Horizon 2020

Space Call - Earth Observation: EO-3-2016: Evolution of Copernicus services

Grant Agreement No. 730008

ECoLaSS

Evolution of Copernicus Land Services based on Sentinel data

D1.5

"D11.3b – Interim Progress Report (Issue 2)"

Issue/Rev.: 2.0

Date Issued: 04.06.2019

submitted by:

GAF AG

in collaboration with the consortium partners:

SIRS JOANNEUM RESEARCH DIGITAL UCL Université catholique de Louvain DLR

submitted to:

European Commission – Research Executive Agency

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme, under Grant Agreement No. 730008.

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

Disclaimer:

Document Release Sheet

	Name, Function	Date	Signature
Author(s):	Markus Probeck (GAF) David Herrmann (GAF) Christophe Sannier (SIRS) Sophie Villerot (SIRS) Heinz Gallaun (JR) Petra Miletich (JR) Mathias Schardt (JR) Pierre Defourny (UCL) Élie Khalil (UCL) Andreas Hirner (DLR) Benjamin Leutner (DLR)	27.05.2019	
Review:	Katharina Schwab (GAF)	29.05.2019	K. Schwab
Approval:	Eva Sevillano Marco (GAF)	04.06.2019	
Acceptance:	Massimo Ciscato (REA)		
Distribution:			

Dissemination Level

Dissemination Level		
PU	Public	X
CO	Confidential: only for members of the consortium (including the Commission Services)	**Annex 1**

Document Status Sheet

Issue/Rev	Date	Page(s)	Description / Changes
1.0	12.10.2017	45 + 3 (Annex 1)	First issue of the Interim Progress Report
2.0	04.06.2019	158 + 6 (Annex 1)	Second issue of the Interim Progress Report

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	D11.2b - Project Management Plan (Issue 2), Issued: 04.12.2018
AD06	D11.1 - Agendas and Minutes of Meetings, Issued: 07.12.018
AD07	D12.1b – DWH use for 2018, Issued:14.12.2018
AD08	D12.2a – DWH request for 2019, Issued: 19.10.2018
AD09	D21.1a - Service Evolution Requirements Report, Issued: 09.08.2017
AD10	D22.1b - EO and other Data Requirements Report (Issue 2), Issued: 21.02.2019
AD11	D23.1b - Service Infrastructure/Architecture Requirements Report (Issue 2), Issued: 18.02.2019
AD12	D31.1a - Methods Compendium: Sentinel-1/2/3 Integration Strategies, Issued: 26.03.2019
AD13	D32.1b - Methods Compendium: Time Series Preparation (Issue 2), Issued: 15.05.2019
AD14	D33.1a - Methods Compendium: Time Series Analysis for Thematic Classification, Issued: 29.03.2018
AD15	D34.1a - Methods Compendium: Time Series Analysis for Change Detection, Issued: 29.03.2018
AD16	D35.1a - Methods Compendium: HRL Time Series Consistency for HRL Product, Issued: 14.05.2018
AD17	D41.1a - Prototype Report: Time Series-derived Indicators and Variables, Issued: 10.08.2019
AD18	D42.1a - Prototype Report: Consistent HR Layer Time Series/Incremental Updates, Issued: 28.08.2018
AD19	D43.1a - Prototype Report: Improved Permanent Grassland, Issued: 17.07.2018
AD20	D44.1a - Prototype Report: Crop Area and Crop Status/Parameters, Issued: 11.08.2019
AD21	D45.1a - Prototype Report: New LC/LU Products, Issued: 03.08.2018

ID	DOCUMENT NAME / ISSUE DATE
AD22	D51.1c - Stakeholder Consultation Report (Issue 3), Issued: 01.04.2019
AD23	D52.1a – Report on Candidates for Operational Roll-out, Issued: 21.12.2018
AD24	D53.1a – Integration Plan into Copernicus Service Architecture, Issued: 23.12.2018
AD25	D61.1 - Project Website (Issue 1), Issued: 03.07.2018 – website updated 2019
AD26	D61.2b - Communication, Dissemination and Exploitation Plan (Issue 2), Issued: 26.04.2019
AD26	D61.3a - Collection of Communication and Dissemination Material, Issued: 28.06.2018
AD27	Technical Note. Proposed substitutes for Sentinel-3 data. Issued: 04.12.2018
AD28	Technical Note. ECoLaSS Update on ethics issues. Issued: 04.03.2019
AD29	D53.2 -White Paper on Copernicus Land Evolution (Issue 1), Issued: 23.12.2018
AD30	D62.1 Market Opportunities and IPR Strategy (Issue 1), Issued: 28.12.2018

EXECUTIVE SUMMARY

The Horizon 2020 (H2020) project, "Evolution of Copernicus Land Services based on Sentinel data" (ECoLaSS) addresses the H2020 Work Programme 5 iii. Leadership in Enabling and Industrial technologies - Space, specifically the Topic EO-3-2016: Evolution of Copernicus services. ECoLaSS is being conducted from 2017–2019 and aims at 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 assesses the operational readiness of such candidate products and eventually suggests some of these for implementation. This shall enable the key CLMS stakeholders (i.e. mainly the Entrusted European Entities (EEE) EEA and JRC) to take informed decisions on potential procurement as (part of) the next generation of Copernicus Land services from 2020 onwards.

To achieve this goal, ECoLaSS makes full use of dense time series of High-Resolution (HR) Sentinel-2 optical and Sentinel-1 Synthetic Aperture Radar (SAR) data, complemented by Medium-Resolution (MR) Sentinel-3 optical data if needed and feasible and otherwise by similar characteristics sensors (e.g., PROBA-V). Rapidly evolving scientific developments as well as user requirements are continuously analysed in a close stakeholder interaction process, targeting a future pan-European roll-out of new/improved CLMS products, and assessing the potential transferability to global applications.

This Deliverable *"D11.3b: Interim Progress Report (Issue 2)"* is provided upon the Interim Progress Meeting 2 (M27), as a precursor of the Final Report at M36, and is split in two parts: The main report part provides information on the status of the work carried out in different WPs (chapter 2). This contains an overview of achieved deliverables and milestones (section 2.1), a summary of the administrative and project management efforts including risk management (section 2.2), a summary of scientific and technical coordination (section 2.3), and explanations of the work carried out by all Work Packages (WPs) during the first half (M27) of the second reporting period (M36) (section 2.4). The updates of the project impact assessment and the exploitation and dissemination are provided respectively in chapter 3 and chapter 4. Annex 1 of this Deliverable, which is provided as separate, confidential Annex to this Deliverable, provides a review and update of the work plan as well as an explanation of the use of resources for each WP and beneficiary.

