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Grant Agreement No. 730008

# ECoLaSS

## Evolution of Copernicus Land Services based on Sentinel data


# D18.2

## "D53.1b - Integration Plan into the Copernicus Service Architecture" (Issue 2)

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submitted by:

SIRS

in collaboration with the consortium partners:

GAF AG, Joanneum Research Digital, UCL Université catholique de Louvain, DLR

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Consortium Partners

| No. | Participant Organisation Name | Short Name | City, Country |
|---|---|---|---|
| 1 | GAF AG | GAF | Munich, Germany |
| 2 | Systèmes d'Information à Référence Spatiale SAS | SIRS | Villeneuve d'Ascq, France |
| 3 | JOANNEUM RESEARCH Forschungsgesellschaft mbH | JR | Graz, Austria |
| 4 | Université catholique de Louvain, Earth and Life Institute (ELI) | UCL | Louvain-la-Neuve, Belgium |
| 5 | German Aerospace Center (DLR), German Remote Sensing Data Center (DFD), Weßling | DLR | Weßling, Germany |

## Contact:

GAF AG
Arnulfstr. 199 – D-80634 München – Germany
Phone: ++49 (0)89 121528 0 – FAX: ++49 (0)89 121528 79
E-mail: copernicus@gaf.de – Internet: www.gaf.de

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| | Name, Function | Date | Signature |
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| Author(s): | Christophe Sannier (SIRS), Sophie Villerot (SIRS), Antoine Masse (SIRS), Markus Probeck (GAF), Katharina Schwab (GAF), David Herrmann (GAF), Regine Richter (GAF) | 23.12.2019 | |
| Review: | Katharina Schwab (GAF), Eva Sevillano Marco (GAF), Sophie Villerot (SIRS) | 24.12.2019 | K. Schwab |
| Approval: | Markus Probeck (GAF) | 29.12.2019 | |
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## Document Status Sheet

| Issue/Rev | Date | Page(s) | Description / Changes |
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| 1.0 | 23.12.2018 | 26 | First Issue of the ECoLaSS Integration Plan into the Copernicus Service Architecture, at the end of the first Reporting Period. Findings are preliminary, and will be consolidated towards the project end in the next Issue of this Deliverable (D53.1b). |
| 2.0 | 29.12.2018 | 46 | Second, completely updated and revised final issue, at the end of the ECoLaSS project. It comprises a new section 2.2, whereas the previous section on Communication and Assessing Readiness Levels (CARLs) (section 2.2.2 in Issue 1.0) has been deleted as obsolete. Major updates were done throughout the whole report, and final recommendations have been added. |
| 2.1 | 15.02.2020 | 42 | Revision based on reviewer's recommendations at Final Review Meeting, comprising major updates of sections 2.2 and 2.4, as well as minor updates to the Executive Summary and sections 2.5, 3, 3.2, 3.2.1.1-3.2.1.3, 3.2.3, 3.3, 3.4 and 4. |

## Applicable Documents

| ID | Document Name / Issue Date |
|---|---|
| AD01 | Horizon 2020 Work Programme 2016 – 2017, 5 iii. Leadership in Enabling and Industrial Technologies – Space. Call: EO-3-2016: Evolution of Copernicus services. Issued: 13.10.2015 |
| AD02 | Guidance Document: Research Needs Of Copernicus Operational Services. Final Version issued: 30.10.2015 |
| AD03 | Proposal: Evolution of Copernicus Land Services based on Sentinel data. Proposal acronym: ECoLaSS, Proposal number: 730008. Submitted: 03.03.2016 |
| AD04 | Grant Agreement – ECoLaSS. Grant Agreement number: 730008 – ECoLaSS – H2020-EO-2016/H2020-EO-2016, Issued: 18.10.2016 |
| AD05 | D3.2 – D21.1b - Service Evolution Requirements Report (Issue 2). Issued: 31.12.2019 |
| AD06 | D4.2 – D22.1b – EO and other data requirements Report (Issue 2). Issued: 21.02.2019 |
| AD07 | D8.2 – D33.1b - Methods Compendium: Time Series Analysis for Thematic Classification (Issue 2), Issued: 18.12.2019. |
| AD08 | D10.2 – D35.1b - Time Series Consistency for HRL Product (incremental) Updates (Issue 2). Issued: 09.12.2019 |
| AD09 | D13.2 – D43.1b - Prototype Report: Improved Permanent Grassland (Issue 2). Issued: 05.12.2019 |
| AD10 | D14.1 – D44.1b - Prototype Report: Crop Area and Crop Status/Parameters (Issue 2). Issued: 20.12.2019 |
| AD11 | D16.4 – D51.1d - Stakeholder Consultation Report (Issue 4). Issued: 31.10.2019 |
| AD12 | D17.2 – D52.1b - Report on Candidates for Operational Roll-out (Issue 2). Issued: 27.12.2019 |
| AD13 | D18.4 – D53.2b - White Paper on Copernicus Land Evolution (Issue 2). Issued: 31.12.2019 |

# EXECUTIVE SUMMARY

The Horizon 2020 (H2020) research project “Evolution of Copernicus Land Services based on Sentinel data” (ECoLaSS) addressed the H2020 Work Programme 5 iii. Leadership in Enabling and Industrial technologies - Space, specifically the Topic EO-3-2016: Evolution of Copernicus services. ECoLaSS has been conducted from 2017–2019, developing and prototypically demonstrating selected innovative products and methods as candidates for future next-generation operational Copernicus Land Monitoring Service (CLMS) products of the pan-European and Global Components. ECoLaSS has thoroughly assessed the operational readiness of these candidate products and is suggesting some of them for implementation, via this report.

Based on the results of a detailed benchmarking procedure as undertaken in the parallel report on “Candidates for Operational Roll-out” (AD12), as summarised in section 2.2, and the subsequent assessment of individual “integration readiness” (section 2.4) along tailored evaluation methodologies as detailed in section 2.3, individual tailored implementation roadmaps for all finally suggested new candidate services (section 2.5) have been laid out in chapters 3.1 to 0, comprising:

- HRL Imperviousness incremental update: Incremental Imperviousness Density change at 20m
- HRL Forest incremental update: Incremental Tree Cover Loss at 20m
- New Grassland product: Grassland Use Intensity product at 10m
- New Agricultural products: New Crop Mask and Crop Type status layer (HRL Crops) at 10m

The latter two new product recommendations go explicitly along with a clear recommendation for further enhanced political endeavours to establish an agricultural in-situ data policy, to be agreed among the main political decision-makers (sections 0 and 0).

It should be stressed that beyond the above suggested key candidates for new integration into the operational CLMS portfolio, some further recommendations shall be noted here:

- Probably at a slightly later stage (e.g. for HRL update 2021), the HRL Combined Layer should be considered for integration, once respective user requirements are further consolidated.
- If not already part of the upcoming HRL Vegetation Phenology and Productivity (HR VPP) product suite, the Generic Land Cover Metrics and the Crop Growth Condition should also be considered to complement the respective HR VPP portfolio in the future.
- Those products which had also been initially investigated by ECoLaSS, but have meanwhile found their way into the operational CLMS portfolio (i.e. the Improved IMD Status Layer at 10m, the Imperviousness Built-Up Area, the Improved DLT Status Layer at 10m, the Grassland Status Layer at 10m, and the CLC evolution (i.e. CLC+) product), are not further discussed in the report. In any case, their regular continuation as part of the operational CLMS portfolio (beyond 2020) is much supported.

Finally, it should also be noted that ECoLaSS has demonstrated its value in supporting the evolution of CLMS by making it possible to highlight critical issues and provide solutions for future services. Some of the recommendations from ECoLaSS were included in the HRL2018 ITT. It is recommended that such targeted research project initiatives should continue to be supported in the future.

This report primarily aims to provide the scientific-technical sound and substantiated basis for an informed discussion among the main stakeholders on Copernicus, i.e. the EC, the EEA and the JRC, as well as the thematic EC DGs (mainly DG Agri and DG Clima) and the Copernicus User Forum and Copernicus Committee, to enable sustainable subsequent implementation decisions. Additionally, a high-level concise summary of the ECoLaSS key findings is presented in the ECoLaSS *White Paper on Copernicus Land Evolution* (AD13). All provided recommendations conform to the latest and up-to-date level of available information at the end of December 2019.

# Table of Contents

# List of Tables



# List of Figures

# Abbreviations

| | |
|---|---|
| AD | Applicable Document |
| ARL | Application Readiness Level |
| ASTER | Advanced Space-borne Thermal Emission and Reflection Radiometer |
| AWiFS | Advanced Wide Field Sensor |
| AWS | Amazon Web Services |
| BCD | Broadleaved Cover Density |
| CALM | Criteria for consistently Assessing Levels of Maturity |
| CAP | Common Agricultural Policy |
| CARL | Communicating and Assessing Readiness Level |
| CCD | Coniferous Cover Density |
| CEMS | Copernicus Emergency Management Service |
| CLC | CORINE Land Cover |
| CLC+ | CORINE Land Cover next generation |
| CLMS | Copernicus Land Monitoring Services |
| CORDA | Copernicus Reference Data Access |
| CORINE | Coordination of Information on the Environment |
| CSCDA | Copernicus Space Component Data Access |
| DEM | Digital Elevation Model |
| DG | Directorate General |
| DIAS | Data and Information Access Service |
| DLT | Dominant Leaf Type |
| DLTC | Dominant Leaf Type Change |
| DSL | Data Score Layer |
| DSM | Digital Surface Model |
| EC | European Commission |
| ECoLaSS | Evolution of Copernicus Land Services based on Sentinel data |
| EEA | European Environment Agency |
| EEA39 | 39 member and cooperating countries of the EEA |
| EEE | Entrusted European Entity |
| EO | Earth Observation |
| ERS | Environmental Resource Satellite |
| ESA | European Space Agency |
| EU | European Union |
| EU-28 | the 28 member states of the European Union |
| Fmask | Function of mask |
| FP7 | 7th EU Research Framework Programme |
| FTSP | Fast Track Service Precursor |
| GDEM | Global Digital Elevation Model |
| GFOI | Global Forest Observations Initiative |
| GIO | GMES Initial Operations |
| GMES | Global Monitoring for Environment and Security |
| GRA | Grassland |
| H2020 | Horizon 2020 (8th EU Research Framework Programme) |
| HR | High Resolution |
| HRL | High Resolution Layer |
| IACS | Integrated Agricultural Control System |
| IMC | Imperviousness Density Change |
| IMD | Imperviousness Density |
| InVeKoS | Integriertes Verwaltungs- und Kontroll-System |
| IRS | Indian Remote-Sensing Satellite |

| | |
|---|---|
| ITT | Invitation To Tender |
| JRC | Joint Research Centre |
| LC | Land Cover |
| LISS-III | Linear Imaging Self-Scanning Sensor |
| LPIS | Land Parcel Identification Systems |
| LR | Low Resolution |
| LU | Land Use |
| LUCAS | Land Use/Cover Area frame statistical Survey |
| LULUCF | Land Use, Land Use Change and Forestry |
| MAJA | MACCS-ATCOR Joint Algorithm |
| MR | Medium Resolution |
| NASA | National Aeronautics and Space Administration |
| REDD+ | Reducing Emissions from Deforestation and Forest Degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries |
| RF | Random Forest |
| S-1 | Sentinel-1 |
| S-2 | Sentinel-2 |
| S-3 | Sentinel-3 |
| SAR | Synthetic Aperture Radar |
| SDA | Satellite Data Archive |
| SP | Service Provider |
| SPOT | Satellite Pour l'Observation de la Terre/Satellite for observation of Earth |
| SRTM | Shuttle Radar Topography Mission |
| SWF | Small Woody Features |
| T1 | Time step 1 |
| T2 | Time step 2 |
| TACCC | Transparency, Accuracy, Consistency, Completeness and Comparability |
| TCCM | Tree Cover Change Mask |
| TCD | Tree Cover Density |
| TRL | Technology Readiness Level |
| VHR | Very High Resolution |
| VPP | Vegetation Phenology and Productivity |
| WP | Work Package |
| WPD | Work Package Description |

# 1 Introduction

The outcomes of the previous ECoLaSS WP 52, as documented in the final issue of the Deliverable *D52.1b - Report on Candidates for Operational Roll-out* (AD12), present a final assessment of which Copernicus Land Monitoring Service (CLMS) candidate new/improved products are selected and suggested for future implementation in the operational Copernicus service architecture, based on the criteria and procedures specified in WP 52. As next step, a structured process for integration into the CLMS portfolio has been investigated and suggested in WP 53 and documented in the present *Integration Plan into the Copernicus Service Architecture*, which represents one of the main outcomes of ECoLaSS. The current second and final Issue is provided at the end of the final ECoLaSS Reporting Period.

The findings presented in this report therefore represent the final implementation recommendations related to the candidate next-generation CLMS products investigated as part of the project. These recommendations shall be considered as a contribution to an informed stakeholder discussion and decision-taking in view of the future implementation of the CLMS portfolio from 2020. The suggested mechanisms for integrating operational candidate products into the Copernicus service architecture distinguish two main cases:

- Products which constitute improvements or extensions to existing Copernicus Land products will be easier to integrate, and the related integration strategy will be a matter of assessing mainly whether and how the related improvements can be implemented for the next planned regular update cycle of the products.
- For newly developed products, a careful assessment has been undertaken to examine how and when they could be integrated into the Copernicus Land service architecture in terms of availability of respective budget lines, policy relevance and complementarity with other products.

In either case, new products and/or product improvements have been assumed to require reaching a **Technology Readiness Level (TRL) of at least 7** (cf. section 2.3.1) and / or an equivalent **Application Readiness Level (ARL)** (cf. section 2.3.2), which does not only mean that a product definition is mature and a clear methodological path exists to producing it, but also that the infrastructural framework to produce it is secured. This includes notably the availability of **input satellite data**. Another important aspect is related to the availability of required in-situ and other reference data. The progress of the **Copernicus in-situ component, INSPIRE-compliant national data provision** by the EEA39 Member States and the related Copernicus Reference Data Access (**CORDA**) portal have therefore been carefully monitored throughout the ECoLaSS project, to be sure whether relevant data sources are available in time for the integration of the suggested candidate products into the Copernicus Land service architecture.

