switch to a higher resolution or higher temporal frequency would be highly beneficial.

(5) Future continuation potential

Table 24. Scoring description for the criteria "Future continuation potential".

++	+	o	-	--
Strong assurance of long-term continuity: **Fully aligned with future Copernicus data missions, with guaranteed ongoing updates and compatibility. The service is expected to support seamless data streams well into the future.**	**Good potential for future continuation:** Ongoing updates and compatibility is likely to be established.	**Some potential for future series:** Ongoing updates and compatibility might be established (including workarounds) but is not certain.	**Limited capacity for future time series:** Ongoing updates and compatibility are expected to be limited.	**No potential for integration:** with future data.

Table 25. Evaluation of the candidates for the criteria "Future continuation potential".

		Score	Comment
C01	**Continuous forest monitoring**	++	There is no historical continuation of previous products, but the candidate definitely enables continuous time series into the future. Since the algorithm needs a 3-year training period before the start of analysis, the product could be generated as well backwards starting with 2018/2019 as analysis period (due to Sentinel-2 data being available since 2015/2016), if that would be desired.
C02	**Forest disturbance mapping**	+	There is no historical continuation of previous products, but the candidate definitely enables continuous time series into the future (or backwards starting 2018/2019). But C02 is hampered by the non-existing training data.
C03	**Forest biomass mapping**	o	There is no historical continuation of previous products, but future yearly products are enabled, as well as some years backwards depending on the input data situation. For the moment, the desired input EO data are not available which is expected to improve with the launch of future sensors.
C04	**Cover crop type mapping**	-	There is some potential for continuous time series into the future due to availability of Sentinel data. The lack of reference data remains the bottleneck for long term implementation of the candidate
C05	**Cropland/grassland GPP monitoring**	+/++	There is a high potential to create time series, including extending it to future datasets. The prototype requires high resolution VPP products.
C06	**Small landscape features mapping**	+	The candidate is not linked with historical data because it's new. There are some links with SWF (Small Woody features) for long terms to better discriminates SWF and the other classes.
C07	**Improved water bodies mapping**	++	Since there are long time series of optical imagery from 1984 until now, a homogeneous dataset can be produced and easily evolved in the future
C08	**Continuous imperviousness monitoring**	+/++	The production started from 2006, then continued in 2012, 2015, 2018, now 2021 and 2024. So, continuity is assured as long as S2 data are available. The algorithm relies on training data such as the building footprints from OSM, Google and Microsoft, the spatial continuity and quality of which could be heterogeneous across the EEA38.

C09	**Automated land use mapping of urban dynamics**	++	The production started from 2006, then continued in 2012, 2015, 2018, now 2021 and 2024. So, continuity is assured as long as S2 data are available.
C10	**Continuous mapping of land surface categories**	++	The method can be applied to past & future data. The main caveat is the need for partial re-training & in-situ data
C12	**Tree Types mapping**	++	Strong potential for regular (e.g. 3-yearly) updates as long as Sentinel-2 mission continues. Potential bottlenecks due to limited accessibility of high-quality, up-to-date training data.

This criterion assesses whether the candidate can provide future continuation of products at reference years or continuous time series information to end users. This may encompass the continuation of historical products or the ability to generate the candidate further into the future. This capability is crucial for users to investigate changes and trends, and for repeated updates of the candidate.

Almost all candidates score highly for this criterion, which is mostly connected to the continuous availability of EO data from the Sentinel satellites, both back to the past as well as into the future, whereas in situ data availability can reduce the score. For C03, C04 and C06 there are some exceptions:

- For C03, the desired input EO data is not available at the moment, which is expected to improve with the launch of future sensors, and provided the fact that those sensors will offer continuity into the future.
- C04 needs more reference data to better meet this criterion.
- C06 is a further novel development of the Small Woody Features (SWF) product and has limited VHR data available, both in the past as well as the future. However, VHR data quality and availability is expected to improve over time. Inclusion of Super Resolution Sentinel-2 can mitigate this situation, but frequent and homogenous VHR coverage is still mandatory to ensure requested improvements in product spatial resolution.

(6) Backward compatibility potential

Table 26: Scoring description for the criteria "Backward compatibility potential".

++	+	0	-	--
Seamless backward compatibility: Fully integrates with CLMS products or historical Timeseries without any modifications.	Strong backward compatibility: Mostly compatible with historical products, requiring minor adjustments or data conversion.	Moderate backward compatibility: Partial compatibility with historical datasets. Significant adjustments are needed to align with legacy products	Limited backward compatibility: Minimal integration with historical products	No backward compatibility: Incompatible with historical products

Table 27. Evaluation of the candidates for the criteria "Backward compatibility potential".

		Score	Comment
C01	**Continuous forest monitoring**	N/A	N/A (not applicable)
C02	**Forest disturbance mapping**	N/A	N/A (not applicable)
C03	**Forest biomass mapping**	N/A	N/A (not applicable)
C04	**Cover crop type mapping**	+	The method can be applied on the entire Sentinel-2 archive and potentially on the Landsat archive given that in situ data is available.
C05	**Cropland/grassland GPP monitoring**	+	This prototype can be performed from 2016 onwards.
C06	**Small landscape features mapping**	0	No historical data and limitation of availability of VHR.
C07	**Improved water bodies mapping**	+	The product can be reprocessed from the beginning of Sentinel, and even with Landsat data (1985) requiring minor changes, in order to refill Water bodies time series.
C08	**Continuous imperviousness monitoring**	0/+	The product is partially compatible with historical datasets. Although the thematic specifications align with the historical CLMS HRL IMD products, the improved temporal and spatial resolutions represent a new paradigm. Significant adjustments are needed to align with legacy products similar to those made when the HRL IMD products moved from a spatial resolution of 20 metres to 10 metres.
C09	**Automated land use mapping of urban dynamics**	+	Multiple iterations of the product done by this chain are compatible in term of format and can be reprocessed from the beginning of Sentinel 2.
C10	**Continuous mapping of land surface categories**	+	The LSC prototype can be run on the entire period where Sentinel-1 and Sentinel-2 overlap.
C12	**Tree Types mapping**	+	The method can be applied on the entire Sentinel-2 archive given that in situ data is available.

With the perspective to provide continuous time series of products at regular reference years based on historical data to the end user, this criterion assesses whether (i) the candidate is directly compatible with past productions or (ii) if it requires some modifications/adaptations to be compatible with past products or (iii) if the method can be applied to past raw data to generate the historical information.

This capability is crucial for users who want to investigate changes and trends, starting from past periods and using the candidate product to continue a seamless temporal analysis.

For new candidates, this criterion is naturally "non applicable". This is the case for the continuous forest monitoring, forest disturbance mapping and the forest biomass mapping, respectively C01, C02 and C03. For all other candidates, except for C06 and C08, the backward compatibility is considered as strong, mostly because the method can be applied to data acquired since the beginning of availability of Sentinel 1 and 2 images.

C06 and C08 are moderately compatible due to respectively the condition of availability of VHR images and the change of resolution that would require Significant adjustments to align with legacy products.

(7) Link to policy

Table 28. Scoring description for the criteria "link to policy".