Key achievements of the ECoLaSS project after 27 months comprise: Delivery of all 34 project phase 1 reports due by M27 (including 4 delayed deliverables submitted in December 2018) and 9 project phase 2 deliverables (some of them with minor delays); consultation of various stakeholders and finalisation of related CLMS service evolution requirements analysis; coordination with CLMS H2020 projects in place, data sharing and document management methods established and updated in accordance to detected implementation needs; placement of VHR data orders and quota with ESA DWH; finalisation of Sentinel data pre-processing for all phase 2 test sites and demonstration sites to allow for an earlier start of Task 4 activities; ongoing second-phase testing and implementation of all methodological WPs in test and demo sites including methodological developments and testing of high data volume processing lines as part of Task 3 and identification of potential for further improvement; development and implementation of prototypes as part of Task 4; assessment of the operational framework as part of Task 5; several dissemination activities executed; Homepage renewed and Twitter account active.

During the last quarter of 2018, as a result from project reviews, an exchange of recommendations and subsequent consortium reflections was to steer the upcoming implementation throughout the last year in ECoLaSS. Chapter 5 tracks down the recommendations and undertaken actions in this regard. An assessment of the level of work plan completion as well as of the further update needs, together with an in-depth assessment of the use of the project's resources, have been conducted and are presented in a separate Annex due to its confidentiality. Summarising, the project appears to be largely on track without major deviations from the plan. Phase 2 is quick paced as a result from the findings from phase 1 implementation.

Table of Contents

List of Figures

List of Tables

Abbreviations

AD	Applicable Document
AI	Action Item
ACIX	Atmospheric Correction Inter-comparison eXercise
AERONET	AErosol RObotic NETwork
AOD	Aerosol Optical Depth
AOI	Area Of Interest
AOT	Aerosol Optical Thickness
AWiFS	Advanced Wide Field Sensor
AWS	Amazon Web Services
BBCH	Biologische Bundesanstalt and Bundessortenamt und CHemische Industrie
BKG	Bundesamt für Kartographie und Geodäsie (German Federal Agency for Cartography and Geodesy)
BOA	Bottom-of-Atmosphere
BRI	Brightness Index
CAP	Common Agricultural Policy
CCI+	Climate Change Initiative + (follow-up)
CG	Crop Growth Monitoring
CGDD	Comissariat Général au Développement Durable (French General Office for Sustainable Development)
CL	Cropland
CLC	CORINE Land Cover
CLC+	CORINE Land Cover plus (with improved specifications)
CLMS	Copernicus Land Monitoring Service
CNES	Centre National d'Études Spatiales (French Space Agency)
CO	Confidential
CORDA	Copernicus Reference Data Access
CRM	Crop Mask
CRT	Crop Type Map
db	Decibel
D	Deliverable
DAP	Data Access Portfolio
DDV	Dark Dense Vegetation
DEM	Digital Elevation Model
DG/s	Directorate-General/s
DG AGRI	Directorate-General for Agriculture and Rural Development
DG CLIMA	Directorate-General for Climate Action
DG DEVCO	Directorate-General for International Cooperation and Development
DG ENV	Directorate-General for Environment
DG GROW	Directorate General for Internal Market, Industry, Entrepreneurship and SMEs
DG MOVE	Directorate General for Mobility and Transport
DG REGIO	Directorate General for Regional Policy
DIAS	Data and Information Access Service

DLR	German Aerospace Center
DLT	Dominant Leaf Type
DN	Digital Numbers
DO	Dark Object
DRC	Democratic Republic of Congo
DS	Downstream Service
DSM	Digital Surface Model
DWH	Data Warehouse
EAA	Environmental Agency Austria (Umweltbundesamt Österreich)
EARSC	European Association of Remote Sensing Companies
EARSeL	European Association of Remote Sensing Laboratories
EC	European Commission
ECMWF	European Centre for Medium-Range Weather Forecasts
ECoLaSS	Evolution of Copernicus Land Services based on Sentinel data
EEA	European Environment Agency (EEA)
EEA-39	the 33 member and 6 cooperation countries of the EEA
EEEs	European Entrusted Entities
EIONET	European Environment Information and Observation Network
EO	Earth Observation
EO4AGRI	Bringing together the Knowledge for Better Agriculture Monitoring H2020
ESA	European Space Agency
EU	European Union
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FADSL	Forest Additional Support Layer
FAO	Food and Agriculture Organisation of the United Nations
fAPAR	Fraction of Absorbed Photosynthetically Active Radiation
Fmask	Function of mask
FOR	High Resolution Layer Forest
FTP	File Transfer Protocol
GAF	GAF AG (a service provider)
GAI	Green Area Index
GDPR	General Data Protection Regulation
GLC	Global Land Cover
GRA	High Resolution Layer Grassland
GRD	Ground Range Detected
H2020	Horizon 2020
HR	High Resolution
HRL	High Resolution Layer
HRL2015	High Resolution Layer 2015
IACS	Integrated Agricultural Control System
IGARSS	International Geoscience and Remote Sensing Symposium

IGN	Institut National de l'Information Géographique et Forestière (National Institute of Geographic and Forest Information)
IMC	Imperviousness Change Classified
IMD	Imperviousness Degree
IMP	High Resolution Layer Imperviousness
INSPIRE	Infrastructure for Spatial Information in Europe
IPM1	Interim Progress Meeting 1
IPR	Intellectual Property Rights
IRECI	Inverted Red-Edge Chlorophyll Index
ISO	International Organization for Standardization
ISRSE	International Symposium on Remote Sensing of Environment
IUFRO	Interconnecting Forests, Science and People
IT	Information Technology
ITT	Invitation to Tender
IW	Interferometric Wide swath
JECAM	Joint Experiment of Crop Assessment and Monitoring
JR	Joanneum Research
JRC	Joint Research Center
KO	Kick-Off
LAI	Leaf Area Index
LC/LU	Land Cover/Land Use
LGP	Landbouwgebruikspercelen ALV, 2016
LiDAR	Light Detection And Ranging
LPIS	Land Parcel Identification System
LSMSS	Large-Scale Mean Shift Segmentation
LUCAS	Land Use/Cover Area frame statistical Survey
M	Month
MACCS	Multi-sensor Atmospheric Correction and Cloud Screening
MAD	Median Absolute Deviation
MAJA	Maccs-Atcor Joint Algorithm
MARS	Monitoring Agricultural ResourceS
MFF	Multiannual Financial Framework
MNDWI	Modification of Normalised Difference Water Index
MODIS	Moderate Resolution Imaging Spectroradiometer
MMU	Minimum Mapping Unit
MPA	Maximal Phenological Activity
MR	Medium Resolution
MS	Microsoft
MSS	Minimum Segment Size
MTCD	Multi-temporal cloud detection
MTF	Multi-Temporal Filter
MULTIPLY	MULTIscale SENTINEL land surface information retrieval Platform
NA	Non Applicable