The continuous assessment of the infrastructural framework (such as the DIAS'es) has also been one of the focuses of consideration throughout the ECoLaSS project, since particularly computationally intensive products need an ensured and fully operational availability of adequate and reliable processing resources at reasonable cost. Considerations related to the candidate products' ability for spatially explicit large-scale **geographical coverage** (i.e. roll-out potential to at least EEA39) are also taken into account.

The present Deliverable *D53.1 Integration Plan into the Copernicus Service Architecture* is embedded in the extensive assessment work undertaken in the frame of the project's Task 5 Operationalisation Framework, and primarily aims at providing the basis for informed decisions to be taken by the decision makers on Copernicus, i.e. the EC, the EEEs and the Copernicus User Forum and Copernicus Committee. Furthermore, a high-level concise summary of the ECoLaSS key findings is subsequently presented in the Deliverable *D53.2 White Paper on Copernicus Land Evolution*.

This present Integration Plan focuses on outlining a roadmap suggestion for integration of the best-ranked improved and new products into the Copernicus operational service architecture, with a clear description of the requirements and suggested practical modalities for implementing these products.

The consortium acknowledges that funding of the H2020 project in no way commits the EC or Copernicus service operators to deploy the outcomes from this research into the Copernicus operational services.

# 2 Summary of Candidate Services

Based on key CLMS evolution requirement priorities (section 2.1) and the final list of candidate prototypes as has been established in the benchmarking report of WP 52 (section 2.2), and using additional assessment methodologies (as detailed in section 2.3), all top-ranked ECoLaSS final candidate prototypes have been finally evaluated (section 2.4), resulting in the final ECoLaSS list of suggested new candidates services for operational roll-out (section 2.5).

## 2.1 Service Evolution Requirement Priorities

The main focus of the ECoLaSS project has been on the pan-European and Global Component aspects of the Copernicus Land Monitoring Service (CLMS), as these are partially closely related, and take into account the respective needs of the key user and stakeholder community. Findings from the service evolution requirements assessment (AD05) and stakeholders consultations (AD11) have shown that most of the requirements for evolution of existing services and for next-generation new services could be gathered for the pan-European CLMS products, i.e., on the one hand the High Resolution Layers (HRLs) in terms of improvements in thematic information content and provision timeliness/frequency, and on the other hand CORINE Land Cover (CLC) in terms of evolution towards CLC+. Requirements for the Global Component were collected from key representatives of the EC's Joint Research Centre (JRC) and other relevant stakeholders. These had generally been at a less advanced stage of development regarding S-1/S-2 derived thematic products whilst the currently existing Global component portfolio is still mainly focused on biophysical products derived from PROBA-V and now Sentinel 3, and other Medium-Resolution (MR) to Low-Resolution (LR) EO sensors.

There is generally substantial interest in the use of the High-Resolution Layers and/or a next generation thereof, particularly when equivalent information is not available at national level. It should be stressed that several users had indicated that there was still a lack of awareness about the HRLs, which was hampering their uptake and use, although latest user uptake initiatives by the EC have substantially contributed to mitigating this situation. Furthermore, national users showed particularly high interest in products of the Local Copernicus Component, which is clearly related to the higher spatial resolution of the products, better fulfilling the information needs on a regional level and also presumably because these products are thematically closer to those already available locally. There is a general trend towards increased interest in the "raw" Copernicus (Sentinel) satellite data, which was repeatedly mentioned by most users. In terms of specifications, the requirement for shorter update frequencies and change products (incremental updates) was mentioned most often.

Concerning new services, a pan-European Agricultural Service as well as a Phenology Layer were the most frequently recorded responses. A further outcome is a trend towards the desire for more generic or cross-cutting services and products. While it was observed that technical issues and limitations of the CLMS products' (satellite and other) input data, as well as the actual methods for generation of the products are not of major concern to the users, it was also found that (depending on the individual user) the knowledge of specifications of the existing products and metadata is in general rather limited. Requests for obtaining more information on the products and metadata was voiced several times. Additionally, a general requirement for an easier and standardized access to data, products and documentation, on a unified access portal, was repeatedly stated, including the desire for a multi-layer online visualization and/or evaluation tool for the products.

## 2.2 Benchmarking Outcomes of WP 52

The report *D52b – Candidates for operational roll-out* provides an assessment of all the prototypes produced and the application of a comprehensive benchmarking procedure not only checking technical feasibility, but also assessing operational implementation potential. Initial candidate prototypes that are now already included in the CLMS portfolio (e.g. Phenology and CLC+) are not considered as part of this assessment.

Table 1 below summarises the outcome of the benchmarking assessment that was undertaken as part of WP52.

**Table 1: Summary of benchmark results for final ECoLaSS prototypes**

| Service/product candidate | Overall rating after Benchmarking | Overall Benchmark Result |
|---|---|---|
| Incremental IMD Change | +/++ | most promising |
| Incremental Tree Cover Loss | +/++ | |
| Grassland Use Intensity | +/++ | |
| New Crop Mask Status Layer at 10m | +/++ | |
| New Crop Type Status Layer at 10m | +/++ | |
| HRL Combined Layer | + | high potential |
| Crop Growth Condition | + | |
| Generic Land Cover Metrics | + | |
| Crop Emergence Date Map | o/+ | experimental status |
| Multi-Annual Trends and Potential Change | o/+ | |

## 2.3 Evaluation Methodologies

In addition to the detailed benchmarking conducted as part of WP 52, it seemed also useful as a complement, to confront the prototypes with existing recognised methodologies to assess the maturity of technological developments. This was done primarily to confirm the results obtained in WP 52 and to strengthen the robustness of the final product selection of the ECoLaSS prototypes deemed operational for their integration into the CLMS portfolio and architecture.

Various methodologies exist to assess the maturity, operationality or operational integration capability of a technology. There were initially three methods pursued in the phase 1 issue of this report. However, since then, the *Communicating and Assessing Readiness Levels* (CARL) framework, that was originally developed as part of the Global Forest Observations Initiative (GFOI), has been modified to what is now referred to as *Criteria for consistently Assessing Levels of Maturity* (CALM) of Reducing Emissions from Deforestation and forest Degradation (REDD+) concepts[1]. As a result, the concept has become very specific to REDD+ and no longer applicable for the purpose of this WP 53 assessment. Therefore, considering that the CARL concept is no longer maintained or documented, it was decided to abandon it and to replace it by a combination of the TRLs and ARLs which are reviewed in the following sections.

[1] https://www.reddcompass.org/documents/184/0/GFOI_CALM_Criteria_1.0.pdf/6ba261e1-e169-44f0-9550-3194225bd10d

### 2.3.1 Technology Readiness Levels (TRLs)

The TRL scale was developed in the 1970s by NASA to assess the degree of maturity of a technology before integrating it into a broader operational system, and is implemented as an innovation tool policy by the European Union (EU) (Héder, 2017). The first version of this scale contained 7 levels, and nowadays 9 levels are used, which are detailed in Table 2 and below.

**Table 2 - Definition of each TRL**

<table>
<tr><th colspan="2">Phase</th><th>Level</th><th>Description</th></tr>
<tr><td>-</td><td rowspan="2">System Test, Launch & Operations</td><td>TRL 9</td><td>Actual system proven in operational environment</td></tr>
<tr><td rowspan="3">System/ Subsystem Development</td><td>TRL 8</td><td>System complete and qualified</td></tr>
<tr><td>-</td><td>TRL 7</td><td>System prototype demonstration in operational environment</td></tr>
<tr><td rowspan="2">Technology Demonstration</td><td>TRL 6</td><td>Technology demonstrated in relevant environment</td></tr>
<tr><td rowspan="3">Technology Development</td><td>TRL 5</td><td>Laboratory testing of integrating system validated</td></tr>
<tr><td>-</td><td>TRL 4</td><td>Technology component or process validated in laboratory</td></tr>
<tr><td rowspan="2">Research to Prove Feasibility</td><td>TRL 3</td><td>Critical function, experimental proof of concept established</td></tr>
<tr><td rowspan="2">Basic Technology Research</td><td>TRL 2</td><td>Applied Research: technology concept and/or application formulated</td></tr>
<tr><td>-</td><td>TRL 1</td><td>Basic Research: basic principles are observed and reported</td></tr>
</table>

#### TRL 1: Lowest technology degree of maturity

The scientific research is only starting to be translated into applied research and development. Paper study regarding basic properties of the considered technology can be seen as an example.

#### TRL 2: Technology concept and/or application formulated

Practical applications are envisioned, even though they remain speculative. Examples are limited to analytic studies and experimentation.

#### TRL 3: Proof of concept established

Active research and development is launched, with laboratory studies initiated to validate analytical assumptions on separate components of the technology. Those components are not yet integrated or representative.

#### TRL 4: Testing of prototype component in laboratory

Components of the technology are integrated and combined to check their ability to function together. They are not representative of the eventual final system. Examples are ad hoc elements integrated together in laboratory experiments.

#### TRL 5: Testing of the integrated system

Components are combined together in a realistic effort to test them in a simulated environment. The prototype is far closer to the eventual system.

#### TRL 6: PROTOTYPE SYSTEM VALIDATED IN A RELEVANT ENVIRONMENT

The prototype, which is already well beyond the level 5, is tested in a relevant environment – which represents a clear demonstration of the maturity of the technology.

#### TRL 7: DEMONSTRATION OF THE INTEGRATED PILOT SYSTEM

The prototype is close to the planned operational system level, and its design is close to the final system. Tests are carried out in an operational environment. Engineering and/or manufacturing risks are largely removed.

#### TRL 8: SYSTEM INCORPORATED IN A COMMERCIAL DESIGN

The technology has been proven to work in its final form, and in the expected conditions. This level is usually the end of real system development.

#### TRL 9: SYSTEM READY FOR FULL SCALE DEPLOYMENT

The technology has reached its final form for operational deployment. The product or process is ready to be eventually launched commercially and marketed.

The TRL scale provides a valuable tool to unify the understanding of the technology status and to conduct a risk management. However, the “readiness” does not translate exactly the technology maturity, and the evaluation still remains somewhat subjective.

### 2.3.2 Application Readiness Levels (ARLs)

This scale is an adaption of the TRLs adopted by the National Aeronautics and Space Administration (NASA) to track and manage the progression and deployment of funded projects. It aims at better reflecting the three stages of project research, development and deployment. Each level is detailed in Table 3 and below.

**Table 3 - Definition of each ARL**

| Description | Level | |
|---|---|---|
| **Phase III: Integration into Partner’s System** | ARL 9 | Approved, Operational Deployment and Use in Decision Making: Sustained Use |
| | ARL 8 | Application Completed and Qualified: Functionality Proven |
| | ARL 7 | Application Prototype in Partner’s Decision Making: Functionality Demonstrated |
| **Phase II: Development, Testing and Validation** | ARL 6 | Demonstration in Relevant Environment: Potential Demonstrated |
| | ARL 5 | Validation in Relevant Environment: Potential Determined |
| | ARL 4 | Initial Integration and Verification: Prototype and Plan |
| **Phase I: Discovery and Feasibility** | ARL 3 | Proof of Application Concept: Viability Established |
| | ARL 2 | Application Concept: invention |
| | ARL 1 | Basic Research: baseline ideas |

For each ARL, a specific list of methods, availability of data and application scale is provided as guidance for evaluation:

**ARL 1: Basic Research**

- Developed ideas should highlight how specific research results could enhance decision making.
- The baseline support research is identified and documented.

**ARL 2: Technology concept and/or application formulated**

- Independent application components are formulated and created.
- Decision making activities that will be improved by the application are identified.
- A better characterization of the decision making activity is planned.

**ARL 3: Proof of Application Concept**

- Each component of the application is tested and independently validated.
- Limitations and mechanisms of the user decision making process are detailed.
- Case for the viability of the application is established.

**ARL 4: Initial Integration and Verification**

- Technical integration issues arising from the combination of system components are worked out.
- Organizational challenges and human process issues are identified and managed.

**ARL 5: Validation in Relevant Environment**

- The potential of improvement for the decision making activity brought by the application is articulated.
- The combination of system components is evolved in a functioning prototype with realistic supporting elements.

**ARL 6: Demonstration in Relevant Environment**

- Prototype application is beta-tested in a simulated operational environment.
- Projected improvements on performance of decision making activity are demonstrated.

**ARL 7: Application Prototype in Partner's decision making**

- Prototype application system is integrated into the end user's operational environment.
- Functionality of the prototype is tested and demonstrated in the decision making activity.

**ARL 8: Application Completed and Qualified**

- The application is finalized and shown to behave as expected in the user environment.
- The application is approved by the user for the decision making activity.
- Training and user documentation can be provided.

**ARL 9: Approved, Operational Deployment and Use in decision making**

- The application is sustainably used in the decision making activity.

## 2.4 Evaluation of final Prototypes

The ECoLaSS prototypes were assessed following the work done in the report *D52.1b Report on Candidates for Operational Roll-out*, second Issue (AD12), specifically the identification of prototypes and their benchmarking evaluation, focusing in particular on the evaluation along the criteria:

- Answering identified needs;
- State of the art and innovation;
- Maturity;
- Adequate Earth Observation (EO) data availability;
- Adequate in-situ data availability;
- Processing capacity;
- Automation level;
- Roll-out potential;
- Documentation.

The respective evaluation in view of TRLs/ARLs was performed only on the selected candidates and is detailed in the following and summarised in Table 4.

**HRL extension products** – The new grassland use intensity layer to be extending the existing suite of products has also shown promising results and is hence given a rating TRL7 and ARL7 even though access to reliable in situ data would need to be better consolidated. Results from Phase 1 were confirmed during Phase 2, for the HRL incremental updates of the IMD and Tree Cover Loss layer. Both were demonstrated in a quasi-operational environment, hence a rating of TRL7 and ARL7.

Regarding the **Agricultural products**, results from phase 1 were consolidated in phase 2. The new crop mask status layer benefits from a better evaluation for the availability of in-situ data, since the combination of the available national Land Parcel Identification System (LPIS) data and the Land Use/Cover Area frame statistical Survey (LUCAS) database has proven to facilitate the identification of arable lands. However, the identification of crop types relies on the availability of the LPIS or any other form of spatially referenced field information on crop types. It is a known fact that the availability of LPIS data is not homogeneous across Europe and is in any case limited to the EU. LUCAS could be used as complement to the LPIS but is also not conducted all over Europe and is only available every 3 years currently. In addition, although the density of observations may be sufficient for validation, it could be problematic as a source of training data. Nevertheless, ECoLaSS has demonstrated that, whenever LPIS data are available, high quality crop mask and crop type products could be produced. Therefore, a rating of TRL7 and ARL7 is provided for the crop mask and TRL7 and ARL6 for the crop type layer.