++	+	o	-	--
Clear and direct link: **to EU/member state & global policies & indicators; supports implementation.**	**Supports specific policies:** on the topic, though impact may not be substantial. Policies are yet to be adopted.	**Supports general policies**: no specific policies are targeted; relevance unclear.	**Minimal:** unclear alignment with policies; limited support.	**No identifiable link:** to any policies; irrelevant in this context.

Table 29. Evaluation of the candidates for the criteria "link to policy".

		Score	Comment
C01	**Continuous forest monitoring**	++	Monitoring of forest changes/disturbances is clearly related to policies, e.g. EUDR.
C02	**Forest disturbance mapping**	+	It is linked to Forest policies, but it is not so clearly targeting policies as for C01, but the product offers the ability to distinguish between manmade forest removal and natural events (e.g., the annex of forest monitoring law in preparation).
C03	**Forest biomass mapping**	++	Linked to forest-carbon related policies, e.g. LULUCF
C04	**Cover crop type mapping**	++	Policies concerned include LULUCF, CAP, Biodiversity related
C05	**Cropland/grassland GPP monitoring**	+/++	Policies concerned include LULUCF, CAP
C06	**Small landscape features mapping**	++	There is a direct link to CAP (biodiversity, environmental protection, climate change), and Carbon sequestration (at least for SWF – Small Woody features -).
C07	**Improved water bodies mapping**	+/++	The output can be easily modified or used for different user applications: water management. Various EU policies, green deal, … Ramsar convention
C08	**Continuous imperviousness monitoring**	+	The product is already used by EEA and DG REGION (Zero artificialisation, 333). The products from the IMD portfolio are used to monitor urban growth, manage flood risk, protect biodiversity, or plan greener cities.
C09	**Automated land use mapping of urban dynamics**	+	The product is already used by EEA and DG REGION (Zero artificialisation, 333).
C10	**Continuous mapping of land surface categories**	+	The candidate links to NRT changes, occurrence & inter-annual dynamics which is demanded for several policies
C12	**Tree Types mapping**	+	Tree type mapping within European monitoring frameworks would provide valuable support for forestry, biodiversity conservation, and climate reporting

This criterion aims at rating the ability of candidates to support an executive body implementation and monitoring of a given policy. All candidates score highly on this, indicating once again that the requirements were well defined.

- C01, C03, C04, and C06 achieved the maximum score, closely followed by C05 and C07.

4.1.2.3 "Operational Feasibility" benchmarking

The results for **Operational Feasibility** are a bit more diverse. Lack of (adequate and sufficient) in situ data is a general issue for all candidates, despite a few copings a bit better than others due to their reduced need for training data. Lack of in situ data for validation affects all candidates, but this goes well beyond the EvoLand candidates and is almost inherent to all Earth observation products. Level of automation and Timeliness has high scoring values for all candidates, due to adequate infrastructure and data enabling technological advancements in these areas. Finally, in terms of scalability to pan-European or global scale, we see that this is challenging for 3-4 candidates. This means that it is unlikely that in the near future, the service will be available over the whole region of interest. But candidates cannot be put aside this criterion alone as the value of the service may be sufficient even on a restricted regional scale.

(8) Adequate in situ / validation data

Table 30. Scoring description for the criteria "Adequate In situ Data".

++	+	o	-	--
Full availability: **of in situ/validation data across EEA38 (or global) territory; comprehensive.**	**Mostly available:** minor gaps may exist.	**Partial availability:** significant gaps affect implementation.	**Insufficient data**: for comprehensive implementation; key regions missing.	**No adequate:** in situ/validation data available; candidate cannot be implemented.

Table 31. Evaluation of the candidates for the criteria "Adequate In situ/validation Data".

		Score	Comment
C01	**Continuous forest monitoring**	+	No data for training is needed (non-validated product of high quality could be created without in-situ data). Data for validation needs to be created.
C02	**Forest disturbance mapping**	-/0	There is a lack of regional training and validation data, some data needs to be created (would be required with good regional distribution). Main issues are about the timing of events (can be rapid and temporary) and reference data.
C03	**Forest biomass mapping**	0	In situ data to train the production is not fully available for Europe, likewise, to validate. GEDI is commonly used but is at lower resolution to train a 10m product, product stops at 51° north and is actually space data. NFI are more appropriate but are only available for some countries and with different level of detail and geolocation. Transfer of models to other regions must be tested. CCI biomass manages globally concluding to feasibility at lower resolution.
C04	**Cover crop type mapping**	-	In-situ data are limited in terms of availability. Only few countries report cover or secondary crops. LPIS datasets from Member States rarely include information on cover crops. Even when they do, as in the case of the Flemish LPIS, the secondary crop declarations carry some uncertainty.
C05	**Cropland/grassland GPP monitoring**	0	The main limitation is the scarcity of ICOS sites in Europe, especially over crop/grassland sites. Additionally, we have noticed some discrepancies in the quality of the ICOS data.

C06	**Small landscape features mapping**	-/0	For the different features, data can be found for the woody elements (CLC, CLMS, NFI, ...) but for the other classes, nothing has been found.
C07	**Improved water bodies mapping**	0/+	Few data are available to validate water bodies detection, even less to validate ephemeral/permanent water bodies classification. The use of GSW is a possibility but it is provided at 30m and not 10m as we aim to.
C08	**Continuous imperviousness monitoring**	+/0	Input data exists at the European level, the scope of this project (cf. EEA38 , open street map, Microsoft building, google building). We identified a possible lack on a global scale, but such a scale of production is not today a requirement for CLMS.
C09	**Automated land use mapping of urban dynamics**	0	Cadastral data are welcome to improve the delineation (but not available everywhere freely). The OSM data (OpenStreetMap) are available. CLC is needed to train the model for change identification.
C10	**Continuous mapping of land surface categories**	0/+	Global dedicated continuous LSC datasets are lacking. Alternatively, LSC samples can be derived from existing training data sources using some expert rules.
C12	**Tree Types mapping**	-	Access to high-quality in situ data is a challenge as national forest inventories are often not shared with precise coordinates to avoid disturbance of permanent samples. Class imbalance in existing reference data is an issue for the mapping of small classes.

The Adequate In-Situ/Validation data criteria assesses whether sufficient ground truthing data is available or not to ensure that a candidate can reach the required quality. As is shown in the Table 31, this is an area that can be improved for most candidates as there is a general lack of continuous in situ calibration/validation data, but this is generic to all forms of Earth observation data products.

- The lowest score "-" is due for C04 to minimal reporting on cover crops by member states and for C12 to the lack of high quality data from NFI .
- The "o" score is applied to C02, C03, C05, C06 and C09:
  - The problem for C03 is that in-situ data is only available partially and with varying detail and reference data from GEDI is also not available extensively.
  - C05 is affected by the limited number of iCOS sites and issues related to data quality, which lead to significant efforts in data cleaning.
  - In-situ data for the C9 candidate are available at the pan-European level, which includes cadastral data from each national database (where available) and the CLCplus dataset from the CLMS portfolio. At a global level, OpenStreetMap data is freely available, as is the WorldCover land cover classification. While there is a potential gap in data availability at a global scale, it is not currently necessary for the CLMS to fill this gap. The focus remains on using the existing products at a pan-European level.
  - The problem for C02 is that the candidate is hindered by the lack of detailed in situ datasets on forest disturbance agents and timing. The only reference are datasets, e.g. from the European Forest Fire Information System (EFFIS), or the National Detection System for Forest Damages (FNEWSs). Such data often misses the necessary thematic depth, spatial detail and/or the needed temporal information.
  - C06 lacks detailed in situ data on small landscape features
- The slightly higher "o/+" score is applied to C07, C08 and C10.