NASA	National Aeronautics and Space Administration
NDBI	Normalized Difference Built-up Index
NDMIR	Normalized Difference Middle Infrared Index
NDRB	Normalized Difference Red Blue
NDSI	Normalized Difference Snow Index
NDVI	Normalized Difference Vegetation Index
NDWI	Normalized Difference Water Index
NGR	HRL Natural Grassland
NIVA	New IACS Vision in Action H2020
NRC	National Reference Centre
OA	Overall Accuracy
OLCI	Ocean and Land Color Instrument
OPT	Optical
OSM	Open Street Maps
PA	Producer's Accuracy
PCA	Principal Component Analysis
PCC	Post-Classification Comparison
PEDR	Communication, Dissemination and Exploitation Plan
PES	Phenological End of Season
PLS	Phenological Length of Season
PM	Person Month
PO	Project Officer
PPS	Phenological Peak of Season
PROBA-V	PRoject for On-Board Autonomy–Vegetation
PSS	Phenological Start of Season
PU	Public
QM	Quality Management
R&D	Research & Development
REA	Research Executive Agency
RF	Random Forest classifier
RIA	Research and Innovation Action
RMSE	Root Mean Square Error
RSG	Remote Sensing Software Package Graz
RUS	Research and User Support
S-1	Sentinel-1
S-2	Sentinel-2
S-3	Sentinel-3
SAR	Synthetic Aperture Radar
SD	Standard Deviation
SEN4CAP	Sentinels for Common Agriculture Policy
SENSAGRI	Sentinels Synergy for Agriculture

SIRS	Systèmes d'Information à Référence Spatiale SAS
SLC	Single Look Complex
SLSTR	Sea and Land Surface Temperature Radiometer
SME	Small and Medium Enterprise
SNAP	Sentinel Application Platform
SPOT	Satellite Pour l'Observation de la Terre
SRTM	Shuttle Radar Topography Mission
SVM	Support Vector Machines
SWIR	Short-wave Infrared
SyGMa	System for Grant Management
TCC	Tree Cover Change
TCD	Tree Cover Density
TCM	Tree Cover Mask
TEP	Thematic Exploitation Platform
TOA	Top-of-Atmosphere
TRL	Technical Readiness Level
UA	User's Accuracy
UBA	Umweltbundesamt Deutschland (German Environment Agency)
UCL	Université Catholique de Louvain
UN	United Nations
UNCBD	UN Convention on Biological Diversity
UNFCCC	UN Framework Convention on Climate Change
URL	Uniform Resource Locator
UTM	Universal Transverse Mercator
VH	Vertical transmit/Horizontal receive (polarization)
VHR	Very High Resolution
VI	Vegetation Index
VV	Vertical transmit/Vertical receive (polarization)
WAW	HRL Water And Wetness
WMS	Web Map Service
WP	Work Package

1. Introduction and Objectives

INTRODUCTION

The Horizon 2020 (H2020) project, "Evolution of Copernicus Land Services based on Sentinel data" (ECoLaSS) addresses the H2020 Work Programme 5 iii. Leadership in Enabling and Industrial technologies - Space, specifically the Topic EO-3-2016: Evolution of Copernicus services. ECoLaSS is being conducted from 2017–2019 and aims at 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 assesses the operational readiness of such candidate products and eventually suggests some of these for implementation. This shall enable the key CLMS stakeholders (i.e. mainly the Entrusted European Entities (EEE) EEA and JRC) to take informed decisions on potential procurement as (part of) the next generation of Copernicus Land services from 2020 onwards.

To achieve this goal, ECoLaSS makes full use of dense time series of High-Resolution (HR) Sentinel-2 optical and Sentinel-1 Synthetic Aperture Radar (SAR) data, complemented by Medium-Resolution (MR) Sentinel-3 optical data if needed and feasible. Rapidly evolving scientific developments as well as user requirements are continuously analysed in a close stakeholder interaction process, targeting a future pan-European roll-out of new/improved CLMS products, and assessing the potential transferability to global applications.

Figure 1 shows the timeline of operational Copernicus Land implementations and where ECoLaSS is embedded, in order to suggest prototypes for potential implementation into a future Copernicus Land Service 2020+. The overall duration of the project is 36 months (Jan 2017 - Dec 2019), with two development cycles of 18 months each.

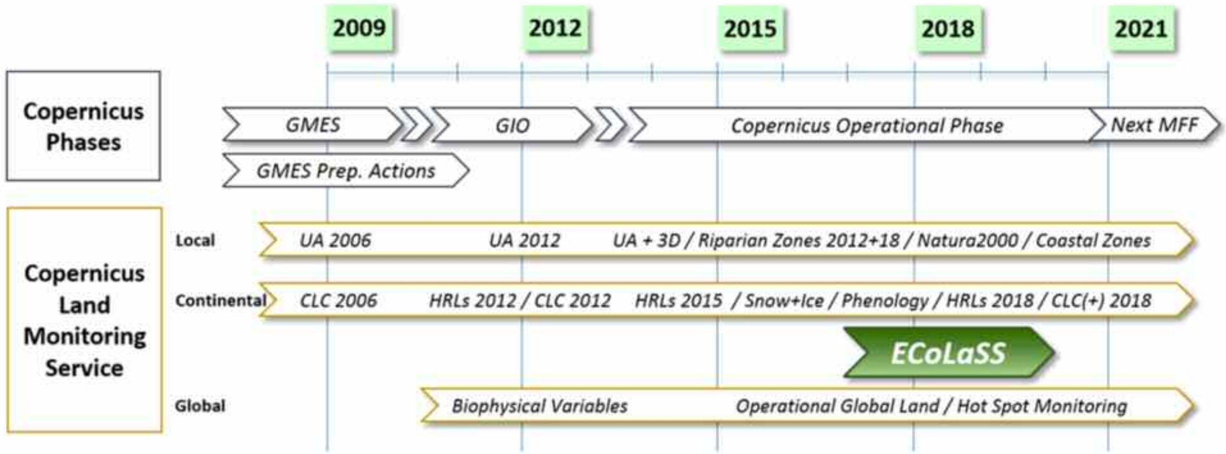


Figure 1: ECoLaSS Project embedding in the operational Copernicus timelines

The "**Interim Progress Report (Issue 2)**" accounts to progress in ECoLaSS up to M27. In addition, this report sets the grounds for the upcoming Interim Progress Meeting 2 and is set up in two parts: The main report part provides information on the status of the work carried out in different WPs (chapter 2). This contains an overview of achieved deliverables and milestones (section 2.1), a summary of the administrative and project management efforts including risk management (section 2.2), a compendium of scientific and technical coordination (section 1.1), and explanations of the work carried out by all Work Packages (WPs) during the first half of the second reporting period (M27) (section 2.4). The second part evaluates the impact, updates the exploitation and dissemination plan and observes the approaches undertaken regarding project reviews remarks during phase 1 and deviations monitoring. Thus, an update of the project impact assessment is provided in chapter 3, the reassessed plan for exploitation and dissemination of the results is depicted in chapter 4, and a follow-up of recommendations from the Periodic Review

Meeting – End of phase 1 at M18 is displayed in chapter 5, with the corresponding actions in place in phase 2. Annex 1 (provided as a confidential separate document) of the ECoLaSS Interim Progress Report (Issue 2) provides a review and update of the work plan as well as an explanation of the use of resources for each WP and beneficiary up to M27.