For the **HRL Combined Layer**, even though some of the specifications would need to be fully agreed by the relevant stakeholders, their production is clearly demonstrated and the TRL rating provided is at 7. However, there is still a lack of clear requirement in terms of decision making potential, hence an ARL rating of 5.

In terms of the **Time series indicator** products, Generic Land Cover Metrics (Phenology) were produced successfully for two demonstration sites and were used as input to the CLC Evolution prototype production, thus demonstrating their potential applications. Crop Growth Conditions are also similar in their assessment, as their usefulness has since long been demonstrated when produced from Medium Resolution (MR) EO data, and their application with Sentinel data seems to provide useful insights in crop development. However, they remain difficult to validate in the absence of field observations, even though detailed in situ data are not required for their production. Therefore, they were both provided a TRL6 and ARL5. The Emergence Date Map relies on data available at small-scale, as demonstrated over the African sites. The prototypes for Multi-Annual Trends and Potential Change both also lack large-scale in-situ data. They are therefore rated at TRL/ARL level 3.

**Table 4 - Assessment of selected prototypes following the TRL / ARL framework.**

| | Prototype | TRL | ARL |
|---|---|---|---|
| WP 41 Time series indicator | Crop Growth Condition | 6 | 5 |
| | Crop Emergence Date Map | 3 | 3 |
| | Generic Land Cover Metrics | 6 | 5 |
| | Multi-Annual Trends & Potential Change | 3 | 3 |
| WP 42 Imperviousness incremental update | Incremental IMD Change | 7 | 7 |
| WP 42 Forest incremental update | Incremental Tree Cover Loss | 7 | 7 |
| WP 43 Improved Grassland | Grassland Use Intensity Layer at 10m | 7 | 7 |
| WP 44 New Agriculture product | New Crop Mask Status Layer at 10m | 7 | 7 |
| | New Crop Type Status Layer at 10m | 7 | 6 |
| WP 45 New Products | HRL Combined Layer | 7 | 5 |

## 2.5 Suggested Candidate Services for Operational Roll-out

Most of the activities during Phase 1 & 2 of ECoLaSS have focused on the improvement of existing products and on the development of new products. Few new products had been regarded candidates for integration into the operational domain during Phase 1, considering they were still at an earlier stage and further work during phase 2 was required, before most of the developments made could be fully considered candidates for full operational roll-out. Nevertheless, needed to be modified, considering the combination of the ARL/TRL assessment and WP52 Benchmarking. However, some products such as the CLC Evolution and Phenology are now already being included in the operational CLMS portfolio (both contracted in Dec. 2019 by the EEA and starting in 2020), despite being considered –through the results of ECoLaSS – at a relatively early stage of development and testing under close-to-operational conditions. In addition, the HRL status layers at 10m are considered fully operational (high TRL / ARL rating), but have received a relatively lower benchmark score (cf. section 2.2) because they have meanwhile also already been included in the operational CLMS portfolio since the HRLs 2018, and therefore do not need to be considered as new elements for the implementation plan from 2020.

Regarding the agricultural products, even though they are classified as most promising (section 2.2), there are still some substantial issues to be resolved in relation to in-situ data availability, before they can be considered fully operational. Nevertheless, a respective new HRL (called 'HRL Crops') has meanwhile already been included in the Copernicus Work Programme for 2020, thus presumably becoming part of the operational CLMS portfolio from 2020 onwards. Based on the results of the benchmarking (AD12) and subsequent assessment as part of this report, the Crop Mask should indeed be ready to be deployed. However, it is suggested that the Crop Type product should go together with a dedicated effort for making available respective in-situ data, in particular providing a solution in terms of harmonising LPIS data across Europe and consolidating political support from Member States.

Finally, the remaining products showing high TRL /ARL rating and considered as most promising from the benchmarking exercise (AD12) are taken up in the list of products recommended by ECoLaSS to be directly included in the operational CLMS portfolio from 2020. Therefore, the final list of products suggested by ECoLaSS is the following:

- **HRL Imperviousness Incremental update:** incremental Imperviousness Density change at 20m (WP 42)
- **HRL Forest Incremental update:** incremental Tree Cover Loss at 20m (WP 42)
- **New Grassland product:** Grassland Use Intensity product at 10m (WP 43)
- **New Agricultural products:** New Crop Mask and Crop Type status layer (HRL Crops) at 10m, in combination with a dedicated in-situ data strategy (WP 44)

With the above recommendations, significant evolution steps are suggested with respect to existing products, in terms of improved temporal and spatial resolution as well as new thematic content. The workflows and methodologies have been designed to take full advantage of the combined Sentinel-1/-2 improved spatial resolution, information content and temporal frequency (by means of time series analysis), allowing to improve the robustness and reproducibility of the products, with less need for manual interaction. The HRL Imperviousness and Forest layer incremental updates will benefit from the change of spatial resolution of the status layers from 20 to 10m, whilst it is suggested that the change layer is kept at 20m resolution at the moment to maintain compatibility with the existing time series layer and avoid introducing too many technical changes due to the improved resolution. However, even though this was not tested as part of ECoLaSS, it can be suggested that the spatial resolution of the change layers also moves to 10m resolution.

Beyond the above suggested key candidates for new integration into the operational CLMS portfolio, some further recommendations shall be noted here:

- Probably at a slightly later stage (e.g. for HRL update 2021), the HRL Combined Layer should be considered for integration, once respective user requirements are further consolidated.
- If not already part of the upcoming HRL Vegetation Phenology and Productivity (HR VPP) product suite[2], the Generic Land Cover Metrics and the Crop Growth Condition should also be considered to complement the respective HR VPP portfolio in the future.
- Those products which had also been initially investigated by ECoLaSS, but have meanwhile found their way into the operational CLMS portfolio (i.e. the Improved IMD Status Layer at 10m, the Imperviousness Built-Up Area, the Improved DLT Status Layer at 10m, the Grassland Status Layer at 10m, and the CLC evolution (i.e. CLC+) product), are not further discussed in this report. In any case, their regular continuation as part of the operational CLMS portfolio (beyond 2020) is much supported.

[2] which will have to be assessed only after the end of the ECoLaSS project, since the final specifications for the HR VPP products, as offered by the successful consortium, will become known presumably only in the course of 2020.

# 3 Integration Plan into the Copernicus Service Architecture

The following sections are organised along the list of products selected as primary candidates for the operational roll-out as a result of the benchmarking exercise of WP 52 (AD12) and the assessments done in the previous sections of this report (cf. section 2.5).

For each product a description of the prototype is made as well as what are the infrastructure and technical requirements or constraints for its implementation. A more general assessment of the technical and availability issues in relation to input EO and in situ data is made in an annex to this document as a follow-up to *D4.2 – D22.1b – EO and other data requirements Report - Issue 2* (AD06). Finally, the political framework, roadmap and timing for integration is also reviewed for each candidate.

## 3.1 Incremental Imperviousness Density Change at 20m

Since the production of the HRL IMD 2006 as first GMES Fast Track Service Precursor (FTSP), a time series of Imperviousness has been delivered for the reference years 2009 (under the FP7 geoland2 project), 2012 (under the GMES Initial Operations (GIO)), and 2015 (as part of the operational CLMS). The reference year 2018 is currently being produced as part of the pan-European component of the operational CLMS, as well. For each of these iterations, the results contain two products: a status layer for any reference year (e.g. IMD 2012), as well as an Imperviousness Density Change layer between consecutive reference years (e.g. IMC 2009-2012) based on the respective Imperviousness product of the previous reference year.

### 3.1.1 Prototype Description and Rationale

The main product for the years 2006 to 2015 was a raster dataset of continuous degree of soil sealing from 0 – 100 % in (formerly) full spatial resolution (20 m x 20 m), provided together with the associated meta-data. A derived product, i.e. a raster dataset of continuous degree of soil sealing from 0 - 100% in aggregated spatial resolution (100 m x 100 m) and in European projection was generated. Several improvements have been tested and prototyped during the first phase of ECoLaSS, and have even been integrated by the EEA into the specifications for the HR Layers of the reference year 2018. This included a new status layer at 10m spatial resolution, taking full advantage of Sentinel-2, and the new Imperviousness Built-Up Area. The recommendation from ECoLaSS to keep the resolution of the IMD Change layer (IMC) at 20m was adopted.

#### 3.1.1.1 Definition of Prototype

The main improvements envisaged and tested for the Imperviousness product in phase 1 of ECoLaSS were related to taking full advantage of the Sentinel constellation, resulting in the following main outcomes:

- Improved more automated and generic workflow, combining the S-2 and S-1 data streams using time series processing techniques, although further work was still required in phase 2 to take full advantage of S-1;
- Improved temporal frequency, with the potential of yearly updates and 10m spatial resolution.

The prototypes tested during phase 1 of the project covered both, an improved status layer at 10m spatial resolution and an incremental update layer at 20m. The reasons for not immediately moving to a 20m spatial resolution for the change product are highlighted in AD08, in which a detailed assessment of the changes detected by the new improved S-2 based workflow had shown that nearly 75% of them could be attributed to omissions from the previous period. This was also confirmed as part of the prototype implementation in WP 42, with figures of a similar magnitude obtained.

Newly improved status layers at 10m spatial resolution are deemed to have reached a TRL of 8, if based on S-2 only and probably TRL 7 when using S-1 and S-2 in combination, but change layers are more at a TRL of 6-7, considering that there is still much to be improved in terms of accurate and unbiased change detection. This is mainly due to the fact that the magnitude of expected changes is below the error rate of the status layers for each date within the time interval considered. Therefore, when changes in terms of increasing impervious area are detected between a time step 1 (T1) and 2 (T2), these could be due to:

- Omission errors from T1
- Actual changes between T1 and T2
- New commission errors from T2

An iterative procedure was developed to minimise the effect of "technical changes", but this requires the re-processing of the T1 status layer or at the very least of the imagery used to produce the T1 status layer to ensure consistent changes. It is not possible to re-analyse the entire time series every time a new update is produced, but it is strongly suggested, that at the very least, the specifications of the change layers should include the identification of omission errors from the T1 status layer.

Prototypes for phase 2 tested the integration of Sentinel 1 and yearly updates, ensured that the technical changes were minimised and that the level of change detected was representative of reality, through an iterative classification procedure. Phase 2 results demonstrated that yearly incremental updates should be possible, but will potentially require the combined use of S-1 and S-2 especially in cloud prone areas. In addition, it should be noticed that there is a trade-off between the magnitude of change and the resulting accuracy of the change detection. In other words, the smaller the time interval between updates, the less changes will have occurred and the less accurate the resulting change map will be.

#### 3.1.1.2 Evolution of Requirements in the HRL 2018

Specifications for the HRL, in particular the IMP layer, have evolved, as detailed in the ITT for the 2018 reference year HRLs[3] considering the phase 1 recommendations of ECoLaSS, for the following products:

- The Imperviousness status product, with an increased spatial resolution from 20m to 10m;
- A continuation of the Imperviousness Change layer between 2015 and 2018, at a stable spatial resolution of 20m, in order to smooth the transition.

It should thus be noted that, even before the end of the current Horizon 2020 research efforts are ended, the evolutions tested and prototyped in the project ECoLaSS have been positively deemed operational at a pan-European scale and are already being implemented in the HRLs for the reference year 2018.

It should be further noted that a new component has been added to the requirements of the 2018 HRL: a built-up status layer, at a spatial resolution of 10m, which has also been planned in the project ECoLaSS and was tested and prototyped in the Phase 2. For this layer, results show that the 10m S2 resolution is borderline when compared to the size of buildings. This was also confirmed as part of the production. In addition, the consistency between the built-up component, which is a binary layer, and the Imperviousness Degree layer, which is a continuous product, is difficult to achieve at 10m resolution.

#### 3.1.1.3 Service Use Cases

The improved spatial resolution should bring the following benefits to users and other Copernicus services:

- The 20m layer often did not have a sufficient level of detail for many users at regional or local level. The 10m layer represents an improvement by a factor of 4 (or even more when considering that 23m or even 30m image data were used as input previously) which should better relate to the level of details that is often required. This added value is already being demonstrated as part of the operational HRL 2018 production
- It should also be better adapted to determine density classes as part of the CLMS local component with a better correspondence to the level of details often required.

The improved temporal resolution is not necessarily required for change detection, considering the magnitude of change. However, yearly incremental updates will:

[3] https://etendering.ted.europa.eu/cft/cft-documents.html?cftId=3865

- automatically reduce the time required to produce these updates. There was always a requirement to reduce the time needed between the reference year and when the product is actually delivered. Currently, the production time was reduced from nearly 3 years for 2012 to just over one year for 2015 (without the time needed to initiate and finalize the tendering process).
- Be more adapted to a wide range of uses, for which the frequency requirements are not necessarily aligned with the current mode of 3-yearly reference years of the CLMS.

### 3.1.2 Technical Infrastructure Constraints/Requirements for Integration

WP22 and WP35 highlighted that relying solely on S-2 would probably not allow the provision of yearly incremental updates for the whole of Europe and that S-1 will also need to be used.

In situ data are mainly needed in terms of provision of topographic reference data and road network for stratification purposes and VHR image data (from the ESA Copernicus SDA) for calibration and validation purposes. The selection of training data for the update of the built-up mask can be extracted from the existing layer for the previous reference year. As such, national reference is not sufficiently easily available at EEA39 level to be used, but this could change if accessibility and homogeneity of available layers is improved in the future.

Previously, the HRL Imperviousness had been completely produced using Service Providers' infrastructure. It is understood that initially, the DIAS infrastructure was more adapted to downstream applications and was not aimed at covering continental areas, such as needed for the production of CLMS core services. Therefore, under the current conditions, core services would be seen as an additional power user. In addition, the producing structure was still not fully clear at the start of the operational HRL Imperviousness 2018 production and time will have to show whether the DIASes are sufficiently adapted for the production of very large areas such as for the pan-European component. It may be envisaged that a separate procurement procedure will be organised to identify a suitable DIAS by EEEs for the implementation of their core service(s), but this is not yet clear.

Finally, there is another argument, for which it is perhaps better to wait before the full production can be transferred to the DIAS, which is linked to the lack of fully stabilised S-2 Level 2A products. This means that the production of the HRL Imperviousness Layer still relies heavily on the bespoke pre-processing of image data. This increases the storage costs, as the S-2 data will need to be duplicated, which makes the use of the DIAS infrastructure probably less attractive, although this would need to be carefully assessed.