  - C07 algorithm at the end of phase 2 is independent from water bodies in situ data, relying completely on EO data (DEM, Sentinel-2). Otherwise, this score can be explained by the scarcity of in situ / validation data for water bodies in the world, and especially to validate the discrimination between ephemeral and in-situ data.
  - In situ data for the C08 candidate are available at the pan-European level, which includes datasets from sources such as the CLMS portfolio from the EEA (historical HRLs, HRL VLCC/NVLCC), OSM, Microsoft Building footprints, and Google Building). These datasets provide comprehensive and detailed information that is sufficient for the scope of the project. While we have a potential gap in data availability on a global scale, addressing this gap is not currently necessary for the CLMS. The focus remains on leveraging the existing pan-European level products
  - C10 scores above average as different in situ data sources can be harmonized and to retrieve land cover information.
- The highest score of "+" is applied to C01.
  - C01 scores the highest as it does not need training data, due to utilizing an unsupervised methodology. Nevertheless, validation data would be needed, but in situ data on forest disturbances is rather rare. Therefore, reference data was created from multiple data sources like the FNEWSs for Germany, containing reference data for forest disturbances (e.g. bark beetle and wind throw) and the EFFIS data, containing near real-time and historical information on forest fires.

(9) Adequate EO data

Table 32. Scoring description for the criteria "Adequate EO Data".

++	+	o	-	--
Fully available and adequate**:** **supports seamless implementation.**	**Mostly available and adequate**: minor gaps.	**Partially available**: significant gaps limit full deployment.	**Inadequate EO data:** affects candidate's accuracy.	**Lack of EO data:** deployment impossible.

Table 33. Evaluation of the candidates for the criteria "Adequate EO Data".

		Score	Comment
C01	**Continuous forest monitoring**	+/++	The EO data are available as the production is based on S2, a new S2 satellite has been launched a few months ago. The pre-processing and cloud-screening need to be improved. This candidate is, at the moment, based on optical data but we also compare it with a SAR-based approach (S1). For that the loss of Sentinel 1B hampers options.
C02	**Forest disturbance mapping**	+	The EO data are available as the production is based on S2, a new S2 satellite has been launched. The pre-processing needs to be improved. Same for the cloud-screening, although this is less of an issue than for C1. Leaf-off/winter season is not relevant with S2.
C03	**Forest biomass mapping**	-/0	The preferred data (long-wave SAR: NISAR, BIOMASS...) are not available. But some data is available (referring to S1, S2) and some ALOS (restricted temporal coverage, good quality of yearly mosaics, but analysis ready data (single scenes)). Concerning GEDI, it is only specific flights, (should ideally be repeated but it is on ISS) and is not the ideal data

			for continuation. Upcoming constellations might fill the gap in the future.
C04	**Cover crop type mapping**	0/+	Sentinel-1 and 2. Due to the acquisition period (winter) there is less high quality S2 data available. In addition, to better classify the different cover crops (incl. seed mixes from multiple plant families) additional EO data needs to be investigated.
C05	**Cropland/grassland GPP monitoring**	+	Yes, there is adequate EO data as the candidate is Sentinel-2 based. There might be however room to improve the ET component with Remote Sensing products
C06	**Small landscape features mapping**	0	This candidate needs VHR, annual coverage. It needs also, phenological data and time series for relative discrimination (coming from S2).
C07	**Improved water bodies mapping**	+/++	S2-based data are perfectly suitable. The processing also welcomes Landsat datasets.
C08	**Continuous imperviousness monitoring**	++	The production is Sentinel-2 based. Thus, the candidate can be produced as long as Sentinel 2 exists.
C09	**Automated land use mapping of urban dynamics**	+	Production is based on the Sentinel2-L3A (Theia method), it is available in some areas and can be processed on new areas on demand (e.g. Cote d'Ivoire).
C10	**Continuous mapping of land surface categories**	+/++	Yes, the method requires Sentinel-1 and 2
C12	**Tree Types mapping**	++	Yes (S-2 time series data is and will be available)

As is displayed in Table 33, most services have a satisfactory level of EO data availability except C03, C04 and C06.

- For the latter the limitation comes from using VHR data as the main input data source.
- For C03, sensors operating in the preferred SAR wave lengths are not available whereas C04 would require more Sentinel 2 data. These candidates would benefit from investigating additional EO data sources.

(10) Level of automation

Table 34. Scoring description for the criteria "Level of Automation".

++	+	o	-	--
Fully automated: **no human intervention required.**	**High automation**: occasional human oversight needed.	**Partial automation**: substantial human intervention required.	**Minimal automation: heavily** dependent on human operators.	**Not automatable:** full manual operation needed.

Table 35. Evaluation of the candidates for the criteria "Level of Automation".

		Score	Comment
C01	**Continuous forest monitoring**	++	Level of automation is high, due to unsupervised and automatic tool. Needs tuning for Europe (error handling etc.) then does not require human operators.

C02	**Forest disturbance mapping**	0/+	Algorithm runs automatic. Training data and algorithm training requires generation of data and human intervention (verification, feeding in algorithm, regional adaption of models, cross-checking for interpretation...).
C03	**Forest biomass mapping**	+	The algorithm runs automatic but needs pre-training, and that requires training data and then also validation data
C04	**Cover crop type mapping**	0/+	Some steps of the workflow can be automatized. However, there remains a need for data cleaning and interaction for model training.
C05	**Cropland/grassland GPP monitoring**	+/++	The candidate only requires manual interaction for calibration, once this is done the prototype can be automatised.
C06	**Small landscape features mapping**	+	The candidate does not require correction from human intervention for the woody. All processing is done on-demand because the main input data is VHR data.
C07	**Improved water bodies mapping**	++	The candidate is conceived to be easily used and deployed for mass production. Processing is automatic and allows scalability.
C08	**Continuous imperviousness monitoring**	++	The chain is currently 100% automated (training data, calibration and training models etc).
C09	**Automated land use mapping of urban dynamics**	+	The candidate does not need of human intervention except to prepare the data.
C10	**Continuous mapping of land surface categories**	++	Yes, high potential, once the model is trained it can be deployed automatically.
C12	**Tree Types mapping**	+	Preparation of training data requires manual interaction, but the model training and classification is done automatically

The level of automation criterion indicates whether a candidate can provide a product without human intervention. This is important to ensure the robustness of a service in an operational context.

As in shown in Table 35, most service are performing pretty well. C01, C07, C08 and C10 achieve the highest scores as they already operate without requiring human intervention.

In the case of C03, C05, C06, C09 and C12, at this stage of the development, only occasional human intervention is required. once the development phase is completed.

For C02 and C04, some steps still require human intervention making those candidates not yet ready for fully automatised operationalisations.