PROJECT OBJECTIVES

The overall objective of the ECoLaSS project is to **improve existing & develop novel products/services for the pan-European & Global Copernicus Land components**. In more detail, the key objectives of the ECoLaSS project are shown with the most relevant outcomes:

PROJECT CONCEPT

- Conduct a dedicated stakeholder consultation process, assessing and analyzing relevant **user requirements**, and taking them into account for improving existing and developing novel CLMS products/services;

  Phase 1 WP21.1a, WP22.1a, WP23.1a, WP51.1a, WP51.1b, CLMS H2020 projects meeting November 2018, Webinars (EIONET/NRC & EC DGs)

  Phase 2 WP21.1b, WP22.1b, WP23.1b, WP51.1c, CLMS H2020 projects meeting April 2019

- Make full use of **high data volume processing of dense time series** of SAR and optical Sentinel (and other) EO data;

  Phase 1 WP31.1a, WP32.1a, WP33.1a, WP41.1a, WP42.1a, WP43.1a, WP44.1a, WP45.1a

  Phase 2 WP32.1b

- Develop **several prototypes** of new or enhanced Copernicus Land services of the Continental and the Global Component;

  Phase 1 WP41.1a, WP42.1a, WP43.1a, WP44.1a, WP45.1a

  Phase 2 WP11.3_1b

- **Benchmark** all operational product candidates in view of their innovation potential and technical excellence, automation level, potential for roll-out to pan-European level and/or global scale, timeliness for operational implementation, costs versus benefits, etc.;

Phase 1 WP52.1a, WP32.1a

Phase 2 WP32.1b

- **Suggest** to EC and the relevant decision-makers **candidates for operational integration** into the future Copernicus Land Monitoring Service from 2020 onwards.

Phase 1 WP52.1a, WP53.1a

Phase 2 tbd

Throughout the project, **requirements** for future Copernicus Land services evolution have been gathered in terms of (i) needs from Copernicus Land user and stakeholder groups, (ii) Earth Observation (EO) and other data to be used for deriving products and services, and (iii) infrastructure and architecture to process high volume data, as shown in the project overview scheme (Figure 2) (AD 09, AD 10, AD 11).

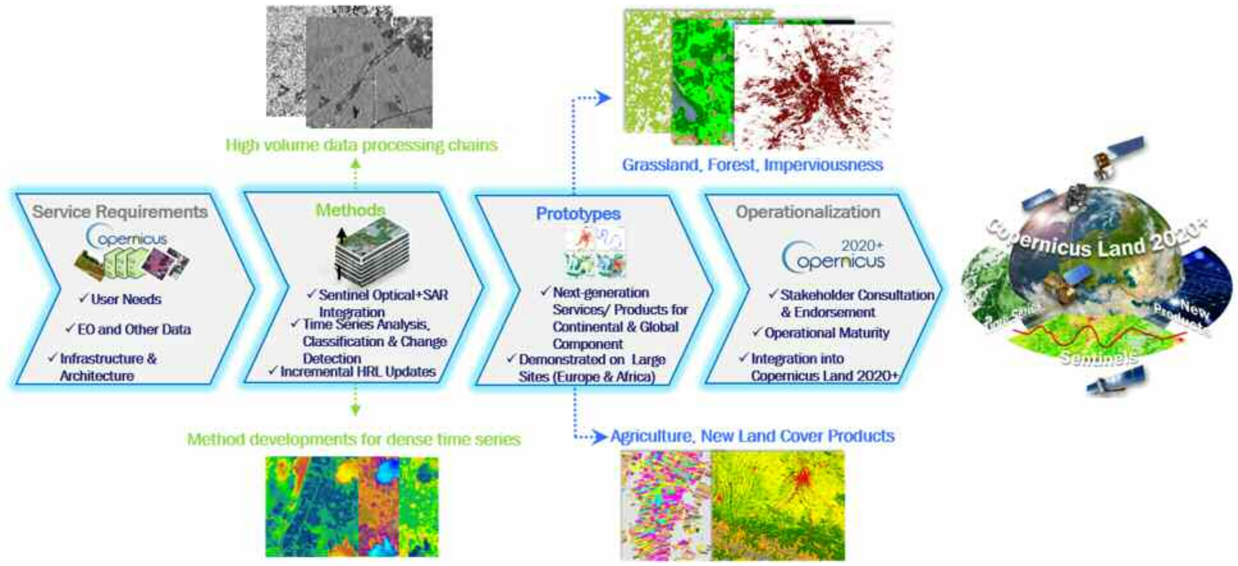


Figure 2: ECoLaSS project concept

With these requirements as basis, **innovative methods** for automated high volume data processing of Sentinel (optical and SAR) time series are being developed to improve existing and test novel products and services for the pan-European and Global Copernicus Land Components. The most important methods are in the fields of (i) Sentinel-1/-2 time series integration, (ii) time series pre-processing methods, (iii) thematic classification from time series analysis, (iv) change detection from time series analysis and (v) incremental update methodologies for the Copernicus Land High Resolution Layers (HRLs). All methods are applied on test sites, located both in Europe and Africa, and are undergoing a benchmarking process.

By applying these methods in large prototype sites of bio-geographical diversity, **prototypes** for improved and novel next-generation operational Copernicus Land services are demonstrated. Prototypic implementations are envisaged for: (i) indicators and variables from high spatial and temporal resolution data, for both the Continental and Global component products; (ii) incremental update strategies for the main pan-European products (i.e. at least the HRLs Forest and Imperviousness) (iii) improved permanent grassland identification, (iv) crop area and crop status/parameters monitoring; and (v) further novel LC/LU products.

In order to get to final service candidates for operational implementation, the project applies an **operationalization framework**, comprising (i) a continuous stakeholder consultation process throughout the project, (ii) a benchmarking framework of candidate services in view of their technical excellence and operational implementation potential (roll-out), as detailed by (iii) dedicated integration plans into the Copernicus Land service environment from 2020 onwards. The benchmarking approach evaluates the service prototypes for future implementation to benefit CLMS from 2020 onwards. An assessment matrix cross-checking manifold criteria suchlike long term evolution, portfolio complementarities, identified needs, political support, state of the art, maturity, timing, EO & in-situ data availability, processing capacity, automation level, roll-out potential and cost/benefit. A preliminary White Paper on Copernicus Land Evolution starts the definition of roadmap towards potential integration and operationalization mechanisms.

During the project implementation, requirements findings further stressed evolving demands for tailored applications, high resolution timeliness status and change layers production, in particular phenology and agriculture services developments. Lessons learned from technical tasks contribute to identify the processing issues and methods limitations. However, more importantly ECoLaSS is already providing robust operational prototypes, realistically establishing Sentinel derived Land Cover production guidelines.