It should be noted that using a DIAS for the production of the HRL for the reference year 2018 had been strongly encouraged in the ITT. Nevertheless, the decision was made by the implementing consortium not to use DIAS for the HRL 2018 Imperviousness production, as there was still a lack of stability when the production was launched and the decision had to be made.

### 3.1.3 Political Framework, Roadmap and Potential Timing for Integration

The Imperviousness layer was the precursor and first initial implementation for 2006 of what was to become the CLMS pan-European component's High Resolution Layers and the political framework is already well established. The improvements to the Imperviousness Layer are directly in the continuity of the existing layers and are already partially being implemented as part of the 2018 updates. Further improvements such as incremental updates have been tested as part of phase 2 of the project and can be implemented from 2020 with a view to the next HRL reference year 2021.

The mechanisms for stakeholder decision and implementation are not expected to be critical, as these improvements are already in line with some of the improvements already envisaged as part of the 2018 update.

It is suggested that the 3-year cycle is kept until 2021, with yearly incremental updates implemented from 2021. However, the term incremental should be understood as imposing a cut-off data for the acquisition of input image data for a given year. This could be set at the end of the vegetation period, e.g. end of October in the northern hemisphere. The identification of changes would still rely on classification of time series because detecting changes on single images would potentially degrade the quality of the results. Change layers would then be produced on a yearly basis, but the production of status layers could still be kept on a 3-yearly basis and would ensure consistency with the time series.

This will probably require a change in the procurement procedures from framework contracts which are specific to a reference year to multi-annual framework contracts, similar to what is already implemented as part of the CLMS Global component or the CEMS.

## 3.2 Incremental Tree Cover Loss at 20m

In 2012, the HRL Forest became (initially) operational on pan-European level as part of the GIO phase. Following a 3-yearly update cycle, HR forest products for the EEA39 have been updated for the reference year 2015 with an extended product portfolio including first (experimental) change products. The reference year 2018 is currently being produced as part of the pan-European component of the operational CLMS.

This section is about the specific integration plan for the Forest prototypes investigated and produced in ECoLaSS into the service architecture of the Copernicus Land Monitoring Service. Therefore, the prototype description and rationale (section 3.2.1) as well as the technical infrastructure constraints/requirements for integration (section 3.2.2) as well as the political framework, suggested roadmap and potential timing for integration (section 3.2.3) are described.

### 3.2.1 Prototype Description and Rationale

In the following three subsections, information on the HRL Forest related prototype is provided, focussing on the definition of the prototype (section 3.2.1.1) and the evolution of requirements as currently operationally implemented in the HRLs 2018 (section 3.2.1.2), followed by some service use cases (section 3.2.1.3).

#### 3.2.1.1 Definition of Prototype

The prototype for evolution of the HRL Forest has been primarily based on the HRL 2015 Forest product definitions in ECoLaSS phase 1, aiming at delivering improved production concepts and enhanced forest product characteristics, considering various upcoming user requirements in terms of establishing a long-term sustainable input EO/ancillary data base and increasing the speed of HRL production. In detail, this meant that for the production of the prototype, the complete Sentinel-2 A+B and Sentinel-1 time series was used in an integrated time series analysis approach, thus significantly increasing the exploitable EO based intra-seasonal information content. The associated high amounts of data necessitated applying an improved level of automation and a suitable cloud computing environment to allow a faster production and thereby shorter monitoring intervals. By the combined use of SAR and optical data, it was not only possible to benefit from the multi-sensor characteristics, but to additionally overcome the potential regional shortness of the optical time series due to frequent cloud cover and/or short vegetation season. The thematic classification accuracy has been improved by using spatio-temporal features, making use of the different phenological behaviours, but also because of the increased spatial resolution from 20m to 10m, which is providing much more spatial detail in general (by a factor of 4 or more).

This way, one new prototype has been developed related to further evolution of the HRL Forest specifications: an incremental Tree Cover Loss layer at 20m spatial resolution.

A map-to-map change detection approach was tested in the first project phase for the incremental Tree Cover Loss layer at 20m spatial resolution, to ensure continuity with the precursor HRL 2015 products. It compares the HRL 2015 and HRL 2017 products to detect areas of forest loss. Due to the very short time interval between the two masks (de-facto mostly 2016 vs. 2017), the layer concentrates on negative changes (loss) only. Due to (relative) shortcomings in the 2015 tree cover mask, caused by the then limited EO data and time series availability and the spatial resolution of 20m, an initial MMU of 3 ha had been preliminarily applied to the final Tree Cover Loss prototype map in the first phase of ECoLaSS, to allow focusing on forest loss with high reliability. Due to methodological advances, this has been significantly decreased in the second project phase to a finally suggested change MMU of 1ha.

#### 3.2.1.2 Evolution of Requirements in the HRL 2018

The service evolution towards an increased spatial resolution of 10m is now part of the specification of the HRL2018 Forest status layers, which are currently being operationally produced. Another aspect that has already become part of the operational HRL 2018 is the combined use of SAR and optical data from Sentinel-1 and Sentinel-2, which has been fully implemented in ECoLaSS. Furthermore, the related time series analysis approach based on time-features, as developed and demonstrated by ECoLaSS, forms another operational aspect, which, although not prescribed as such by the HRL 2018 ITT, is kind of imperative and is accordingly being implemented as part of the operational HRL Forest 2018 production.

In terms of change products, it should be noted that the HRL 2018 product specifications comprise simplified change products at 20m spatial resolution, i.e. a Dominant Leaf Type Change (DLTC) and a Tree Cover Change Mask (TCCM), with a 3-yearly update cycle, whereas the respective ECoLaSS Tree Cover Loss prototype is going a step further, having assessed an incremental tree cover update on annual basis at 20m spatial resolution.

It should be further noted that some new components were added to the specifications of the operational HRL 2018, i.e. aggregated dominant leaf type products at 100m spatial resolution, namely the Broadleaved Cover Density (BCD) and the Coniferous Cover Density (CCD) layer. However, as per their definitions, no significant development work is needed to implement these. Besides, the primary status layers have to be provided together with a series of quality and confidence layers, which are actually only addressed in form of the Data Score Layer (DSL) within ECoLaSS. In this particular case, the operational HRL 2018 demand has emerged faster than the developments in ECoLaSS could anticipate.

#### 3.2.1.3 Service Use Cases

One of the findings of WP 35 (Time Series Consistency) had been that it is difficult to reliably identify tree cover changes (both gain and loss) with a yearly update cycle, since (i) the trees' regrowth rates are relatively slow and respective increases in tree cover typically cannot be captured, neither spectrally nor via the intra-seasonal time series analysis, in such short time intervals, and (ii) in "normal" years, the spatial extent of tree cover losses (e.g. due to clear-cuts or forest damages) is limited compared to the amount of detectable "technical changes" caused by increased spatial resolution and temporal frequency of the more recent EO input data, improved methodologies, etc. Therefore, it is recommended to focus for yearly incremental updates on the tree cover extent, which would capture primarily rapid (negative) changes. Any incremental update intervals below one year were found technically not feasible with the currently available EO data and methodologically not reasonable with the current approach, since not allowing a proper seasonal time series analysis.

For monitoring the changes in tree cover characteristics/properties (such as dominant leaf type and tree cover density), the currently pursued HRL 3-yearly update cycle should be maintained. Consequently, the temporal aspect covered by ECoLaSS, considering a yearly incremental update, can be rated as an improvement of the latest forest change product definitions of the HRL 2018 in terms of tree cover, which are still maintaining the current 3-yearly monitoring interval (2015-2018).

With the improved spatial resolution of 10m, much more spatial detail of forest internal structures and leaf type composition will be provided with the 3-yearly status layers to users, with at the same time increased geometric and thematic accuracy. Considering the further improved incremental (yearly) update times, a range of requirements will be addressable, enabling users to valorise the more frequent products for their specific tasks (e.g. forest monitoring systems at regional level) or applications in the downstream service domain.

With respect to the Copernicus Land Monitoring Service, the upcoming 3-yearly DLT and TCD products at 10m spatial resolution will provide more reliable information with much more spatial detail. Consequently, they are partially better suited to serve as complementary data source to products of the local component (e.g. LC/LU product of the Riparian Zones, enabling attribution of specific forest density classes). Moreover, they can provide complementary information on land cover characteristics to other High Resolution Layers and can be generally used to improve their thematic quality (e.g. by a gradual semi-automatic plausibility analysis).

### 3.2.2 Technical Infrastructure Constraints/Requirements for Integration

With the launch and operation of the Sentinel family, together with other established systems such as Landsat, massive EO data sets have become available to the users. In order to cope with these large data volumes, adequate resources (storage and processing units) need to be in place. In the past, these resources have been often provided by the service providers themselves as part of their own IT infrastructure. However, the ever increasing requirements of the EEEs and the Copernicus user community towards future Copernicus services and products generally require the integration of ever more EO data plus suitable in-situ data sets. Consequently, powerful storage and processing solutions need to be increasingly used, and respective costs properly considered in the budget planning.

Cloud-based storage solutions and processing platforms (such as the DIASes) are meanwhile established and in place, aiming at enabling (highly) automated parallel processing environments for Copernicus. Thanks to these solutions, storage capacity issues seem to be things of the past. On the other hand, the assessment of the pure cost-benefit ratio in terms of storage and processing costs (versus a private cloud solution approach) does not yield a clear result yet, since the DIAS infrastructure designs have originally not been targeting Copernicus core service productions on continental scales specifically, and therefore currently require a significant effort for customisation and adjustment to fit e.g. an operational HRL production environment. This experience has been made specifically for the operational HRL Forest 2018 production by the contracted consortium, which had deliberately decided to produce on the Copernicus DIASes and has therefore chosen the Mundi DIAS as processing environment. Once set up, the capabilities are certainly enormous, but the time and effort required to solve all details was found substantially more than anticipated. This is at least partially certainly the case because such scale of massive operational parallel processing had seemingly not been attempted before. With growing experience, both on service providers’ and DIAS operators’ side, it is likely that the DIASes will further establish as the standard processing, storage and dissemination environment for CLMS products – at least if costs, offered data and other services remain/get competitive with other commercial platform like Amazon Web Services (AWS).

### 3.2.3 Political Framework, Roadmap and Potential Timing for Integration

As part of the CLMS pan-European component, the HRL Forest became operational in 2012 and was, alongside the HRL Imperviousness Layer, the most mature layer at high spatial resolution and pan-European level. Lessons learned from the productions of 2012 and 2015 were picked up in the operational production of the HRL Forest for the reference year 2018, like were several improvements tested and demonstrated by ECoLaSS (except the incremental update), which have already become part of the HRL Forest 2018 update process. After eight years of CLMS operationality, the political framework is well established and the mechanisms for stakeholder decision-making and user consultation (by the EEEs, the EC and the Copernicus Committee and User Forum) and service procurement are not expected to be critical, as the ECoLaSS suggestions for the HRL Forest can be considered just the logical future continuation of the other suggested improvements having become already part of the HRL Forest 2018 update.

In that sense, the Incremental Tree Cover Loss as demonstrated in ECoLaSS has reached the technical excellence level aimed for. The future roll-out-potential and benefit is assessed positive (cf. section 2.5) and it is assumed that it could be established together with the next HRL procurement for the reference year 2021.

It is suggested that for the HRL Forest products, the 3-year status layer cycle is kept until the reference year 2021, with yearly incremental updates implemented from 2021. Like in case of the suggested HRL

Imperviousness's incremental IMD update, the term 'incremental' should be understood as imposing a cut-off data for the acquisition of input image data for a given year. This could be set at the end of the vegetation period. The identification of changes would still rely on classification of time series because detecting changes on single images would potentially degrade the quality of the results. Change layers would then be produced on a yearly basis, but the production of status layers could still be kept on a 3-yearly basis and would ensure consistency with the time series.

## 3.3 Grassland Use Intensity product at 10m

In 2015, the first operational HRL Grassland had been produced for all EEA39 countries. That product included an operational pan-European grassland map and two expert products: a ploughing indicator and a grass vegetation probability index. Since early 2019, the new HRL Grassland for the reference year 2018 with improved product specifications and a new change product is being implemented through a fully cloud-based processing solution on the Mundi DIAS.

This section describes the specific plan for integration of the Grassland prototype "Grassland Use Intensity", which has been developed and demonstrated in ECoLaSS, into the operational service architecture of the Copernicus Land Monitoring Service. In the following sub-sections, the product is described and explained (section 3.3.1) and the required technical infrastructure and related requirements and constraints for an integration are explained (section 3.3.2). This is followed by an analysis of the political framework and the potential timing for integration (section 3.3.3).

### 3.3.1 Prototype Description and Rationale

In the following three subsections, information on the recommended HRL Grassland related prototype (i.e. Grassland Use Intensity) is provided, comprising the definition of the prototype (section 3.3.1.1), the evolution of requirements as currently operationally implemented in the HRL Grassland 2018 (section 3.3.1.2) and some service use cases (section 3.3.1.3).

#### 3.3.1.1 Definition of Prototype

The ECoLaSS grassland prototype finally suggested for operational implementation from 2020 onwards, i.e. the Grassland Use Intensity, aims at extending the latest operational products currently being implemented by the HRL 2018 Grassland. It has been demonstrated in the ECoLaSS demonstration sites as additional product accompanying the improved Grasslands status layer 2018 at 10m spatial resolution (AD09), distinguishing intensively/extensively mowed grasslands as binary product. The intensively mowed grasslands have been defined by three or more detected mowing events and the extensively mowed grasslands by two or less mowing events.

A crucial precondition for deriving Grassland Use Intensity is the presence of a highly reliable associated Grassland status layer, with 10m spatial resolution and a high thematic accuracy, as has been successfully demonstrated in ECoLaSS with the improved Grassland status layer product in 10m spatial resolution, and it is expected that the operational pan-European HRL Grassland 2018, once finalised, will mirror that. In terms of EO input data, this requires using the complete Sentinel-1 and Sentinel-2 time series, in order to provide a thematically accurate, seamless and spatially complete product with a maximum degree of reduction of data gaps caused by cloud cover. Furthermore, a high level of automation of the classification processes, making use of specific time features and indices for a detailed distinction between grassland and cropland, has been demonstrated in the second ECoLaSS project phase.