(11) Timeliness

Table 36. Scoring description for the criteria "Timeliness".

++	+	o	-	--
Optimal timeliness: **minimal latency for operational use.**	**Acceptable timeliness**: slight delays.	**Some delays:** may impact usability.	**Significant delays:** operational utility affected.	**Impractical:** Delivery timeline is impractical for timely use.

Table 37. Evaluation of the candidates for the criteria "Timeliness".

		Score	Comment
C01	**Continuous forest monitoring**	++	For 'monthly-resolved' yearly products: Trying to improve from VLCC (reference year+1): Pre-processing efforts hamper timeliness for, but automated workflow is in favour. In case of NRT: for NRT there would be different timeliness requirements which were not voiced yet by stakeholders (reference month + 1).
C02	**Forest disturbance mapping**	+	Pre-processing efforts hamper timeliness for delivery. Dependency on the C1 prototype and requires some post processing analysis.
C03	**Forest biomass mapping**	+/++	Yes, this could be a timely product delivered in a year after reference year, no NRT product, only yearly products.
C04	**Cover crop type mapping**	+	The timeliness depends on the publication of the VLCC products
C05	**Cropland/grassland GPP monitoring**	+	The candidate can be run in near real time, however there is a short delay due to smoothing of the input S2 timeseries.
C06	**Small landscape features mapping**	0	The availability of data (VHR) is the bottle neck. Processing S2 is OK.
C07	**Improved water bodies mapping**	+/++	The processing is conceived to be NRT-ready. It takes under 1 minutes for processing 1 tile.
C08	**Continuous imperviousness monitoring**	+	The candidate can be run continuously but requires minor adjustments to improve some time-consuming processes. The processing time for one tile using the CPU is 2 hours. Utilizing a GPU for the processing chain can also result in significant time savings. The current computation time of the Sentinel-2 super-resolution technology is prohibitively high for envisaging its full operationalization on a pan-European scale
C9	**Automated land use mapping of urban dynamics**	++	Concerning the latency, the candidate has no problem of calculation for yearly production and no issue of production, thanks to the near-real time availability of Sentinel-2 imagery.
C10	**Continuous mapping of land surface categories**	++	The model can operate in near-real time and can capture temporal fluctuations between different land cover classes such as sparsely vegetated areas and herbaceous cover.
C12	**Tree Types mapping**	++	Yes this could be a timely product delivered in year after the reference year, meeting requirements as implemented for other CLMS products.

The assessment of the timeliness criterion presented in Table 36, indicates that most services meet or exceed the required delivery timelines, which were defined based on current (e.g. reference year + 1 for the high resolution layers) or desired timeliness as stated in the user requirements. Timeliness will also be different for yearly products than for monthly to near-real-time products.

- The lowest score is for C06 because C06 is impacted by the unavailability of VHR data,
- The score "+" is achieved for C02, C04, C05 and C08. For instance, for C02 and C04, the timeliness is impacted by dependency on other products).
- The highest scores are achieved for C01, C03, C07, C09, C10 and C12.

- In the past the delivery time for Priority Area Monitoring products has been voiced to be too late for users, i.e. too far away from the reference year, which was clearly targeted to be improved with C09. Results are here.
- Timeliness was also a cornerstone of the C10 prototype, enabling the processing of near-real-time (NRT) sentinel-2 data streams and allowing for the accurate capture of water, snow, and cropland dynamics.

(12) Scalability to EEA38+UK/global scale

Table 38. Scoring description for the criteria "scalability to EE38/global scale".

++	+	o	-	--
Full scalability: **across the entire EEA38 (or global) territory.**	**Mostly scalable:** across EEA38 (or globe); minor limitations.	**Limited scalability**: restricted to certain regions.	**Highly restricted:** scalability; small coverage area.	**No scalability:** Cannot be scaled beyond limited area; utility severely restricted.

Table 39. Evaluation of the candidates for the criteria "scalability to EE38/global scale".

		Score	Comment
C01	**Continuous forest monitoring**	++	Can be rolled out (no regional training data needed etc.)
C02	**Forest disturbance mapping**	0	limited scalability due to need for reference data; regional differences; but some workarounds possible; scalability not sufficiently tested.
C03	**Forest biomass mapping**	0/+	Regional adaptation of models still not clear. GEDI as reference data, even if not fully area-covering and at 100m, but globally available. Is stand-by on ISS and is planned to fly again; scalability not sufficiently tested.
C04	**Cover crop type mapping**	-	There is a limited potential to scale this candidate due to need for reference data or lack thereof.
C05	**Cropland/grassland GPP monitoring**	+	Yes, there is potential for scalability, but the main drawback is the limited number of ICOS sites.
C06	**Small landscape features mapping**	o	The workflow is easily scalable, the current limitation comes from the availability of data (VHR images). Processing S2 is OK.
C07	**Improved water bodies mapping**	++	The candidate can be scaled European and global level.
C08	**Continuous imperviousness monitoring**	++	The candidate has full scalability across the entire EEA38+UK (or global) territory
C09	**Automated land use mapping of urban dynamics**	+	The candidate is scalable because only EO data are needed to run the chain. They are slight limitation for in-situ data (cadastral).
C10	**Continuous mapping of land surface categories**	++	Yes, the model can be scaled to cover EEA38+UK/global
C12	**Tree Types mapping**	0/+	Scalability is generally given. The availability of adequate reference data is a limiting factor.

This final criterion covers the spatial coverage capabilities of each candidate, namely whether it can easily cover the EE38+UK or a global geographical extent.

Only C02, C03, C04, C06 and C12 display clear limitations.

- For C02, C04 and C12, this is due to limited training and validation data,
- For C06, the lack of VHR data is an issue. and due to regional calibration.
- C03 has not yet been sufficiently tested to clearly define its capability for scalability, which will be hampered by regional calibration and the availability of input data covering the full territory.

All the other candidates are expected to be feasible for scaling up although there are some limitations for C05 and C09.

4.2 Technology Readiness Level

4.2.1 Summary table

The Technology Readiness Level (TRL) reached for each candidate at the end of phase 2 of the EvoLand project is presented in the table below and commented in the next paragraph. The definition of the TRL criteria is given in section 2.3. The target is to achieve TRLs between 7 and 8 for future integration.

Table 40. Technical Level Readiness per candidate

	Technology Readiness Level (TRL)	1	2	3	4	5	6	7	8	9
		Basic Research		Applied research		Technology Development		System Development		
C01	Continuous forest monitoring									
C02	Forest disturbance mapping									
C03	Forest biomass mapping									
C04	Cover crop type mapping									
C05	Cropland/grassland GPP monitoring									
C06	Small landscape features mapping									
C07	Improved water bodies mapping									
C08	Continuous imperviousness monitoring									
C09	Automated land use mapping of urban dynamics									
C10	Continuous mapping of land surface categories									
C12	Tree Types Mapping									

4.2.2 TRL analysis

The TRL table shows a wide range of readiness levels:

- Candidates C02, C03, and C06 are still in the Applied research phase, at the proof-of-concept stage to be candidates before moving to technology Development.
    - The C02 prototype is largely depending on adequate training data which is currently not available to a sufficient extent for a European scale roll-out, and the level of automatization needs to be improved.
    - Adequate in situ data is the main bottleneck for the C03 prototype, which hinders scaling out the prototype to other data poor regions.