2. Work Carried Out

This chapter provides detailed explanations of the work carried out in the project's WPs in the first half of Reporting Period 2 (M27):

- Section 2.1 reports on achieved milestones and deliverables, WP progress and Deliverable status;
- Section 2.2 documents the work performed in terms of administrative management (as part of WP 11), including project management, meetings, reporting, coordination and risk management;
- Section 2.3 reports on technical and scientific coordination work and activities, and on the quota and acquired additional VHR data sources via ESA's Data Warehouse (DWH) and their use;
- The final section 2.4 contains detailed explanations of the work carried out by the project, with respect to all ongoing and completed WPs in the project phase 2 up to M27, including relevant achievements up to present where appropriate.

The **key achievements** of the ECoLaSS project in the first 27 months runtime are:

- 43 Deliverables submitted; among them all phase 1 34 Deliverables, and phase 2 9 Deliverables of Tasks 1, 2, 3 and 5.
- Various stakeholder consultations at all envisaged levels conducted
- Copernicus Land service evolution requirements analysis concluded (Task 2 finalized)
- Data sharing & document management methods established & updated according to implementation detected needs
- Sentinel data pre-processing for all phase 2 test and demonstration sites finalized
- DWH VHR data orders and quota placed for 2017+2018+2019; data for 2017+2018 received and used for product calibration & validation
- All phase 1 methodological developments and testing as part of Task 3 completed; Phase 2 methodological developments and testing in WPs 31–35 ongoing in alignment with phase 1 findings and Task 4 developments
- Implementation of phase 1 high data volume processing lines achieved
- Prototype developments as part of Task 4 ongoing and implementation in demonstration sites overlapping with test sites methods in phase 2
- Phase 1 assessment of the operational framework finalized
- Several dissemination measures in place, project homepage and Twitter account active. Homepage renovated & viewer service introduced, Twitter account active
- Numerous high-level conferences attended, ECoLaSS oral and poster presentations given, thematic topics publications set up, as well as further dissemination activities executed and further ones planned

2.1 Achieved Milestones and Deliverables

This section describes the achieved Milestones (Table 1) and the consecutive status of WPs (Table 2) and Deliverables (Table 3) until M27. The status of WPs and Deliverables is described, and the Gantt chart is adapted to the current status.

Table 1: List of Milestones

MILE-STONE NO.	MILE-STONE NAME	RELATED WPs[1] (PARTICIPANT PORTAL)	RELATED WPs[2] (PROJECT STRUCTURE)	DUE DATE (IN PROJECT MONTH)	MEANS OF VERIFICATION
1	Kick-Off Meeting	1-2	11-12	1	• Agenda of Kick-Off Meeting provided • Project contract signed • Consortium Agreement in place • Project management procedures established • Test and demonstration site concept provided • Project concept presented by consortium
2	Interim Progress Meeting 1	3-5, 19	21-23, 61	9	• Project Management Plan implemented • Copernicus Land Evolution Requirements (product specification: EO, infrastructure) consolidated • Final test and demonstration sites established • 1st draft of high data volume processing lines • 1st round of Stakeholder Consultations concluded • 1st issue of Communication, Dissemination and Exploitation Plan provided • 1st Interim Progress Report delivered
3	Periodic Review Meeting - End of Phase 1	1-2, 6-10, 11-15, 16-18, 19-20	11-12, 31-35, 41-45, 51-53, 61-62	18	• 1st set of methods for high data volume processing lines in place • 1st issues of Methods Compendia provided • 1st set of Prototype data sets and reports (incl. accuracy assessments) provided for demonstration sites • 2nd round of Stakeholder Consultations concluded • 1st recommendations for operational product candidates provided • 1st round of Communication and Dissemination activities concluded • CLMS H2020 Projects Meeting • 1st Periodic Report delivered
4	Interim Progress Meeting 2	1-2, 3-5, 6-9, 19	11-12, 21-23, 32-35, 41-45 51-53, 61	27	• Updated Project Management Plan implemented • Updated Copernicus Land Evolution Requirements finalised • Final high data volume processing lines presented + pre-processing finished • 2nd issues of Methods Compendia drafted • 3rd round of Stakeholder Consultations concluded • 2nd issue of Communication, Dissemination and Exploitation Plan provided • CLMS H2020 Projects Second Meeting • Project website renewal + Viewer service • 2nd Interim Progress Report delivered

[1] Sequential WP name, as specified in the EC Participant Portal
[2] WP names corresponding to project structure (Tasks) as have been kept in the WP title;

Four out of five clearly defined Milestones (Table 1) have been successfully completed with the **Kick-Off Meeting** on 20 January 2017 in Munich (Milestone 1) and the **Interim Progress Meeting 1** on 19 October 2017 in Brussels (Milestone 2). Milestone 3 was completed with the **M18 Periodic Review Meeting - End of phase 1** on 5 September 2018 in Brussels. With the **Interim Progress Meeting 2** (12 July in Brussels) Milestone four is going to be completed.

Table 2 lists all Work Packages, with information on the lead partner and planned start and end dates of each project phase. Information on the respective start time and ongoing status until M27 is provided for every WP. The WPs which have started on-time, or even earlier than planned, and which are still on track as compared to the initial planning are marked in green in the status column. Some WPs had a later start either due to external reasons (e.g. developments in the community, such as in case of WP 23 with the procurement of DIAS and Sentinel 3 operationality hindrance towards integration of Sentinel-2/Sentinel-3 as was intended in WP31), or due to a longer lasting user requirements analysis and coordination with other CLMS H2020 projects, such as in case of WP 21. In phase 1 these had also an impact on the starting of Task 3 WPs which further impacted the start of Task 4 WPs. These shifted starting dates did not, however, significantly influence the overall work plan. Even though delivery dates for some Deliverables have been shifted in phase 2, this has been done to prioritize quality of work and efficient workflows and linkages among WPs. In this manner, WP 2 had to be extended by two months as compared to the initial plan, and in particular the WP21 associated Deliverable is experiencing a significant delay, to integrate exchanged content as a result of ongoing coordination with the next CLMS H2020 projects meeting in April at the time of reporting and allow for additional most up to date statements. Moreover, after the developments and lessons learned in phase 1, a slight delay in reporting of the method developments of Task 3 is taking place to attain a larger overlap with Task 4. This measure is aimed at optimizing the alignment of technical tasks building on phase 1 results and streaming workflows between tests and demonstration sites.

<u>Remark on WP and Deliverable Nomenclature:</u> (i) WP names with **sequential numbering** are specified in the EC Participant Portal, whereas (ii) WP/Deliverable names corresponding to the **project structure (Tasks)** have been kept in the WP/Deliverable title (as defined in the proposal and Grant Agreement phase). As in the Project Management Plan [AD05], WP and Deliverable names in the present report refer to (ii).