#### 3.3.1.2 Evolution of Requirements in the HRL 2018

A first experimental attempt of a HRL Grassland product had been undertaken by the EEA already for the reference year 2012, based on a combination of two pan-European HR optical EO data coverages (of IRS-P6 LISS-III and SPOT-4/5) and a series of monthly MR coverages of IRS-P6 AWiFS. It turned out however, that on this basis, only more or less 'natural grassland' could be identified, and the validation by Member States was accordingly not favourable; hence this product was not further continued.

Since the establishment of a new operational HR Grassland Layer in 2015, which was at that time based primarily on first Sentinel-2 data complemented by IRS Resourcesat-2, SPOT-5 and Landsat-8, the service and its products have evolved. The changes established with the latest HRL 2018 particularly concern the spatial resolution of the grassland status layer, which is increasing from 20m to 10m. In parallel, the minimum mapping unit is changing from 1 ha to 1 pixel. Both adaptations aim at enhancing the spatial detail of the grassland status map in order to support a broader use of the service. A multi-temporal approach based on an integrated optical/SAR-based processing chain, using the entire S-1 and S-2 archives instead of a pre-selection of best-suited acquisitions (as applied for the HRL 2015 approach), is another important operational improvement of the HRL Grassland 2018. Additionally, a Grassland Change product 2015-2018 and a confidence layer have been added.

Furthermore, an option to produce a "biomass extraction frequency" product is part of the contract with the implementing consortium of the current HRL Grassland 2018, but the option has not been drawn by the EEA yet, and as far as is known, there seem to be no such plans at present. It is considered that such product would largely resemble the 'grassland mowing frequency' intermediate product, from which the Grassland Use Intensity product has been derived in ECoLaSS by mowing event thresholding (AD09).

In ECoLaSS, the grassland mowing intensity has been successfully derived by estimating the number of mowing events from Sentinel-2 time series with a Kalman filtering approach, used to track the signal levels of the Tasselled Cap Components Brightness, Greenness, and Wetness through time on pixel-level. The method assumes that the removal of (vital) biomass after a mowing event causes on the one hand an abrupt drop of the Greenness signal, and on the other hand a drop of the Wetness level as a result of an increased soil reflectance. Thus, the implemented algorithm signals a mowing event if a statistically significant change vector in the two-dimensional feature space created by Greenness and Wetness is detected and its direction corresponds to a drop of both variables. A detailed description of the method is given in AD07.

As detailed in AD05, multiple user requests exist towards a consistent Grassland Use Intensity product, both at European, national and regional level. Therefore, it is expected that at latest with the HRL Grassland update for the reference year 2021, a respective product will be contracted for operational implementation.

#### 3.3.1.3 Service Use Cases

The Grassland Use Intensity product as addressed by ECoLaSS is expected to bring (at least) the following benefits to users and other Copernicus services:

- Facilitating ecosystem accounting and related EEA/EU assessment work;
- Improved biodiversity and environmental conservation policies monitoring and supporting respective supervision and decision-making, through allowing a better distinction between extensively and intensively used grassland and related changes/conversions;
- Identification of pressures and threats to protected areas and species on a regionalised level, in regular monitoring intervals;
- Allowing to better monitor the transition in agricultural practices, e.g. abandonment of grazing and subsequent shrub encroachment, etc.
- Enabling various other downstream applications, e.g. making use of an intermediate product related to the number of mowing events. For instance, natural grasslands could be identified as grassland areas which remain stable over time, but where no mowing events are detected at all.

### 3.3.2 Technical Infrastructure Constraints/Requirements for Integration

As a precondition for monitoring Grassland Use Intensity, a time series of high-quality grassland cover status products is required, like will be established with the upcoming availability of both the HRL

Grassland 2015 and 2018. The respective mapping requires a multi-temporal, multi-sensorial EO data base for adequately portraying this challenging class with high quality in a pan-European consistent way. With the Sentinel-1 and -2 archives, the situation has highly improved, enabling a highly automatic grassland mapping and monitoring. Moreover, grassland cover mapping capabilities of S-1 data have been demonstrated in ECoLaSS. Data gaps due to clouds/haze/snow cover therefore should be no longer limiting factors except for mountainous areas, where SAR detection possibilities are limited due to the SAR acquisition geometry.

In ECoLaSS, the additional Grassland Use Intensity prototype product represents a complementary dataset, adding a further level of grassland characterisation detail to the HR Grassland Layer (in this case: 2018). It has been prototypically derived from a 'mowing intensity' intermediate product, which itself is derived by estimating the number of mowing events through identification of multi-dimensional change vectors from Sentinel-2 derived time series of spectral indices with a Kalman filtering approach. The statistical significance of a mowing event detection is influenced not only by the change vectors' magnitude, but also by the length of the time interval between consecutive observations. Large gaps in the time series will result in a lower sensitivity of the detection method, because of limited information to distinguish between abrupt and gradual signal changes. A detailed description of the method is given in AD07. For pan-European operational application, it may be necessary to complement the Sentinel-2 A/B observations with Landsat-8 (and probably the upcoming Landsat-9) data as gap-fillers.

An alternative method, which had been tested in ECoLaSS, are coherence features derived from SAR data (Sentinel-1), although according to the undertaken accuracy versus performance benchmarking (e.g., computation costs, product quality and timeliness, etc.) and taking into account the upscaling need of the products to larger scales in a cost-efficient manner, the optical (Sentinel-2) based approach was selected for its overall better performance. In addition, it was concluded that coherences are highly sensitive to changes of boundary conditions, even on micro-level, and therefore, events like heavy rainfall are likely to make coherence images unusable for grassland use intensity analysis. Thus, besides the cost of SAR coherences processing, a SAR based approach appeared also too risky when considering the required high level of automation and large scale coherent production.

In any case, reliable in-situ reference data are required. In that respect, the situation could be better and particularly further improved by LPIS data being made consistently available across Europe. This would be an asset both for more reliably discriminating grassland from cropland and for an identification of the grassland use intensity with a sufficiently high level of automation. Very positive is the expansion of the LUCAS classification scheme regarding grasslands, as grassland types and grassland use classes have been included in the survey. Hence, these new LUCAS data have been tested positively in phase 2 of the ECoLaSS project for training and validation purposes. In general, also CORDA is a good tool for in-situ data search and provision. However, in terms of harmonisation, European data sets are preferred over region-specific or national information.

Unfortunately, direct reference data on grassland mowing intensity are generally not easily available. From the addressed ECoLaSS demonstration sites, only for the Austrian part of the Central demonstration site, access to a national IACS dataset (also known as InVeKoS in Austria) could be established, providing crucial information on the number of mowing events to train the classification algorithms. For operational large-scale production, local expert knowledge and/or in-situ training data, like InVeKoS data in Austria, are required. A lack of in-situ data affects in particular production of the grassland mowing intensity and hence the derived Grassland Use Intensity.

In the ECoLaSS demonstration sites where the in-situ data situation was sub-optimal, grassland mowing intensity was calculated alternatively from NDVI time-series change events detection by counting signal drops larger than 0.2 from a pre-cutting NDVI greater than 0.5. While this method is rapid in production, and the two thresholds could be regionally calibrated across Europe, it would require careful tuning of the two thresholds, at a presumably limited achievable accuracy level. That is why the recommendation of a new HRL Grassland Use Intensity product for operational implementation (cf. section 2.5) goes along with the recommendation to the EC and MSs to make also respective in-situ data available as widely and openly as possible, but as a minimum to the EEA and their contractors for operational CLMS production.

In terms of infrastructure requirements, preferably the identical cloud-based processing and storage infrastructure and processing platform as in case of the HR Grassland cover status Layer production should be used also for operational large-scale implementation of the Grassland Use Intensity product, since largely identical (optical) datasets will have to be accessed, and substantial synergies could be leveraged. That means that both products should be contracted and implemented together.

Like for the HRL Forest 2018 production (cf. section 3.2.2), one of the DIASes (Mundi) was selected also by the consortium contracted by the EEA for the operational HRL Grassland 2018 implementation, aiming at enabling (highly) automated parallel processing. With such solution, processing power and storage capacity are no limiting factors any more. However, also in this case, the assessment of the pure cost-benefit ratio in terms of storage and processing costs of such public cloud solution versus a fully private cloud solution approach does not yield a very clear result yet. The DIAS infrastructure designs have originally not been targeting Copernicus core service productions on continental scales specifically, and therefore currently still require substantial effort for customisation and adjustment to fit e.g. an operational HRL production environment.

This experience has been made for the operational HRL Grassland 2018 production by the contracted consortium, which had deliberately decided to produce on the Copernicus DIASes as "the Copernicus solution" rather than on other commercial public cloud platforms like AWS. The time and effort required to solve all details was however found substantially more than anticipated and probably more than would have been the case in another fully mature and specialised cloud environment. However, it is foreseeable that with growing experience, both on service providers' and DIAS operators' side, it is likely that the DIASes will be further established as <u>the</u> standard processing, storage and dissemination environment for CLMS products – at least if their financial, data and service offerings proof long-term competitive.

### 3.3.3 Political Framework, Roadmap and Potential Timing for Integration

As the first HRL Grassland precursor product on "Natural Grassland" had been discontinued after the reference year 2012, a new grassland baseline product based on a 7-year EO optical time series was established with the HRL 2015 Grassland layer. The EO data situation as well as the production workflows and results were not yet at a fully optimal stage at that time and were subsequently improved with a view to the HRL 2018. Some of these improvements (spatial resolution, MMU, integrated SAR/optical approach, change, etc.) have been anticipated and demonstrated in ECoLaSS, proving their feasibility.

In extension to these established grassland products, the ECoLaSS projects recommends the implementation of a Grassland Use Intensity product, which should contractually be implemented together with the associated HRL Grassland status layer products of the same reference year, in order to leverage synergies (cf. section 3.3.2). Contractually speaking, this could either take place with the next regular HRL reference year 2021, or potentially as a thematic extension to the current HRL Grassland production 2018. In either case, a sufficient reference data availability would have to be ensured alongside.

The political framework and the mechanisms for the relevant stakeholders' decision-making (i.e. EEEs, the EC and the Copernicus Committee and User Forum) and service procurement are well-established, with the aim being that the ECoLaSS recommendations support an informed decision-taking on the evolution of the grassland products.

Due to the novel and innovative nature of the Grassland Use Intensity product, it is further recommended to keep the current 3-yearly update cycle for this product.

## 3.4 New Crop Mask and Crop Type status layer (HRL Crops) at 10m

The last ECoLaSS prototypes to be described in detail in the context of the present Integration Plan into the Copernicus Service Architecture are the agricultural products related to crop mask and crop type mapping. In the following sub-chapter, the prototype description and the rationale will be given (section 3.4.1). Besides that, the potential technical constraints and specific requirements related to data and infrastructure will be named (section 3.4.2), before the focus is laid on the political framework and a suggested timing/roadmap for the integration (section 3.4.3).

### 3.4.1 Prototype Description and Rationale

In the following three sub-sections, the details for the crop mask and crop type prototypes are given, comprising a short definition of the prototypes (section 3.4.1.1), the evolution of requirements as currently operationally implemented in the HRLs 2018 (section 3.4.1.2) and some suggested service use cases (section 3.4.1.3). It should be noted that all this refers to the prototypes produced for the pan-European sites (West Belgium/ France and Central). The crop mask/type prototypes for the Mali and South Africa sites are not considered, since the in-situ data sources are completely different and the approach also slightly differs from the one used for the other sites.

#### 3.4.1.1 Definition of Prototype

The new agricultural products suggested for operational implementation into the Copernicus service architecture are the “New crop mask status layer at 10m” and the “New crop type status layer at 10m”. Both are not yet included in the operational CLMS portfolio as of now. The prototypes have been produced for four different sites; two sites in Europe i.e. Central and West (from which the “West” demo site was further split into a Belgian and French part due to the nature of different time frames of reference data availability), and for the African demo sites in Mali and South Africa.

The crop mask is a binary product (crops / no crops), which is based on both optical and radar input data (S-1/S-2 or only S-2; depending on data availability per region). From these input data, temporal features and metrics are derived and classified with the Random Forest Classifier. For the model training as well as for the validation, LPIS and sampling data based on the HRLs 2015 were used. The output is a binary pixel-based crop mask. Like the crop mask product, the product “New crop type status layer at 10m” is a newly conceptualised prototype, which is not yet part of the HRLs 2018, and targets the approximately 15 most meaningful crop types in Europe at a 10m spatial resolution.

#### 3.4.1.2 Evolution of Requirements beyond the HRLs 2018

Since the prototypes on the agriculture topic are the first products of their kind, there are still many aspects to be clarified before a pan-European layer can be implemented, not the least on political level between the EC and the Member States. Presumably for these reasons, there was no HRL on Agriculture (crop land) included as part of the HRLs 2018 yet. It is however expected and suggested that for a next implementation of the reference year 2021, the necessary boundary conditions may be met.

Based on the user/stakeholder requirements assessment in WP 21, the main aspects that should be addressed by a future HRL Crops, comprising a crop mask and a crop type product, are (i) the integration of the complete Sentinel-1 and Sentinel-2 time series in order to benefit from the multi-sensor characteristics, (ii) a high level of automation for the classification, (iii) at least a seasonal update cycle.

These requirements have been largely tested and demonstrated by ECoLaSS. The various prototype implementations have made use of combinations of optical and SAR input data already. An exception is the French part of the demonstration site West, where only S-2 data were used due to availability issues of reference data for individual years. Provided availability of adequate reference data, the level of prototype automation can be regarded high. Another aspect that many potential users of such product have voiced was to investigate the most useful update cycle. Beyond manifold wishes for continuous intra-seasonal crop growth and health status monitoring, biomass and carbon accounting as well as yield forecasts (AD05), which are currently not addressable as a Copernicus core service with nowadays' free and open HR satellite data only, it seems that what most users/stakeholders seem to desire in this context is a seasonal update cycle.

#### 3.4.1.3 Service Use Cases

At least in terms of user requirements, it is undoubted that many users on European, national and sub-national level request a new, additional HRL Crops (AD05), as this is the most obvious and glaring thematic gap in the current CLMS pan-European product portfolio of HR Layers, and the land cover/land use class with the highest economic and ecological impact.