  - Industrialization of C06 prototype (as explained in previous sections) is mainly dependent on VHR availability (feasibility of annual coverage + associated costs) for annual update of the product.
- Candidates C01, C04, C07, C08, C09 and C12 are still under Technology Development, they require more work to become operational.
  - The C1 prototype still needs improvements in the pre-processing efforts to move to a higher TRL.
  - C04: the lack of in situ data hinders the application of this prototype in additional sites.
  - C07: Robustness could be strengthened before being deployed in a pre-operational environment.
  - C08: The processing time for one tile using the CPU is 2 hours (pre-processing, classification and post-processing) and is therefore not scalable to European territory for a monthly or 6-monthly update. The following industrialization activities would be to improve the use of a GPU for the processing chain, which could also result in significant time savings.
  - C09: The system has been validated into a development environment and has been tested to a larger scale into a relevant environment. The chain is dockerized and would be ready to start industrial testing.
  - C12: Further improvements have to be made for the handling of minority classes. Transferability across Europe has to be assessed in detail, as well as the integration of additional data to enhance discrimination between species
- Candidates C05 and C10 have already demonstrating significant maturity.
  - C05: the prototype has been successfully applied on Sentinel-2 data, and considerable improvements were made on including a drought indicator to the model.
  - C10: allows to predict NRT changes in LSC. The model uses the NDVI profile of the past year to reduce seasonal fluctuations in woody vegetation cover. The implemented model captures the water, snow, and cropland dynamics well. Additional finetune can be done before making the prototype operational.

5. Use cases

The following chapter provides an overview of potential use cases in relation to candidates.

5.1 C01 – Continuous Forest Monitoring

The C01 Continuous forest monitoring candidate would be a valuable data service for various applications. Potential use cases are:

Use case 1: EUDR - Regulation on Deforestation-free Products

Promotion of the consumption of deforestation-free products, reducing the impact on global deforestation and forest degradation triggered by the EU, and thus reducing greenhouse gas emissions and biodiversity loss. Therefore, commodities that have been produced in areas deforested after 31.12.2020, may no longer be imported into the EU.

Problem
The production of various goods like cattle, wood, cocoa, soy, palm oil, coffee, rubber, and derivatives thereof, such as leather, chocolate, tires or furniture, drives deforestation around the globe. The EU is a major consumer of such goods and therefore partially responsible for this problem outside of Europe (European Commission, 2025). Moreover, wood, soy and cattle produced within the EU needs to be regulated.

Solution
Getting precise information on forest change by detecting spatial and temporal patterns of tree cover loss on a dense Sentinel-2 time series at 10m spatial resolution. The product provides monthly/Near-Real-Time (NRT) information on tree cover disturbance location and timing.

Policy impact
Especially the temporal component, with the identification of the point in time, when a tree cover disturbance happened, can support the monitoring for the EUDR.

Potential users & stakeholders
The European Commission, National authorities, all companies that import, place on the European market or export one or more of the affected raw materials or specific derived products, (cattle, wood, cocoa, soy, palm oil, coffee, rubber), farmers producing and selling the products to traders exporting to the EU.

5.2 C02 – Forest Disturbance Mapping

The C02 Forest disturbance mapping candidate would be a valuable data service for various applications. Potential use cases are:

Use case 1: Monitoring of forest disturbance agents with a focus on insect infestations

Detect the drivers of forest/tree cover disturbances (i.e. insect infestations, windthrow, wildfires and thinning/clearing). S special focus on insect infestations in Europe is of potential interest to the users, to be able to detect the disturbances, take the right measures, i.e. for prevention of further damage, as well as planning of afforestation. Further, enable efficient use of affected wood and planning for timber industry and provide input for insurance companies to verify loss.

Problem
With changing climate conditions and thus more frequent extreme weather events, like droughts or heavy thunderstorms, European forests are getting more vulnerable to insect infestations due to decreasing resistance. Infestations, e.g. by bark beetle, is being facilitated and their impact is more severe. Early detection and close monitoring are therefore urgently needed to be able to act accordingly and protect and restore the European forests.

Solution
The C02 candidate provides information on the agent/driver of a forest disturbance event (loss of tree cover/tree cover density), mapping:

- Insect infestation (e.g. bark beetle)
- Wind throw/storm damage
- Wildfire
- subsequent human-induced forest clearing, as well as
- clear cut and logging/thinning activities

Policy impact
The Forest disturbance monitoring can potentially provide valuable input to various policies like the EUDR and to the Sustainable Development Goals (SDGs) 13 (Climate Action) and 15 (Life on Land).

Potential users & stakeholders
Forest authorities, private forest owners, Insurances, the woodworking industry.

5.3 C03 – Forest Biomass Mapping

The C03 Forest biomass mapping candidate would be a valuable data service for various applications. Potential use cases are:

Use case 1: Modelling of carbon cycles

Provide valuable information on the amount of carbon stored in forest ecosystems.

Problem
Biomass estimation is vital for assessing the role of forests in carbon cycling, understanding their contribution to climate regulation, evaluating their capacity to support biodiversity, and performing ecosystem accounting. In that sense it is an important input for example for the nationally determined contributions (NDCs), being the core of the Paris Agreement.

Solution
Mapping Above-ground woody Biomass (AGB) estimation in tons/ha as oven dry weight of the woody parts (stem, bark, branches and twigs) of all living trees excluding stump and roots, as well as Forest Canopy Height (FCH), both on an annual basis.

Policy impact
Policies like the SDGs 13 (Climate Action) and 15 (Life on Land) need data for monitoring, where modelling of carbon cycles with help of the biomass mapping can be an important input.

Potential users & stakeholders
National and international authorities entrusted with climate protection.

Use case 2: Estimation of potential wood supply

Estimation of the potential timber yield of forest areas, enabling reliable inventories of forest areas and potential supply for industry.

Problem
Forest owners might be interested in the potential timber yield of their forest areas, to be able to estimate value, plan efficient harvest and subsequent afforestation activities. Further, such estimations help to assess the loss in case of damage, e.g. due to windthrow or insect infestations.

Solution
Mapping Above-ground woody Biomass (AGB) estimation in tons/ha as oven dry weight of the woody parts (stem, bark, branches and twigs) of all living trees excluding stump and roots, on an annual basis.

Policy impact
N/A

Potential users & stakeholders
Forest authorities, private forest owners, the woodworking industry.

5.4 C04 – Cover Crop Type Mapping

The C04 Cover crop type mapping candidate would be a valuable data service for various applications. Potential use cases are:

Use case 1: CAP Compliance & Subsidy Verification

Problem:
Ensure that farmers adhere to Common Agricultural Policy (CAP) regulations by verifying the use of cover crops as part of eco-schemes and Good Agricultural and Environmental Conditions (GAEC) standards.

- CAP eco-schemes require farmers to implement cover cropping for soil health, biodiversity, and carbon sequestration.
- Manual inspections are expensive, time-consuming, and prone to errors.
- Farmers may falsely report cover crops to qualify for subsidies.