Table 2: Status of Tasks and Work Packages

Task	WP No[1]	Work Package Title[2]	Lead (Name)	Start Month Phase 1	End Month Phase 1	Start Month Phase 2	End Month Phase 2	Status			
								Actual Start Phase 1	Current Status Phase 1	Actual Start Phase 2	Current Status Phase 2
1	1	WP 11 - Administrative Management	GAF	1	18	19	36	on-time (M1)	phase 1 completed on-time (M18)	on-time (M19)	ongoing
	2	WP 12 - Scientific Coordination	GAF	1	18	19	36	on-time (M1)	phase 1 completed on-time (M18)	on-time (M19)	ongoing
2	3	WP 21 - Assessment of Service Evolution Requirements	GAF	1	4	19	21	on-time (M1)	phase 1 completed delayed (M8)	on-time (M19)	phase 2 extension delayed
	4	WP 22 - Assessment of EO and other Data Requirements	SIRS	1	9	19	24	later than planned (M3)	phase 1 completed on-time (M9)	on-time (M19)	phase 2 completed slightly postponed (M26)
	5	WP 23 - Assessment of Service Infrastructure/Architecture Requirements	DLR	1	9	19	24	later than planned (M4)	phase 1 completed on-time (M9)	on-time (M19)	phase 2 completed slightly postponed (M26)
3	6	WP 31 - Sentinel-1/2/3 Integration Strategies	DLR	2	14	19	35	on-time (M2)	phase 1 completed slightly postponed (M15)	upon recommendations agreement (M35)	*To be drafted after Task 3 completion*
	7	WP 32 - Time Series Preparation	JR	3	14	19	26	on-time (M3)	phase 1 completed on time (M14)	on-time (M19)	phase 2 completed slightly postponed (M28)
	8	WP 33 - Time Series Analyses for Thematic Classification	UCL	4	14	19	27	on-time (M3)	phase 1 completed slightly postponed (M15)	on-time (M19)	ongoing
	9	WP 34 - Time Series Analyses for Change Detection	JR	4	14	19	27	on-time (M4)	phase 1 completed slightly postponed (M15)	on-time (M19)	ongoing
	10	WP 35 - Time Series Consistency for HRL Product (incremental) Updates	SIRS	4	14	19	29	slightly later than planned (M5)	phase 1 completed delayed (M17)	on-time (M19)	ongoing
4	11	WP 41 - Time Series-derived Indicators & Variables	UCL	9	17	22	31	slightly later than planned (M10)	phase 1 completed slightly postponed (M19)	on-time (M21)	ongoing
	12	WP 42 - Incremental Updates of HR Layers	GAF	11	17	22	33	on-time (M11)	phase 1 completed slightly postponed (M19)	on-time (M21)	ongoing
	13	WP 43 - Improved Permanent Grassland Identification	JR	11	17	22	33	on-time (M11)	phase 1 completed slightly postponed (M19)	on-time (M21)	ongoing
	14	WP 44 - Crop Area and Crop Status/Parameters Monitoring	UCL	11	17	22	33	on-time (M11)	phase 1 completed slightly postponed (M19)	on-time (M21)	ongoing
	15	WP 45 - New LC/LU Products	SIRS	11	17	22	33	on-time (M11)	phase 1 completed slightly postponed (M19)	On-time (M21)	ongoing

Task	WP No[1]	Work Package Title[2]	Lead (Name)	Start Month Phase 1	End Month Phase 1	Start Month Phase 2	End Month Phase 2	Status			
								Actual Start Phase 1	Current Status Phase 1	Actual Start Phase 2	Current Status Phase 2
5	16	WP 51 - Stakeholder Consultation	GAF	7	18	22	34	earlier than planned (M3)	phase 1 completed slightly postponed (M19)	on-time (M20)	ongoing
	17	WP 52 - Candidates for Operational Roll-out	GAF	13	18	25	35	later than planned (M15)	phase 1 completed delayed (M24)	on-time (M24)	ongoing
	18	WP 53 - Integration Plan into Copernicus Service Architecture	SIRS	13	18	25	36	later than planned (M15)	phase 1 completed delayed (M24)	on-time (M24)	ongoing
6	19	WP 61 - Communication, Dissemination & Exploitation	DLR	4	18	19	36	earlier than planned (M1)	phase 1 completed on-time (M18)	on-time (M20)	phase 2 completed slightly postponed (M28)
	20	WP 62 - Market Opportunities & IPR Strategy	GAF	10	18	31	34	on-time (M10)	phase 1 completed delayed (M24)	M31	Not started

[1] Sequential WP name, as specified in the EC Participant Portal
[2] WP names corresponding to project structure (Tasks) have been kept in the WP title;
Green = according to plan or earlier than planned
Yellow = slightly postponed (up to ~ 1-2 months)
Orange = delayed (> 2 months)
Red = missing delivery, still planned

Until the third quarter of the project, **44 Deliverables** due at M27 were successfully submitted at, or shortly after, the estimated delivery date (Table 3). In phase 1, with the exception of two Deliverables (D21.1a, D35.1a), almost all were submitted on-time or with minor delays of one to two months (D52.1a, D53.1a, D62.1). *"D21.1 - Service Evolution Requirements Report"* was planned to be delivered at M4 but had to be delayed until M8. This was due to adjusting the user and stakeholder interviews and respective documentation to the timetable of the involved stakeholders. One Deliverable: *"D23.1 - Service Infrastructure/ Architecture Requirements Report"* had been rejected in the M9 interim review and was subsequently updated and re-submitted. In phase 2, Task 2 is complete, even though Deliverables were submitted with minor delays. Interconnections with other WPs activities is given more weight in phase 2 reporting tasks. From the Project Management point of view, the rationale is that the final documents in ECoLaSS should encompass WPs linkage and contain enriching reflections from the implementation lessons learned towards the end of the project.

As part of the Grant Agreement Amendment from 9 February 2018, four new confidential deliverables have been inserted into Part A of the Annex 1 to the GA, which represent Annexes to existing public deliverables: "*D1.7 – D11.3a - Interim Progress Report - Annex (CO)"*, with delivery date M9; "*D1.8 – D11.3b - Interim Progress Report - Annex (CO)"*, with delivery date M27; "*D3.3 – D21.1a - Service Evolution Requirements Report - Annex (CO)"*, with delivery date M4; and "*D3.4 – D21.1b - Service Evolution Requirements Report - Annex (CO)"*.

With regards to the technical tasks, *"D35.1 - Methods Compendium: HRL Time Series Consistency for HRL Product"* was delivered at M17 instead of M14, since it builds on the Deliverables D33.1a and D34.1a which had to be completed well before. By the end of project phase 1 there was an overall deliverable delay of one to two months due to addressing technical challenges for implementation of Task 4 demonstrators, further improvements of the prototype products and a consecutive dependency of the Task 5 and 6 Deliverables on Task 4. To avoid further impacts in scheduling and an optimized streamline performance during phase 2 a larger overlap between Task 3 and Task 4 was considered a more efficient approach for a better match between methods and results feedback loops between test and demonstration sites implementation.