Regarding the complementarity to other CLMS products, it can be stated that there is no product available yet that has the focus on arable land. The potential to include this thematic focus topic in the future HRL portfolio in the coming HRL update cycle is clearly there, but there is still a certain lack of specification consolidation on the side of the user community, which needs to be clarified before the actual operationalization can start. In that respect, ECoLaSS has done basic research and investigations of a feasible pan-European class nomenclature, which can serve as a robust common denominator for a pan-European product. As a result, a nomenclature of approximately 15 most meaningful crop type (groups) in Europe at 10m spatial resolution is suggested in the final issue of the Prototype Report on Crop Area and Crop Status/Parameters (AD10). This is considered suitable for crop type differentiation and, subject to proper in-situ data availability, at the same time suitable for a Pan-European roll-out. It should be noted that this nomenclature comprises crop type classes such as soybeans and rice, which are actually grown just in limited regions of Europe, thus not all of these crop types will be covered in each specific region.

One conceptual issue that will need to be decided is on the potential overlap with other HR Layer products, as the suggested crop type nomenclature currently also lists land cover/use classes such as Temporary Grassland (< 5 years) + fodder/agrarian grass (potential classification confusions with HRL Grassland, although conceptually distinct) as well as Olive Groves (definition overlap with HRL Forest) and Other Permanent Crops (partial definition overlap with HRL Forest in terms of fruit trees/orchards). Thematically, these areas are certainly regarded part of the agricultural crop-growing area. Since per definition, the HRLs can have thematic overlaps, and thus certain land cover/use types can conceptually belong to more than one HR Layer, this topic is considered manageable.

More than any other currently existing HR Layer, a future HR Crops Layer is considered highly relevant for aiding various kinds of farming downstream applications (such as pest and fertiliser control, crop yield estimation, drought monitoring, etc.), CAP monitoring and subsidies control, precision farming, environmental protection efforts, R&D, scientific studies, etc.

### 3.4.2 Technical Infrastructure Constraints/Requirements for Integration

The current full availability of the S-1 and S-2 constellation data is enabling the production of a Crop Mask, applying the methodology tested and demonstrated in ECoLaSS. As highlighted in previous sections of this report, cloud processing and storage infrastructure is not regarded a technically limiting factor any more, although costs and timing implications need to be carefully observed (sections 3.1.2, 3.2.2, 3.3.2).

What is rather critical for the implementation, particularly of the Crop Types, is the unequal access/availability to LPIS data across the EEA39. Besides the HRLs as sample basis for a regionally calibrated crop mask classification algorithm training, LPIS data are needed as well as a reference, for both training and validation. Unfortunately these data are not equally accessible throughout the EEA39 states. Some countries provide the data set via CORDA, whereas others don't. Furthermore, the contents of the datasets differ a lot from each other, e.g. the French LPIS data do not contain permanent agricultural classes while the German ones do. This has consequences for the calculation of the crop mask and particularly of the crop types, and requires specific adjustments of the workflow and the methods to ensure a somewhat consistent product quality throughout.

In any case, it is suggested that on political level, endeavours are increased to make LPIS data available across Europe, at least for the purpose of producing the new HRL Crops.

### 3.4.3 Political Framework, Roadmap and Potential Timing for Integration

Unlike the previously described candidate products for integration into the operational Copernicus service architecture, certain unclarities exist for the HRL Crops prototype in terms of the Member States' equivocal political support for integrating such product into the CLMS portfolio, either of the pan-European or the global component. Whereas the user requirements assessment undertaken by ECoLaSS clearly underpins the users' need for a Copernicus HRL Crops (comprising a crop mask and a crop type product), the political support for such decision by the main stakeholders seems currently not fully guaranteed. The interests of the main involved players, i.e. EC DG Agri, DG Clima, the EEA, the JRC, the EU-28 and EEA-39 Member States (via the Copernicus User Forum and the Copernicus Committee), appear not uniform, and the political debate has not yet been concluded. However, the acceptance among Member States appears to have grown during the second project phase of ECoLaSS.

This current politically slightly unclear situation is related particularly and primarily to the ongoing political process of the CAP reform, which seems to require further time until a sufficient level of consolidation is reached between the EC and the Member States. In the absence of related clear decisions, it appears yet unclear whether a CLMS HRL Crops will be sufficiently supported – since the delta (or not) to the planned CAP services cannot yet be clearly named. Likewise, it is not yet secured whether related budget lines will be made available for such service, although the current draft budget plans for the upcoming Copernicus 2.0 (after 2020) do clearly foresee an increase of Copernicus budget for establishing new services.

Probably the strongest indication for grown Member State support is the inclusion of a new HRL Crops in the final Copernicus Work Programme 2020, as part of the pan-European CLMS component, although the targeted reference year (2018 or 2021) remains unclear. The Work Programme explicitly mentions „A new High Resolution Layer Crops addressing major groups of crop types and so linking to managed cropland needed for upcoming Land use, Land Use Change and Forestry (LULUCF) based carbon accounting".

In that sense, it appears that a dedicated European HR Crops Layer would make sense as part of the next generation of HRL products from the reference year 2021 onwards. In the same sense, the final Copernicus Work Programme 2020 states "With the preparatory work finalised in 2019, the kick off for the production of this new HRL product will take place in 2020". This would also allow to realise significant synergies with the HR Grassland Layer, allowing to potentially increase both products' quality through an integrated production approach. This would make sense, as the biggest challenge for both layers is to mutually distinguish grassland and crop land use, rather than from other land cover classes. A HRL Agriculture would also fit to the current 3-yearly (and potential future 1-yearly) update cycle. It seems that in terms of service specifications and use cases, a clear distinction and separation should be envisioned from upcoming CAP-related agricultural EO-based services, since these will most likely be serving different purposes, user communities and time steps. Global-level agricultural products/services may be conceived with similar specifications, or evolve from a first European-level implementation.

In any case, and identical to the recommendations for the HRL Grassland Use Intensity product (cf. sections 3.3.2 and 3.3.3), a renewed and increased political effort should be made alongside the HRL Crops service procurement, to ensure that sufficient reference data will be available.

# 4 Conclusions and Outlook

This Integration Plan into the Copernicus Service Architecture comprehensively summarises the ECoLaSS project's key research outcomes, and outlines the operational service implementation perspectives and scenarios of the most promising new and improved CLMS prototype services and products, which the ECoLaSS team has been assessing in the course of the 3-year Horizon 2020 project. As such, this report also constitutes the essence and condensed outcome of the various user interaction, testing, developing and prototyping efforts which have been conducted by ECoLaSS.

Based on the results of a detailed benchmarking procedure (AD12) and the subsequent assessment of individual "integration readiness" as part of this report (section 2.4), individual tailored implementation roadmaps for all finally suggested candidate services (section 2.5) have been laid out in chapter 0, addressing:

- **HRL Imperviousness incremental update:** incremental Imperviousness Density change at 20m
- **HRL Forest incremental update:** incremental Tree Cover Loss at 20m
- **New Grassland product:** Grassland Use Intensity product at 10m
- **New Agricultural products:** New Crop Mask and Crop Type status layer (HRL Crops) at 10m

The latter two new product recommendations go explicitly along with a clear recommendation for further enhanced political endeavours to establish an agricultural in-situ data policy, to be agreed among the main political decision-makers (cf. sections 0 and 0).

Nevertheless, these new products and/or product improvements have all been confirmed to have reached a Technology Readiness Level (TRL) of at least 7 (cf. section 2.3.1) and an Application Readiness Level (ARL) of at least 5-6 (cf. section 2.3.2), which does not only mean that a product definition is mature and a clear methodological path exists to producing it, but also that the infrastructural framework to produce it is secured (section 2.4).

It should be stressed that beyond the above suggested key candidates for new integration into the operational CLMS portfolio, some further recommendations shall be noted here:

- Probably at a slightly later stage (e.g. for HRL update 2021), the HRL Combined Layer should be considered for integration, once respective user requirements are further consolidated.
- If not already part of the upcoming HRL Vegetation Phenology and Productivity (HR VPP) product suite, the Generic Land Cover Metrics and the Crop Growth Condition should also be considered to complement the respective HR VPP portfolio in the future.
- Those products which had also been initially investigated by ECoLaSS, but have meanwhile found their way into the operational CLMS portfolio (i.e. the Improved IMD Status Layer at 10m, the Imperviousness Built-Up Area, the Improved DLT Status Layer at 10m, the Grassland Status Layer at 10m, and the CLC evolution (i.e. CLC+) product), have not been further assessed in this report, albeit their regular continuation as part of the operational CLMS portfolio (beyond 2020) is much supported.

Finally, it should also be noted that ECoLaSS has demonstrated its value in supporting the evolution of CLMS by making it possible to highlight critical issues and provide solutions for future services. Some of the recommendations from ECoLaSS were included in the HRL2018 ITT. It is recommended that such targeted research project initiatives should continue to be supported in the future

The report primarily aims at providing a scientifically-technically sound and substantiated basis for informed decisions to be taken by the decision makers on Copernicus, i.e. the EC, the EEEs and the Copernicus User Forum and Copernicus Committee. Additionally, a high-level concise summary of the ECoLaSS key findings is presented in the ECoLaSS *White Paper on Copernicus Land Evolution* (AD13). All provided recommendations conform to the latest and up-to-date level of available information at the end of December 2019.

# 5 References

Héder, M. (2017). From NASA to EU: the evolution of the TRL scale in Public Sector Innovation. *The Innovation Journal: The Public Sector Innovation Journal, 22*(2), 1-23.

# Annex
# Review of issues encountered regarding input data sources as part of ECoLaSS prototype Implementation relevant to CLMS Future Implementation

## Introduction

Issues related to the use of EO data and ancillary data (e.g. in situ) as part of ECoLaSS were primarily documented in "D22.1b – EO and other data requirements Report". However, this report was finalised at M24 during the project and since then a number of issues were encountered as part of the prototypes implementation and some evolution also took place. Most of these have been documented as part of the ECoLaSS deliverables, but it seemed relevant to document them at the end of the project to ensure that they are dully considered for future CLMS implementation

## Input EO Data

### Sentinel Constellation

#### Sentinel-1

The S-1 mission consists in the provision of high-resolution radar imaging, even though cloudy atmosphere and during the night. SAR observations foreseen for land applications will include terrain motion surveillance or data for emergency response. Details can be found on the official webpage of the mission at https://sentinel.esa.int/web/sentinel/missions/sentinel-1. S-1 ensures the continuity of the C-band SAR Earth Observation ESA missions of ERS-1, ERS-2 and ENVISAT.

Dense S-1 time series in the testing and prototypic production of an improved GRA status layer and new agricultural layers in ECoLaSS have proven to be a reliable source of information, in particular for phenological purposes, to complement the optical time series. Further integration of radar acquisitions in the processing chains of the other prototypes was also tested in the second phase of the project. In general, if a good coverage S-2 data is available, the additional value provided by S-1 is not worth the effort. However, without a good S-2 coverage, S-1 data can be used to provide a cloud-free coverage. Finally, C-Band data is probably not the best for land applications and in particular for forest characterisation.

#### Sentinel-2

The S-2 constellation is set to produce high-resolution multispectral imaging, that are being used as the primary sources of data for Copernicus operational land services, in the continuity of Landsat, SPOT and IRS satellite missions. S-2 will be mainly focused on land cover and usage, change detection and geophysical variable maps, and will also be of use during emergency management. Details can be found on the official webpage of the mission at https://sentinel.esa.int/web/sentinel/missions/sentinel-2.

For future Copernicus Services based on optical Sentinel data, ideally, a consolidated and reviewed method to generate atmospherically and terrain corrected Level 2A products would be required. Currently, several L2A processors exist in parallel, providing different results, and the user community has not finally decided which method is to be favoured. In addition, aside from a precise atmospheric and terrain correction of the Sentinel data, the cloud masks currently generated are still inadequate, often resulting in artefacts in derived indices/metrics and thus hampering the analysis of S-2 dense time series. Adequate L2A products will significantly reduce the efforts of the Copernicus service providers in view of the EO data pre-processing (atmospheric correction, scene-by-scene calibration, topographic normalisation) which are fundamental pre-processing steps for large-scale operational production. In this context, properly processed L2A products provide the basis for effective multi-temporal analysis and consecutive harmonised products, while simultaneously increasing cost efficiency. In case of gap-filling approaches within existing Sentinel coverages (e.g. due to high cloud cover within short observation intervals), contributing satellite data should be ideally also atmospherically corrected.

The development of new services also requires access to historical EO data. Experience from the HRL2015 production has shown that missing or incorrect metadata entries in historic IMAGE_20XX datasets mean that metadata files had to be laboriously updated by service providers, but the resulting workaround-results have never been re-injected into the ESA Data warehouse.

Maintaining the quality of historic EO data collections and improving access thereto may become of increasing importance, as there appears to be a trend to consider retrospective monitoring approaches, to extend the time series of EO based LC/LU assessment and change analyses into the past. One recent example is an open Call for Tenders published by the EC's DG Environment just before Christmas 2018, aiming at establishing a system for a monitoring of grassland areas inside Natura2000 protected sites across Europe back to as late as 1992.

### Sentinel-3

The S-3 mission is focalized on land and ocean colour, temperature, as well as sea and terrain topography, through the use of medium-resolution multispectral imaging and altimetry.

S-3, like S-1, is also ensuring the continuity of the C-band SAR Earth Observation ESA missions of ERS-1, ERS-2 and ENVISAT. Details can be found on the official webpage of the mission at https://sentinel.esa.int/web/sentinel/missions/sentinel-3.

The operational production of S-3 SYN products is still delayed at the time of the writing of this report, therefore it ProbaV was used to simulate the potential added value that could be brought by S-3 satellites. However, it should be noted that this issue is not viewed as a critical gap in the Sentinel data availability, since S-2 satellites have been outperforming and their coupling with S-1 data has been leading to satisfying results in ECoLaSS phase 1.

### Sentinel Data Distribution – Rolling Archive

Beginning with S-1 and now also S-2, ESA has begun enforcing a rolling archive strategy on the Copernicus Open Access Hubs, whereby data acquisitions older than twelve months will no longer be held online for immediate access but have to be individually requested from an offline long-term archive (LTA). This has become necessary to deal with the fast growing archive of Sentinel acquisitions. Details are given at https://scihub.copernicus.eu/userguide/LongTermArchive. While an API to access the LTA is provided, very stringent user quotas are being enforced, allowing only around 40 such requests per day for retrieval of single scenes from the LTA. Facing this restriction has rendered large-scale, long-term time-series analyses, as demonstrated so successfully in the ECoLaSS project, almost impossible for users relying on data distributed directly by ESA. While alternative free data sources such as the Alaska Satellite Facility or commercial providers like the DIASes or Amazon AWS can be solutions to this problem, this is a step back in terms of open access and should be remedied by a better performing retrieval infrastructure and more realistic user quotas in order to keep on exploiting the unprecedented potential of the Sentinel fleet.