Solution:

- Automated detection of cover crops at 10m resolution using multi-temporal Sentinel-1 & Sentinel-2.
- Differentiates true cover crops vs. bare soil, weeds, or cash crops.
- Near-real-time (NRT) updates allow continuous monitoring rather than relying on annual field surveys.

Policy Impact:

- Supports CAP[3] subsidy allocation based on verifiable cover crop usage.
- Ensures compliance with GAEC standards[4], reducing the risk of fraud.
- Provides EEA, JRC, and national paying agencies with an efficient MRV (Monitoring, Reporting, and Verification) tool.

Potential users & stakeholders

- EU Commission (DG AGRI, DG CLIMA, DG ENV) - Law enforcement
- National Agencies - CAP subsidy allocation
- Farmers & Cooperatives - CAP compliance verification

5.5 C05 – Cropland/Grassland GPP Monitoring

The C05 Cropland/grassland GPP monitoring candidate would be a valuable data service for the Copernicus Land Monitoring Service. Potential use cases are:

Use case 1: Improvement of the spatial resolution of the CLMS HR-VPP service

Problem
Current CLMS GPP products rely on medium-resolution imagery (Sentinel-3, MODIS), making them insufficient for detailed cropland and grassland productivity monitoring.

[3] Common agricultural policy - European Commission
[4] Glossary:Good agricultural and environmental conditions (GAEC) - Statistics Explained

Solution
Improved crop yield estimation, from 300m to 10m, allowing for within-field variation analysis

Policy Impact
- Beneficial for policymakers and food security organizations monitoring European agricultural production trends.
- CAP[5] through monitoring the performance of agricultural policy.

Potential users & stakeholders
- European Environment Agency (EEA) – The contracting authority overseeing the Copernicus Land Monitoring Service (CLMS).
- National and Regional Authorities – Environmental agencies, ministries, and local governments.
- Scientific & Research Communities – Universities, research institutes, and projects studying vegetation phenology, land cover dynamics, and climate impacts.

Use case 2: Including drought stress the GPP calculation.

Problem
The CLMS GPP calculation does not include any drought indicators which is a known weakness of the model.

Solution
An improved GPP product which considers drought. Developed prototype demonstrates that the accuracy of the GPP product improved by including a drought stress indicator.

Policy Impact
Integrating drought stress into the GPP calculation enhances the accuracy of climate impact assessments, particularly for agriculture and ecosystem monitoring. This improvement provides policymakers, land managers, and stakeholders with more reliable data on drought-induced vegetation stress.

Potential users & stakeholders
- European Environment Agency (EEA) – The contracting authority overseeing the Copernicus Land Monitoring Service (CLMS).
- National and Regional Authorities – Environmental agencies, ministries, and local governments.
- Scientific & Research Communities – Universities, research institutes, and projects studying vegetation phenology, land cover dynamics, and climate impacts.

5.6 C06 – Small Landscape Features Mapping

The C06 Small Landscape Features candidate can be envisaged as useful input for different use cases related to biodiversity monitoring.

Use case 1: Indicator for the CAP

Problem
The CAP[6] includes assessment and monitoring of landscape features in agricultural areas. Solutions are need.

Solution:
CLMS HRL SWF is already used as a useful input for the CAP requirement and especially computation of CAP indicator I.21 aiming at assessing the area covered by

[5] Common agricultural policy - European Commission
[6] https://agriculture.ec.europa.eu/common-agricultural-policy/cap-overview/cap-glance_en

landscape features in agricultural land. SLF prototype will increase the relevance of this indicator computation by including additional landscape features.

Policy Impact
Beneficial for policy makers and organizations involved in ecosystem monitoring services and CAP.

Potential users & stakeholders
- European Environment Agency (EEA) – The contracting authority overseeing the Copernicus Land Monitoring Service (CLMS).
- National and Regional Authorities – Environmental agencies, ministries, and local governments.
- Scientific & Research Communities – Universities, research institutes, and projects studying vegetation phenology, land cover dynamics, and climate impacts.

Use case 2: Carbon Sequestration

Problem
Carbon sequestration measurement relies heavily on National Forest inventories which are focused on forested areas as defined by policies. Trees outside those forested areas also play a role in carbon sequestration and should be identified and monitored to update carbon sequestration assessment.

Solution:
By mapping small woody elements outside forests, SLF prototype will also contribute to better assessment of woody coverage not mapped by conventional landcover maps or forest inventories, impacting Carbon Sequestration assessment in a significant way for areas where fragmented landscapes are common.

Policy Impact
Beneficial for policy makers and organizations involved LULUCF[7] regulation, European Climate Law[8] and greenhouse gas emissions monitoring.

Potential users & stakeholders
- European Environment Agency (EEA) – The contracting authority overseeing the Copernicus Land Monitoring Service (CLMS).
- National and Regional Authorities – Environmental agencies, ministries, and local governments.
- Scientific & Research Communities – Universities, research institutes, and projects studying vegetation phenology, land cover dynamics, and climate impacts.

5.7 C07 – Improved Water Bodies Mapping

The C07 improved water bodies mapping candidate would be a valuable data service for various applications to assess the changes of water content for both climate studies and water stock monitoring. Potential use cases are:

Use case 1: Drought surveillance

Problem

During drought events, the monitoring of water surfaces at a regional level is a key factor to establish the impact of water scarcity. Indeed, along with flora and fauna impact, irrigation and nuclear plant cooling might suffer from lack of awareness in

[7] https://climate-energy.eea.europa.eu/topics/climate-change-mitigation/land-and-forests/intro
[8] https://climate.ec.europa.eu/eu-action/european-climate-law_en

water availability at a given date. An accurate, regular and reliable information of water surface estimate is thus needed.

Solution:
The provision of high pace water surfaces is a crucial information to estimate the availability of water resource and their potential change with time over a whole area. The provision of water pixels being permanent or temporary adds a new information on a drought impact on the water surface.

Policy Impact
Proper drought surveillance may help the deciders to have an accurate knowledge of the water availability at a given date, providing them with information about areas which are under water stress or not for better policy making.

Potential users & stakeholders

- European Environment Agency (EEA) – The contracting authority overseeing the Copernicus Land Monitoring Service (CLMS).
- National and Regional Authorities – Environmental agencies, ministries, and local governments.
- Scientific & Research Communities – Universities, research institutes, and projects studying vegetation phenology, land cover dynamics, and climate impacts.

Use case 2: Flood monitoring / prevention (past floods)

Problem:
During flood events, the knowledge of precise flood extent is of sheer interest to know where to deploy rescue teams, the impact on urban areas and the accessibility of roads.

Solution:
The correct classification of the pixels on a satellite image as being water or not helps monitor such event with high precision and rapidly. The robustness of the algorithm is key to detect properly water with high deposit content or not, but also to detect areas which correspond to permanent or temporary water pixels, and that as fast as possible for fast distribution of the data.

Policy Impact
A proper flood extent delineation helps the deciders in where to dispatch the rescue teams, and which roads are to be closed to traffic. The knowledge of past flood events might also drive the choice to be made in terms of legislation (buildable areas, road construction suitability, etc.).