Table 3: List of Deliverables

Deliv. No1	Deliverable Name[2]	WP No[1]	WP No[2]	Lead	Type[3]	Diss. Level[4]	Deliv. Date		Status
							Planned	Actual	
D1.1	D11.1 – Agendas and Minutes of Meetings	1	11	GAF	R	CO	cont.	17.02.2017, 16.10.2017, 07.12.2018	✓
D1.2	D11.2a – Project Management Plan	1	11	GAF	R	CO	31.01.2017	17.02.2017	✓
D1.3	D11.2b - Project Management Plan	1	11	GAF	R	CO	31.08.2018	04.12.2018	✓
D1.4	D11.3a – Interim Progress Report	1	11	GAF	R	PU	30.09.2017	12.10.2017	✓
D1.7	D11.3a – Interim Progress Report - Annex	1	11	GAF	R	CO	30.09.2017	12.10.2017	✓
D1.5	D11.3b – Interim Progress Report	1	11	GAF	R	PU	31.03.2019	04.06.2019	✓
D1.8	D11.3b – Interim Progress Report - Annex	1	11	GAF	R	CO	31.03.2019	04.06.2019	✓
D2.1	D12.1a – DWH use for 2017	2	12	GAF	R	PU	30.09.2017	29.09.2017	✓
D2.2	D12.1b – DWH use for 2018	2	12	GAF	R	PU	30.09.2018	14.12.2018	✓
D2.4	D12.2a – DWH request for 2018	2	12	GAF	R	PU	30.09.2017	15.09.2017	✓
D2.5	D12.2b – DWH request for 2019	2	12	GAF	R	PU	30.09.2018	19.10.2018	✓
D3.1	D21.1a – Service Evolution Requirements Report	3	21	GAF	R	PU	30.04.2017	28.08.2017	✓
D3.2	D21.1b – Service Evolution Requirements Report	3	21	GAF	R	PU	31.12.2018		
D3.3	D21.1a – Service Evolution Requirements Report - Annex	3	21	GAF	R	CO	30.04.2017	28.08.2017	✓
D3.4	D21.1b – Service Evolution Requirements Report - Annex	3	21	GAF	R	CO	31.12.2018		
D4.1	D22.1a – EO and other Data Requirements Report	4	22	SIRS	R	PU	30.09.2017	30.09.2017	✓
D4.2	D22.1b – EO and other Data Requirements Report	4	22	SIRS	R	PU	31.12.2018	21.02.2019	✓
D5.1	D23.1a – Service Infrastructure/ Architecture Requirements Report	5	23	DLR	R	PU	30.09.2017	10.10.2017	✓
D5.2	D23.1b – Service Infrastructure/ Architecture Requirements Report	5	23	DLR	R	PU	31.12.2018	18.02.2019	✓
D6.1	D31.1a – Methods Compendium: Sentinel-1/2/3 Integration Strategies	6	31	DLR	R	PU	28.02.2018	23.03.2018	✓
D7.1	D32.1a – Methods Compendium: Time Series Preparation	7	32	JR	R	PU	28.02.2018	28.02.2018	✓
D7.2	D32.1b – Methods Compendium: Time Series Preparation	7	32	JR	R	PU	28.02.2019	15.05.2019	✓
D8.1	D33.1a – Methods Compendium: Time Series Analysis for Thematic Classification	8	33	UCL	R	PU	28.02.2018	29.03.2018	✓
D8.2	D33.1b – Methods Compendium: Time Series Analysis for Thematic Classification	8	33	UCL	R	PU	31.03.2019		
D9.1	D34.1a – Methods Compendium: Time Series Analysis for Change Detection	9	34	JR	R	PU	28.02.2018	29.03.2018	✓
D9.2	D34.1b – Methods Compendium: Time Series Analysis for Change Detection	9	34	JR	R	PU	31.03.2019		
D10.1	D35.1a – Methods Compendium: HRL Time Series Consistency for HRL Product	10	35	SIRS	R	PU	28.02.2018	14.05.2018	✓

Deliv. No1	Deliverable Name[2]	WP No[1]	WP No[2]	Lead	Type[3]	Diss. Level[4]	Deliv. Date		Status
							Planned	Actual	
D11.1	D41.1a – Prototype Report: Time Series-derived Indicators and Variables	11	41	UCL	R	PU	31.05.2018	10.08.2018	✓
D11.3	P41.2a – Data Sets of Time Series-derived Indicators and Variables	11	41	UCL	DEM	PU	31.05.2018	10.08.2018	✓
D12.1	D42.1a – Prototype Report: Consistent HR Layer Time Series / Incremental Updates	12	42	GAF	R	PU	31.05.2018	23.07.2018	✓
D12.3	P42.2a – Data Sets of HR Layer Incremental Updates	12	42	GAF	DEM	PU	31.05.2018	06.08.2018	✓
D13.1	D43.1a – Prototype Report: Improved Permanent Grassland	13	43	JR	R	PU	31.05.2018	17.07.2018	✓
D13.3	P43.2a – Data Sets of HRL Permanent Grassland Products	13	43	JR	DEM	PU	31.05.2018	20.07.2018	✓
D14.1	D44.1a – Prototype Report: Crop Area and Crop Status/Parameters	14	44	UCL	R	PU	31.05.2018	10.08.2018	✓
D14.3	P44.2a – Data Sets of Crop Area and Crop Status/Parameters Products	14	44	UCL	DEM	PU	31.05.2018	10.08.2018	✓
D15.1	D45.1a – Prototype Report: New LC/LU Products	15	45	SIRS	R	PU	31.05.2018	03.08.2018	✓
D15.3	P45.2a – Data Sets of New LC/LU Products	15	45	SIRS	DEM	PU	31.05.2018	06.08.2018	✓
D16.1	D51.1a – Stakeholder Consultation Report	16	51	GAF	R	PU	30.09.2017	30.09.2017	✓
D16.2	D51.1b – Stakeholder Consultation Report	16	51	GAF	R	PU	30.06.2018	20.07.2018	✓
D16.3	D51.1c – Stakeholder Consultation Report	16	51	GAF	R	PU	31.03.2019	01.04.2019	✓
D17.1	D52.1a – Report of Candidates of Operational Roll-out	17	52	GAF	R	PU	30.06.2018	21.12.2018	✓
D18.1	D53.1a – Integration Plan into Copernicus Service Architecture	18	53	SIRS	R	PU	30.06.2018	23.12.2018	✓
D18.3	D53.2a – White Paper on Copernicus Land Evolution	18	53	SIRS	R	PU	30.06.2018	23.12.2018	✓
D19.1	D61.1 – Project Website	19	61	DLR	DEC	PU	30.06.2017	03.07.2017 (*Mar 2017)	✓
D19.2	D61.2a – Communication, Dissemination and Exploitation Plan	19	61	DLR	R	PU	30.09.2017	29.09.2017	✓
D19.3	D61.2b – Communication, Dissemination and Exploitation Plan	19	61	DLR	R	PU	31.03.2019	29.04.2019	✓
D19.4	D61.3a – Collection of Communication and Dissemination Material	19	61	DLR	R	PU	30.06.2018	28.06.2018	✓
D20.1	D62.1a – Market Opportunities and IPR Strategy	20	62	GAF	R	PU	30.06.2018	28.12.2018	✓

[1] Sequential Deliverable name (WP.issue), and WP name, as specified in the EC Participant Portal
[2] Deliverable/WP names corresponding to project structure (Tasks and WPs) have been kept in the Deliverable title; D: Document, P: Product;
[3] R: Document/Report, DEM: Demonstrator/Prototype, DEC: Website
[4] Dissemination Level: PU = Public, CO = Confidential
*Deliverable "D61.1 - Project Website" (Type: DEC) was online since mid-March 2017
✓ submitted on-time/in advance
✓submitted with minor delay (up to ~ 1-2 months)
✓submitted with major delay

Figure 3 provides the updated Gantt chart with necessary adjustments as they were discussed in the Periodic Review Meeting on September 5th 2018, visualised as grey markings, which signalise WPs that started earlier or lasted longer than planned, and brighter colours which symbolise delayed starts of WPs as compared to the initial plan. A grey rhombus signalises a planned but shifted Deliverable date, and all actual delivery dates are marked with a black rhombus.