### VHR2018

The VHR2018 dataset from the Copernicus Space Component Data Access (CSCDA), coordinated by the European Space Agency (ESA)[4], will be used as one of the primary data sources for production of some of the CLMS products such as the HRL Small Woody Features (SWF) and CLC+ Softbone. In addition, VHR2018

[4] Detailed overview on relevant Copernicus dedicated satellite missions (Sentinels) and Contribution missions of CSC Data Access Portfolio Data Warehouse 2014-2020:

https://spacedata.copernicus.eu/documents/12833/14545/DAP+Document+-+current/c2449218-3ed9-434a-b32c-edfbb95b9362 is also used as a main data source for the CLMS Hot Spot Monitoring products and as a source of training data and validation for most CLMS products.

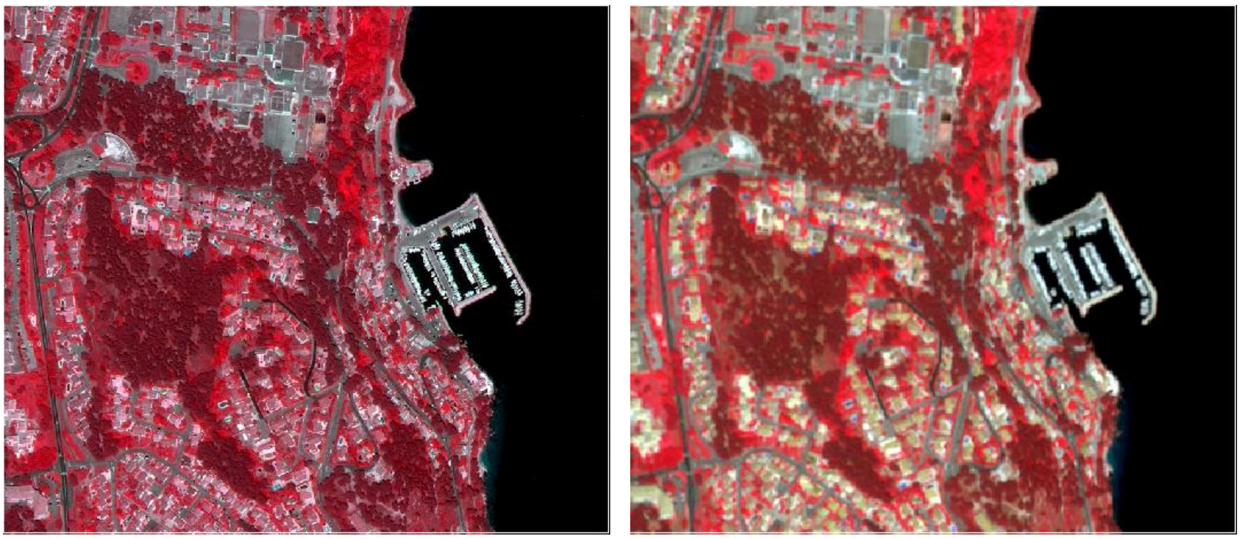
The VHR2018 dataset providing one VHR EEA39 complete coverage for the 2018 reference year +/- one year at 2-4m multispectral spatial resolution. The VHR2018 dataset was acquired from selected satellite missions to cover the whole of EEA39 including overseas DOM based on a partition of EEA39 into 140 large regions. The following allocation was implemented as follows:

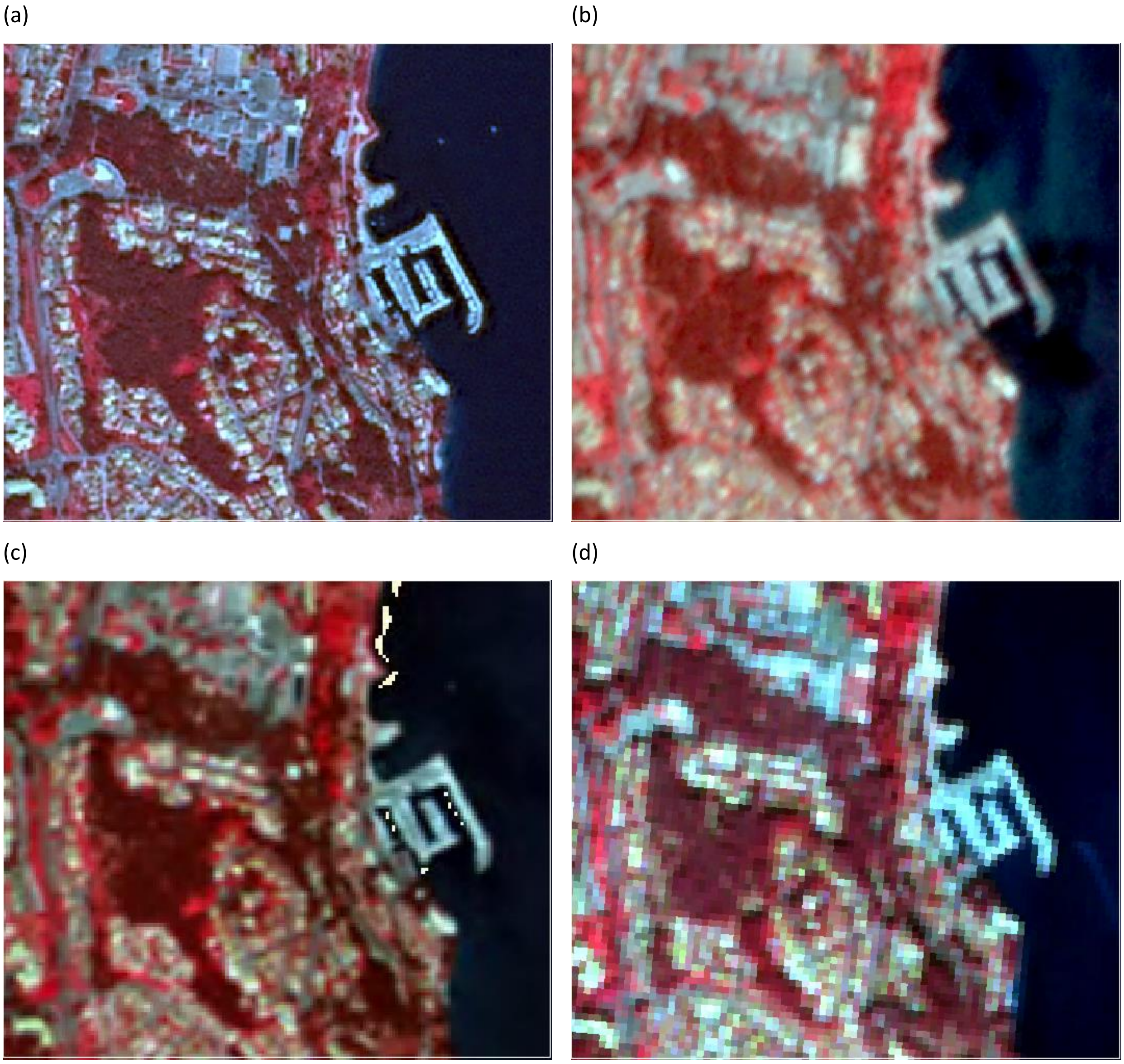
- Primary satellite missions:
  - Pléiades 1A & 1B: around 47% of the total area
  - PlanetScope: 15% coverage
  - SuperView-1: 7%
  - Kompsat-3/3A: 10%
- Backup Satellite missions:
  - SPOT6/7: 20%
  - TripleSat: less than 1%

The VHR2018 dataset is much of an improvement as compared to the VHR2015 coverage. Even though the delivery was also delayed, it was done in large blocks as opposed to a patchy coverage, this is welcome to support automated processing over large areas such as in the HRL. Unlike for VHR2015, there were no detected issues with respect to geometry. There was a coordinated effort for gap filling due to cloud cover and only the 'usable part' of the imagery now appears to be provided which is welcome for large area automated processing since the cloud cover is now masked. However, the unusable part of the primary image is now filled with small patches over unusable part, this is fine for visual interpretation, but not for automated supervised classification for which it will not be possible to get sufficient samples to classify these areas acquired at different time and with different sensors.

Focusing on 2-4m spatial resolution is probably not the ideal option, some of the Planet data is clearly not sufficient (spatial resolution is closer to RapidEye than SPOT 5 data, see example below in Figure 1). However, Planet indicated that this was based on the first Dove sensors that are now much improved and some of this imagery has now been replaced. Nevertheless, an alternative option would probably have been better to focus on 1.5m pan-sharpened such as that provided from SPOT6/7 data.

With respect to recommendations for VHR2021, favouring sensors with larger image swath such as SPOT 6/7, would greatly enhance the outcome of automated classification approaches and would also provide a more homogeneous coverage for visual interpretation. When part of an image is not usable, this should be filled with additional complete scenes to avoid large number of small patchy scenes. Finally, each scene should be accompanied with a reliable usable / unusable layer including the identification of cloud and cloud shadows.





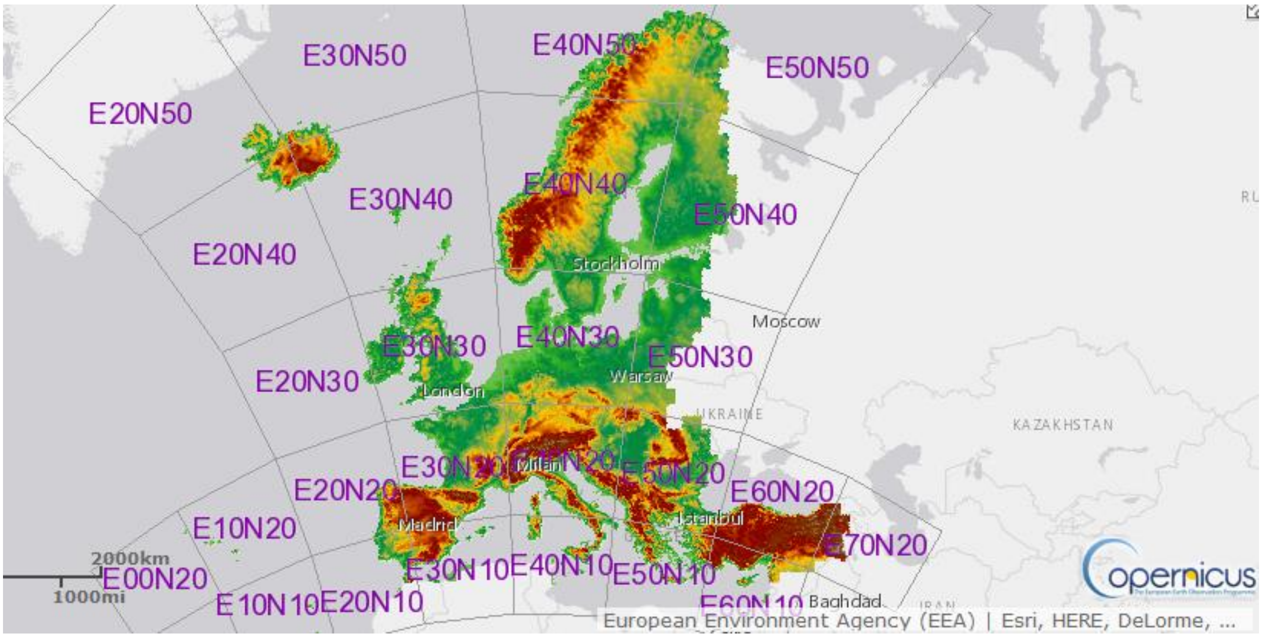

(e) (f)

**Figure 1: Comparison of different optical sensor spatial resolution (a) Pléiades 0.5m, (b) Pléiades 2m, (c) SPOT 5 2.5m, (d) Planet 4m, (e) RapidEye 5m and (f) Sentinel-2 10m**

# In situ ancillary data

## EU-DEM

The EU-DEM is a pan-European reference dataset, which is fully, freely and openly available for download via the Copernicus Land portal (http://land.copernicus.eu/). It provides spatially explicit digital information on the land surface elevation and fully covers the 39 EEA countries. The EU-DEM is a hybrid Digital Elevation Model (DEM) based on SRTM (Shuttle Radar Topography Mission) and ASTER-GDEM (Advanced Space-borne Thermal Emission and Reflection Radiometer - Global Digital Elevation Model) data, fused by a weighted averaging approach. Also publicly available Russian topographic maps were incorporated for areas north of 60° northern latitude. The EU-DEM provides pan-European elevation data at one arc second (approximately 30 m) posting. It is currently available as updated version 1.1 as a 32-bit GeoTIFF raster dataset with 25m pixel size and a vertical accuracy of 7 m RMSE. The dataset can be downloaded in tiles of 1000 x 1000 km size.




*Ref.:* http://land.copernicus.eu/pan-european/satellite-derived-products/eu-dem/eu-dem-v1.1

**Figure 2: Spatial coverage of the EU-DEM (v1.1)**

DEMs provide information required for a broad range of applications with different technical requirements and use cases in the various fields of earth observation. From a Copernicus Services perspective, a consistent EU-DEM is considered important for various kinds of applications at pan-European level, such as consistent satellite image processing, data modelling, future higher-frequency HRL updates or other Copernicus and EU initiatives employing extensive time series analyses.

Many users as well as Copernicus service providers have voiced a clear and urgent requirement for an update/improvement of the EU-DEM, which appears necessary to fulfil the quality requirements (in terms of dataset/time series consistency, higher spatial resolution, better vertical accuracy) for further applications at pan-European level, particularly in consideration of the increased 10 m spatial resolution of S-2. A consistent European DEM of further improved quality would also be beneficial for various kinds of downstream Land applications on more regional scale, for example: water storage and volume assessment, assessment of precipitation run-off and flood risk, risk assessment of landslides and soil erosion. Moreover, the inclusion of high-resolution and high-quality DEMs is desired for various applications in urban areas (e.g. building height, damage assessment, or 3-dimensional modelling) and mountainous areas, which are subject to small-scale topography changes.