Potential users & stakeholders

- European Environment Agency (EEA) – The contracting authority overseeing the Copernicus Land Monitoring Service (CLMS).
- National and Regional Authorities – Environmental agencies, ministries, and local governments.
- Scientific & Research Communities – Universities, research institutes, and projects studying vegetation phenology, land cover dynamics, and climate impacts.

Use case 3: Input to water stock monitoring

Problem:
The overall monitoring of water stocks at a regional level (or higher) cannot be done properly without in-situ gauges or accurate water surfaces time-series.

Solution:
Hybridized with hypsometric or area-volume rating curves, the water bodies' areas can provide estimate of water quantity changes and stocks, allowing the development of water management capacities from space alone.

Policy Impact
The knowledge of available water stocks at a given date may help to prepare the future needs and use at a regional level and drive the policies to be made. It can also help dam manager to take the action of filling or emptying a reservoir during snow melt or heavy rainfall events for instance, to avoid dam failures or overflowing, leading to flood events.

Potential users & stakeholders
- European Environment Agency (EEA) – The contracting authority overseeing the Copernicus Land Monitoring Service (CLMS).
- National and Regional Authorities – Environmental agencies, ministries, and local governments.
- Scientific & Research Communities – Universities, research institutes, and projects studying vegetation phenology, land cover dynamics, and climate impacts.

5.8 C08 – Continuous Imperviousness Monitoring

The C08 Continuous imperviousness monitoring candidate would be a valuable data service for various applications to improve land management. Potential use cases are:

Use case 1: Urban Planning

Problem:
Urban expansion often leads to increased impervious surfaces, such as roads, buildings, and parking lots, which can have significant environmental and socio-economic impacts: urban heat island effects, reduced water infiltration, increased flooding risks, and loss of biodiversity. Additionally, rapid urbanization can occur without adequate planning, making it difficult to ensure sustainable development, efficient land use, and resilient infrastructure.

Solution:
Mapping the impervious surfaces can contribute to identifying the new urban areas, the urban densification and the transformation of green areas into built-up zones (green parks and areas to mitigate heat island effects), and so, contribute monitoring the urban expansion over time to support sustainable city growth.

Policy impact:
Accurate impervious surface mapping can contribute to the development of policies that regulate land-use planning, environmental conservation, and climate adaptation.

Potential users & stakeholders
- European Environment Agency (EEA) – The contracting authority overseeing the Copernicus Land Monitoring Service (CLMS).
- National and Regional Authorities – Environmental agencies, ministries, and local governments for policy making, land-use regulation, environmental and biodiversity protection, climate resilience strategies.
- Urban planners, real estate developers for sustainable development of infrastructure
- Scientific & Research Communities – Universities, research institutes.

Use case 2: Flood risk and Management

Problem
Impermeable surfaces prevent water from naturally infiltrating the ground, leading to increased surface runoff. This excess runoff can overwhelm drainage systems, heightening the risk of flash floods, particularly in densely built urban areas. In coastal regions, urban expansion further exacerbates flood risks by reducing water infiltration capacity and altering natural hydrological patterns. Without proper monitoring and management, uncontrolled urbanization can significantly increase the frequency and severity of flooding events, threatening infrastructure, public safety, and water quality.

Solution
Through the monitoring and regulation of these surfaces, urban planners can alleviate the threat of flash floods caused by intense discharge. This may entail the implementation of more permeable surfaces in the areas, or the development of efficient drainage systems. Regarding the issue of coastal and river flooding, mapping the impermeable surfaces can also contribute evaluating how urbanization affects flood prone areas and water infiltration capacity to support latest prevention regulation.

Policy Impact
Data on impervious surfaces can support the development of regulations aimed at reducing flood risks and improving water management

Potential users & stakeholders
- European Environment Agency (EEA) – The contracting authority overseeing the Copernicus Land Monitoring Service (CLMS).
- Urban planners, local authorities and real estate developers to design flood-resilient cities and incorporate permeable surfaces
- Risk management organizations to implement flood mitigation policies and strategies

Use case 3: Biodiversity and Environment ecosystem

Problem
Extensive impervious surfaces contribute to habitat fragmentation and biodiversity loss. As urban areas expand, natural ecosystems are impacted, reducing the connectivity of habitats and limiting the movement of wildlife. Additionally, the conversion of agricultural and natural lands into built-up environments leads to the loss of green spaces, diminishing ecosystem services such as carbon sequestration, and water filtration. Without proper monitoring and management, urbanization can accelerate environmental degradation, threatening biodiversity.

Solution
Monitoring such surfaces helps in identifying critical areas where the natural environment is under stress, guiding conservation efforts and the integration of green spaces in urban planning. Mapping the impermeable surfaces can also contributes monitoring the loss of agricultural or natural lands to urban expansion.

Policy Impact
Mapping the impermeable surfaces can help supporting policy actions to preserve ecosystems such as the EU's Biodiversity strategy for 2030.

Potential users & stakeholders
- European Environment Agency (EEA) – The contracting authority overseeing the Copernicus Land Monitoring Service (CLMS).
- National, Regional and Local Authorities – Environmental agencies, ministries, and local governments to protect ecosystems.
- Urban planners, real estate developers for sustainable development of green infrastructure, ecological corridors.
- Agricultural authorities to monitor and prevent the loss of productive lands.
- Scientific & Research Communities – Universities, research institutes for ecological studies.

Use case 4: Climate change and environmental impact studies

Problem
Impervious surfaces absorb and retain heat more than natural environments, leading to elevated temperatures in urban areas. This phenomenon, known as the Urban Heat Island effect, has an impact on the climate change by increasing energy consumption, deteriorating air quality, and posing health risks such as heat-related illnesses. Additionally, prolonged exposure to higher temperatures can reduce the liveability of cities, disproportionately affecting vulnerable populations,

Solution
Monitoring these surfaces allows the adoption of measures such as green roofs, urban vegetation, or reflective materials to mitigate urban heat island effect.

Policy Impact
Impervious surfaces monitoring can support policies aimed at reducing the urban heat island effect and enhancing climate adaptation efforts. Mapping the impervious areas can also help estimating the carbon footprint and the CO_2 emissions linked to the urban expansion.

Potential users & stakeholders

- European Environment Agency (EEA) – The contracting authority overseeing the Copernicus Land Monitoring Service (CLMS).
- National, Regional and Local Authorities – Environmental agencies, ministries, and local governments for policy making, urban regulation.
- Urban planners, real estate developers for sustainable development of infrastructure
- Public health agencies to address heat-related illnesses and create awareness about urban heat risks.
- Scientific & Research Communities – Universities, research institutes.

5.9 C09 – Automated Land-use Mapping of Urban Dynamics

The C09 Automated land use mapping of urban dynamics candidate addresses for instance the following use cases:

Use case 1: No Net Land Take monitoring (NNLT)

Problem

The no-net-land-take (NNLT) objective aims to halt the net increase in land artificialization by 2050, focusing on preserving natural habitats and reducing urban sprawl. This initiative is crucial for protecting biodiversity and mitigating climate change impacts.

Solution

This candidate could be a part of this monitoring by giving the information on the location of urban dynamic zones and what they are replacing (natural, agricultural, or urban areas).

Policy Impact

Monitor the urban dynamics allows the different policies to better anticipate and manage the changes. It is an essential tool to turn our global city policies into a more sustainable model in terms of environment and quality of life.

Potential users & stakeholders

At different scales, European entities, national administrations and / or municipalities could find interest in this monitoring.

Use case 2: Identifying Illegal Dumping Sites and Unplanned Construction

Problem

The no-net-land-take (NNLT) objective aims to halt the net increase in land artificialization by 2050, focusing on preserving natural habitats and reducing urban sprawl. This initiative is crucial for protecting biodiversity and mitigating climate change impacts.

Solution

The automated change detection can identify new dumping sites and unplanned construction activities as they emerge. By providing high-resolution data annually, the tool enables timely interventions before these issues escalate.

It offers detailed spatial and temporal data, allowing authorities to track changes over time and understand patterns of illegal activities.

It arguments traditional surveillance methods, reducing the need for manual inspections and increasing the coverage area. This efficiency allows for more comprehensive monitoring with fewer resources.

Policy Impact
This tool could enhance policy-making by providing data-driven insights for targeted regulations and improved enforcement and promoting adherence to environmental and building regulations.

- Unauthorized waste disposal sites pose serious environmental and health risks. They can contaminate soil and water, harm wildlife, and create unsanitary conditions for nearby communities.
- Unregulated building activities can lead to inefficient land use, strain on local infrastructure, and potential safety hazards. These developments often bypass zoning laws and building codes, leading to substandard living conditions and increased risk of structural failures.
- It could also have some interest at local level, to manage the city's policies and investments by analyzing the development of residential neighborhoods or industrial / commercial areas.

Potential users & stakeholders
Mainly local policies linked to security or urban planning.

5.10 C10 – Continuous Mapping of Land Surface Characteristics

The C10 continuous mapping of land surface characteristics candidate would be a valuable data service for various applications which require real near time Land Cover classifications. Potential use cases are:

Use case 1: Forest Land to Cropland Conversion Detection

Problem:
Deforestation for agricultural expansion leads to carbon stock losses and affects LULUCF carbon accounting.

Solution:
- o Continuous mapping detects forest canopy loss and its conversion to cropland.
- Distinguishes between temporary clearings (e.g., forest thinning) and permanent land-use changes.
- Identifies early signs of forest degradation (e.g., canopy stress before full clearing).

Policy Impact:
Helps authorities verify reforestation commitments under the EU Biodiversity Strategy 2030[9] and ensure compliance with afforestation/reforestation targets.

Potential users & stakeholders
- European Commission through the EU Deforestation Regulation (EUDR)

[9] https://environment.ec.europa.eu/strategy/biodiversity-strategy-2030_en

- National forest agencies

Use case 2: Grassland to Cropland Expansion Monitoring

Problem:
The conversion of grasslands to croplands reduces soil carbon sequestration and can violate sustainable land-use policies.

Solution:
- Tracks shifts in vegetation cover, distinguishing between permanent grasslands and rotational croplands.
- Identifies regions where plowing, fertilization, or irrigation changes grassland composition.

Policy Impact**:**
Supports CAP[10] compliance monitoring, ensuring that protected permanent grasslands remain intact.

Potential users & stakeholders
European Commission (EC) & EU Agencies
- DG AGRI (Directorate-General for Agriculture and Rural Development) – Ensures compliance with the Common Agricultural Policy (CAP), particularly rules on permanent grassland protection
- DG ENV (Directorate-General for Environment) – Monitors biodiversity and soil carbon losses linked to land-use changes.
- Joint Research Centre (JRC) – Supports CAP monitoring with scientific analysis and land-use models.

5.11 C12 – Tree Types Mapping

The C12 Tree Types Mapping prototype would be a valuable input to support policy needs on national and EU-level. A potential use case is described in the following.

Use case 1: Support to EU Biodiversity Strategy

The EU Biodiversity Strategy aims to protect nature and reverse the degradation of ecosystems on a long-term. It is part of the European Green Deal and contains specific actions and commitments to put Europe´s biodiversity on a path to recovery by 2030 (European Commission, 2025).

Problem
Damaged ecosystems are vulnerable to extreme events and diseases and endangered to lose their ability to serve as stable basis for our life support system. It is therefore of great importance to protect our ecosystems from (further) damage and restore what has been harmed.

Solution
The C12 prototype can help in this regard with providing information about the tree types composition (on species and genus level) of the European forests, as one of the major ecosystems. This information is a crucial input to assess and monitor the health of our forests and can help us understand what it takes to restore and transform them towards climate resistance.

Policy impact
Through concrete commitments and actions, the plan is for EU countries to put in place effective restoration measures to restore degraded ecosystems, in particular

[10] https://agriculture.ec.europa.eu/common-agricultural-policy_en

those with the most potential to capture and store carbon and to prevent and reduce the impact of natural disasters (European Commission, 2025).

In this sense the European Forests play a major role and the assessment and monitoring of forest compositions with regards to different tree types is crucial to enable the restoration and protection of climate resistant forests, being part of a stable basis for our economies and society on a long-term.

Potential users & stakeholders

Stakeholders include amongst others the European Commission, the European Environment Agency, the Joint Research Centre, as well as national governments and regional authorities, land users, businesses and last but not least all citizens of Europe.

6. Conclusion and Outlook

Benchmarking is a key step to ensure the delivery of high-quality products to end users. In line with this objective, all candidate services at the conclusion of Phase 1 of the EvoLand project underwent a comprehensive benchmarking process to assess their potential for integration into the Copernicus Land Monitoring Service portfolio. The same exercise was repeated at the end of Phase 2 to track the evolution of the prototypes and evaluate the maturity of the product candidates. Compared to Phase 1, both an additional criterion and an additional product were included in the assessment.

The evaluation has been done jointly and objectively with all consortium members involved in the production. The evaluation presented in section 4.1 reflects the cross-analyses performed both by rows (all candidates assessed against each criterion) and by columns (all criteria evaluated for each candidate). A Technology Readiness Level (TRL) assessment has also been conducted to gauge the operational maturity of the candidates.

Already at the end of the first phase of the EvoLand project, the results showed that services generally meet user requirements and are well suited for integration within the CLMS portfolio (all scores from + to ++). This is even more the case after the completion of Phase 2. Some limitations have been clearly identified, including the lack of training and validation datasets and constraints in Earth Observation data availability. Among the candidates, the most advanced—C01, C05, C07, and C10—scored highly across all criteria and appear ready for progression beyond EvoLand. Although some improvements are noticeable between phase 1 and 2, C04 and C06 are the candidate with the general lower score. This is not surprising given the complexity of producing an entirely new set of products highly dependent on the availability of VHR and/or in-situ input data and with complex definition. For the rest of the candidates, there is still room for improvement, however, the TRL analysis indicates that most services are approaching operational readiness.

This analysis has been done by products and criterion. No synthetized scoring and ranking are presented per product. While it is evident that some products are more advanced than others, the relative importance of individual criteria may differ according to end-user priorities. Consequently, the overall perception of readiness depends on how end users and Entrusted Entities assign weight to the various criteria.

EvoLand Consortium