In summer 2018, ESA had published an open Call for Tender to procure a new Copernicus DEM. This is foreseeing the provision of a globally homogenous and more accurate 30 m and 90 m DSM and as an option an additional 10 m DSM for the EEA39 countries. In December 2019, the Copernicus DEM has been finally published by ESA, including three instances with different resolutions:

- 90 meter dataset for global coverage (free license)
- 30 meter dataset for global coverage (ESA user license)
- 10 meter dataset for the EEA-39 area (ESA user license)

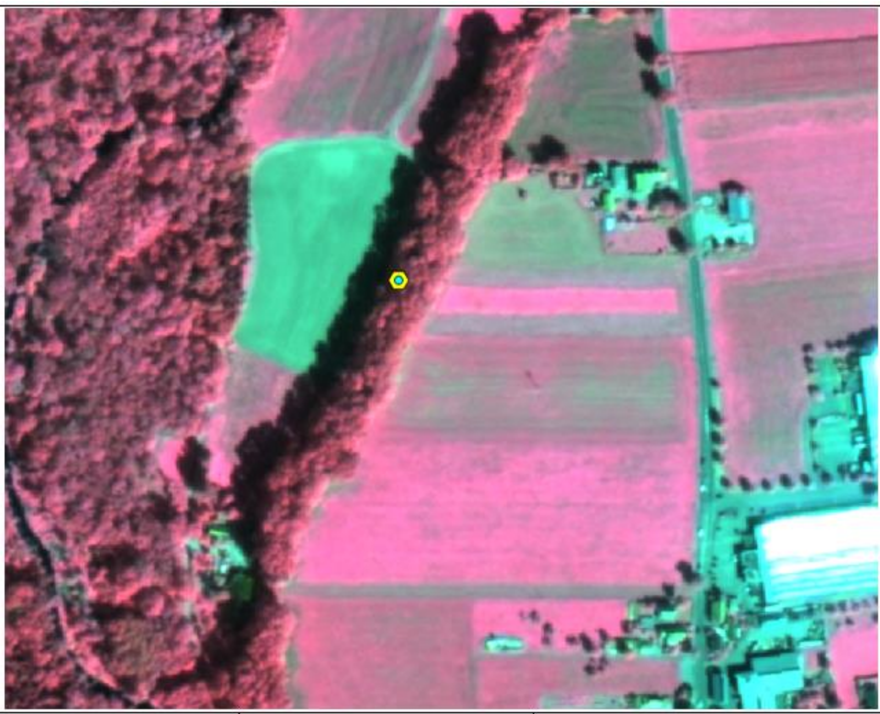
This globally homogenous DEM, based on the SAR-derived WorldDEM (obtained through the TanDEM-X mission at 1 m spatial resolution), is deemed to become the new elevation reference standard for the entire Copernicus programme.

## LUCAS

From the land use / land cover production perspective of the ECoLaSS project, the LUCAS data sets with the field photography are a helpful independent data source for accuracy assessment and as training sample layer.

The free availability and access via a single point, plus the large area distribution (e.g., near continental) are among the most valuable merits of this dataset. The database structure and attributes, particularly the consideration of the land cover mix or purity attribute, facilitates performing selections of samples to derive case-specific training and validation / accuracy assessment sets. However, LUCAS points due to their small spatial support (only 3m radius) should not be used directly for calibration or validation purposes.

Therefore, the newly introduced Copernicus Module has clearly proved its added value in this regard, by enlarging the surveyed surface areas and providing details in four directions. However, the current protocol is experimental and added to the existing one. It seems rather complex to implement and would benefit from being merged with the existing one.



| | | |
|---|---|---|
| Coordinates | X : 585468<br>Y : 5325767 | CRS: WGS 84/UTM zone 32N |
| Background Image | VHR – Deimos –<br>False colour composite; ECoLaSS Test Site Central | |
| SURV_DATE<br>Observation_Type<br>LC1<br>LC1_Species<br>LC1_Cover<br>Class<br>FID (Internal Shapefile) | 2018-08-07 00:00:00<br>1<br>G11<br>8<br>100<br>Water<br>(899) | |
| Comments: Reference Point not usable due to its proximity to ***a forest/grassland area***. It is labelled as ***G11 (Water bodies)*** in the attribute table of the LUCAS Reference Dataset. | | |

**Figure 3: Example of a LUCAS 2018 point being not usable due to its proximity between land cover classes.**

Not surprising, most usability issues of individual LUCAS points were found in transition/border areas between different land cover types, as exemplified in the forest case above. It should be noted that the additional attribute indicating the purity of the land category is particularly of interest for a proper interpretation of the data, especially considering typical scale/pixel size issues when using point data in combination with Earth-Observation datasets.

In view of the Forest and Grassland activities within ECoLaSS, LUCAS 2018 proved to be a valuable input for validation of the test results and final prototypes. For this purpose, LUCAS points have been recoded towards the HRL class nomenclature taking the observation type and land cover purity into account. Even though around 10% of the LUCAS points proved to be not usable due to several reasons (e.g. peripheral point position, tree cover change, poor reference data situation), the remaining points were sufficient to assess the thematic accuracy on demonstration site level. Furthermore, LUCAS proved to be sufficient for a Tree Cover status and Grassland status classification 2018 using the selected Random Forest (RF) classifier, which is capable to manage such an amount of potentially inadequate samples.

In the case of Agriculture, LUCAS 2018, albeit not detailed enough for more specific crop type products, has proven useful for training/accuracy assessment of a cropland mask. Notwithstanding this, its 3-year acquisition frequency represents a limitation to account for crop rotation.

As a commonplace topic when dealing with systematic grid-based reference datasets, minority classes are under-sampled for regional-scale applications (e.g., it was necessary to complement water samples from additional datasets). Regarding New Land Cover products in preparation of CLC+, LUCAS data contributed to samples of several classes, with some such sampling density related limitations for less abundant land cover categories. In particular, in the case of CLC+ categories, the “sparsely vegetated” class has no clear direct match in the LUCAS databases, at least not without a defined percentage of possible vegetation cover. Although the sampling grid density might not fulfil some classifiers’ training sample requirements, it allows easy complementing with other sources or additional interpretation.

The database includes relevant attributes complementing the LULC label which are helpful for case-wise sampling purposes, suchlike the purity and observation type information. However, overall use potential of LUCAS data could be significantly increased if the “inclusion probabilities” per plot would be provided. This would for example allow to combine the EO based results with the LUCAS field survey data for statistically sound area estimation.

However, for consistent and seamless mapping approaches on full pan-European level, a full coverage of LUCAS points would be needed, which is actually not given by the latest survey. This can be seen as one of the main drawbacks of LUCAS when considering large-scale applications.

## LPIS

LPIS data proved to be very useful in the thematic classification process of satellite imagery and the resulting products’ subsequent validation, as it provides reliable information on land cover and land use. This is even an essential dataset for the purpose of producing an annual crop type layer. Even though LPIS data is produced by all EU countries, access to it is still very heterogeneous and the data are currently not made available at full European level (see Figure 4 below). The reason for this is fairly simple: the creation of nation-wide LPIS data is a cost-intensive process and member states and some national institutions have built up business models to distribute such types of data commercially. However, a number of Member States is providing LPIS data on a free and open basis. It is important to note, that this data is made available in different ways (WFS, WMS, shapefile, geodatabase) with varying thematic content (different level of thematic detail) and aggregation, as well as with different temporal extents. Therefore, improvements in the access, consistency and timeliness would be much appreciated by the Copernicus service providers. The current LPIS availability situation is depicted in the figure below.

Even for those countries for which LPIS is available, the availability of the LPIS data for a particular year can be delayed for up to 18 months. For example, in France the 2018 LPIS has yet to be made available at the time of writing this note in December 2019.

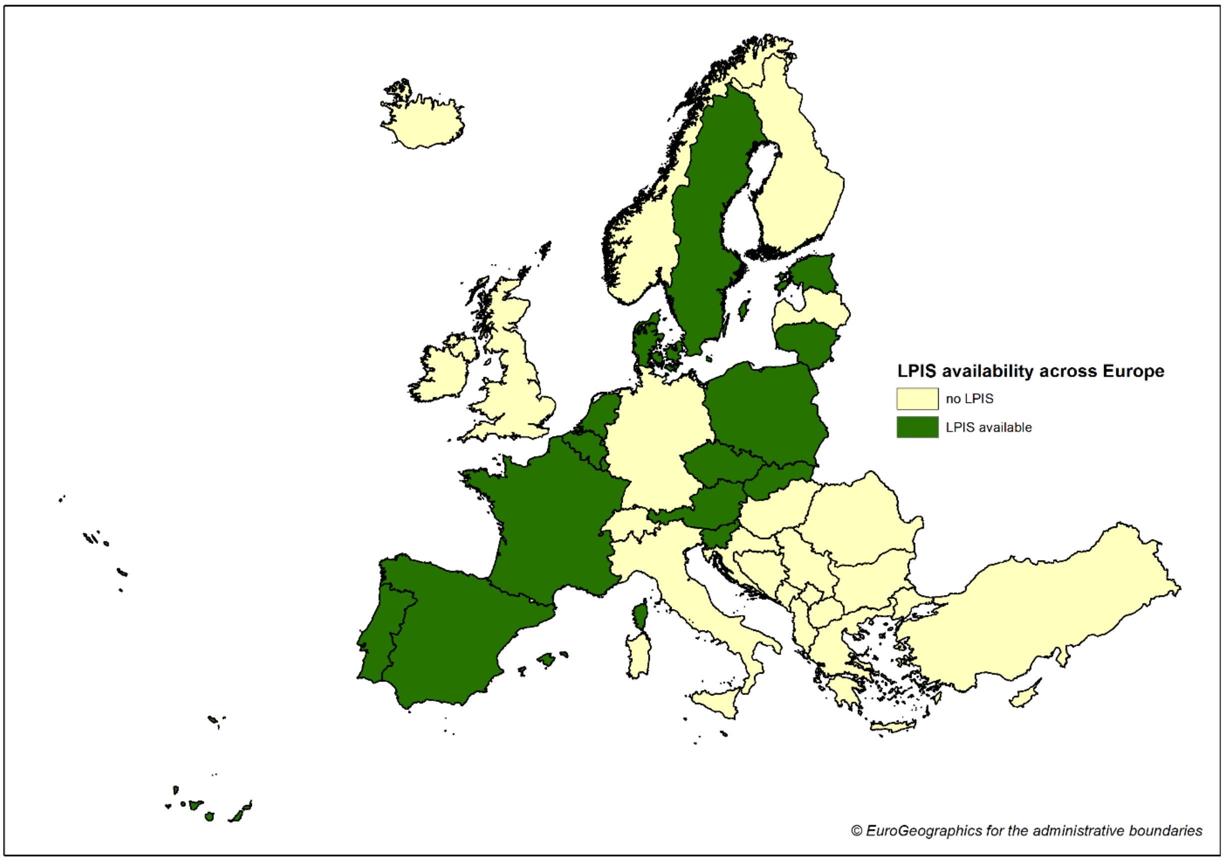



**Figure 4: Availability of accessible LPIS data across Europe**

# Conclusions and outlook

This note represents a summary and update of the previous D22.1b – EO and other data requirements Report, incorporating the experiences made during the ECOLaSS project. This note focuses on the status, but more importantly on the shortcomings of the current data situation, and the consequences this might have for future services.

This review comprised, amongst others, an assessment of the current and recommendations for future offering in terms of EO data including the Sentinel constellations and VHR data for calibration and validation. The EO data situation was also reviewed, to assess any critical gaps and potential mitigation measures as briefly summarised below:

- Although the VHR data coverage has improved with VHR2018, there still need to be some improvements in terms of timeliness and homogeneity both in terms of data sources and quality.
- The specifications of the VHR_IMAGE_2018 data with 2-4 m spatial resolution will pose a limitation in terms of information content and discriminability of landscape features. Specifically, the largely contained Planetscope data will not allow identifying the “quasi-ground truth” calibration information needed for all HR Layers, e.g. it will not be possible to reliably identify individual tree crowns vs. canopy gaps for the HRL Forest’s Tree Cover Density and Dominant Leaf Type products.
- The available standard level of pre-processing for S-2 imagery as provided by ESA/Sen2Cor is currently still not adequate, thus somewhat restricting the quality of the results from automated processing chains based on dense time series. Cloud, haze and shadow masks need to be improved further for large-scale operational applications.
- Alternatives to the cloud mask provided by Sen2Cor, such as MAJA or FMASK pre-processing or a customised cloud mask, have proven to be viable, as outlined in (AD07). The prototypes developed

in Task 4, namely the improved HR IMP, FOR and GRA Layers, which substantially rely on optical S-2 datasets, have demonstrated their operability at a 10 m resolution, for shorter updates.
- Newer candidate products such as phenological layers and crop type layers could benefit more from the deeper integration of S-1 images into the processing chain, in particular to mitigate the occurrence of cloud cover, which will be further tested in the second project phase of ECoLaSS.
- At the time of this report's writing, the products of S-3 were still under review in order to improve their quality and robustness. As a substitute, the densification of the time series of optical data from S-2 will be investigated in the framework of ECoLaSS by using PROBA-V data in the meantime.
- Maintaining the quality of historic HR/VHR EO data collections and improving access thereto may become of increasing importance. Recent examples at European level suggest there may be a trend to consider retrospective monitoring approaches, to extend the time series of EO based LC/LU assessment and change analyses also into the past, allowing comprehensive and informed policy decisions.

In terms of in-situ and other reference data requirements and offering, the following summary conclusions can be drawn from the assessments of ECoLaSS:

- Although a higher-precision DEM for Europe has been procured by ESA in 2019, and finally made available to the Copernicus Service Projects in December 2019, it came too late to support a better geometric consistency of the VHR_IMAGE_2018 dataset. However, future generations of Copernicus services may greatly profit from it.
- Supporting in situ data for training and validation of thematic data are not homogeneous across the EEA-39 countries.
- One of the more obvious examples is LPIS which could provide reliable training and validation data for the production of HRL grassland and a future crop layer, but its availability at pan-European level is far from complete despite the INSPIRE Directive. This would require further support and strengthening of the Copernicus In-situ Component to improve the access to such high quality reference and in-situ data for the Copernicus Services.
- The use of LUCAS dataset was further explored in the second ECoLaSS phase as a basis for a crop mask layer. The Copernicus protocol implemented as part of LUCAS 2018 is certainly an improvement but could probably be simplified to facilitate its use. In addition, inclusion probabilities are required to use LUCAS data for validating Land Cover/Use maps