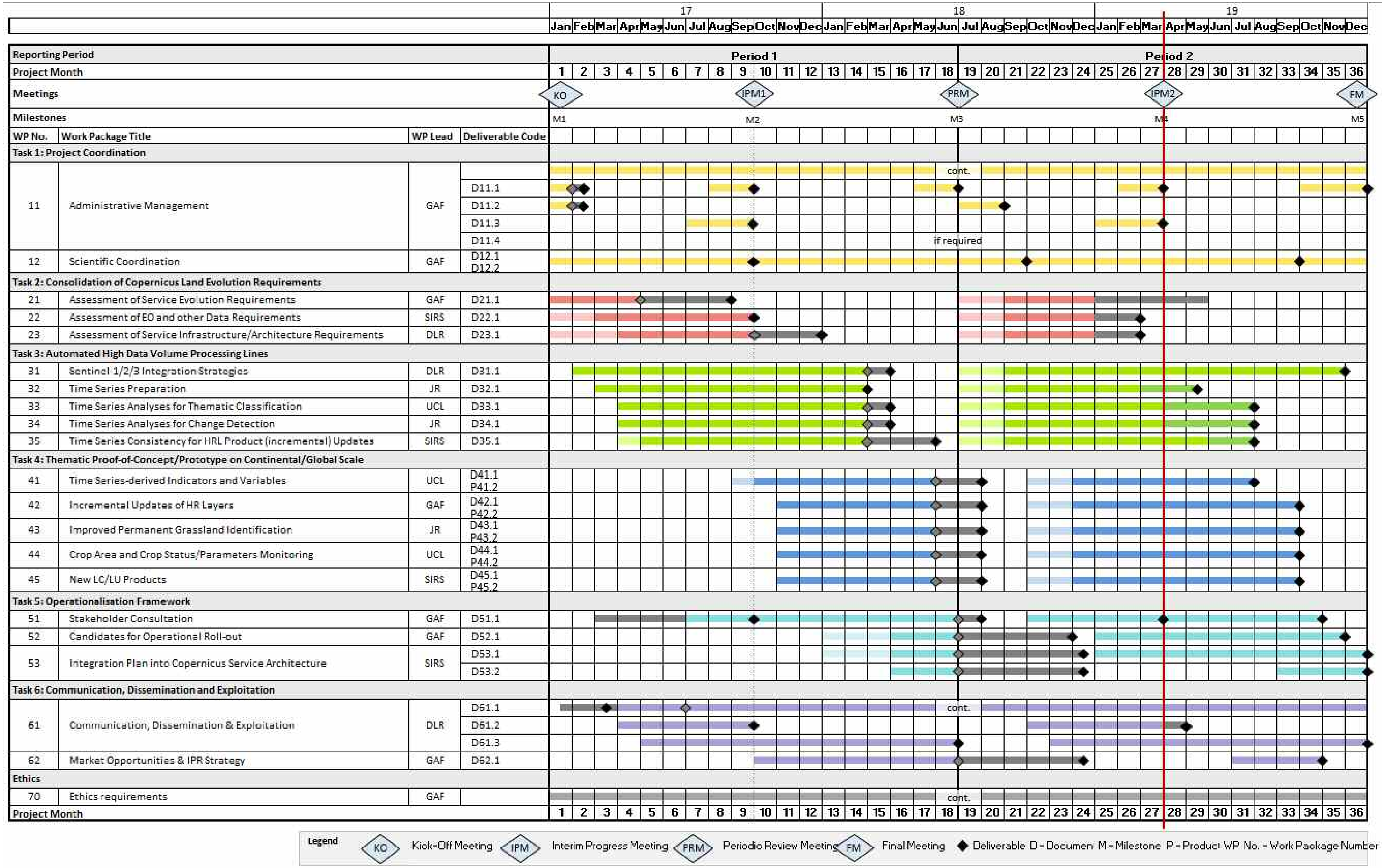


Figure 3: Gantt Chart - Time Plan

2.2 Administrative Management (WP 11)

The applicable ECoLaSS project management procedures are described in detail in the Project Management Plan: "*D11.2 – Project Management Plan (Issue 2)*" [AD05]. They are implemented as part of WP 11 - Administrative Management, which is carried out by the Coordinator GAF. This section describes all measures taken in terms of proper information exchange inside the consortium and with the European Commission, project schedule control, as well as meetings and teleconferences that have been conducted and reporting that has been carried out up to M27. Legal and Ethics aspects are discussed, and an update of the Risk Management and Mitigation Plan is provided.

INFORMATION EXCHANGE WITHIN THE CONSORTIUM AND WITH THE EC:

The consortium is led and managed by Dr. Eva Sevillano Marco, the *Project Coordinator* on behalf of GAF, being responsible for overall management and reporting to the EC on all activities, who is as well the *Scientific Coordinator*, and thereby responsible for coordinating all scientific issues between the WPs, as well as between the project and the scientific community. Both coordinating tasks are performed in close coordination with the former ECoLaSS project coordinator Mr Markus Probeck and the project assistant Ms Katharina Schwab, as well as with the GAF project team, including a proper hand-over stage with Mrs Linda Moser.

The information exchange between the EC, the Coordinator and the project partners is carried out the following way: The Project Coordinator is the general contact point to the EC's Project Officer (PO) for communication with the project team, both for technical and management aspects. The WP Managers report directly to the Project Coordinator. The official communication and reporting is carried out via the EC's Research Participant Portal, where continuous reporting is performed and Deliverables are uploaded. All formal Deliverables are transmitted to the EC by the Project Coordinator. In addition, direct communication between the Project Coordinator and PO via email and face-to-face interaction in the corresponding progress review meetings, as well as informally in other events. A project website and a Twitter account have been established and renewed (see section 2.4.17), via which the most important information and news about the project are published and shared with EC, stakeholders, scientists, the commercial sector and the general public.

PROJECT SCHEDULE CONTROL

The review and monitoring of project progress against the defined schedule and Milestones (see section 2.1) is performed on a regular basis primarily by the Project Coordinator, with support of the WP Managers, via meetings, telephone/video conferences and progress reports. The ECoLaSS project schedule (see Gantt chart – Figure 3) serves as reference for schedule control and reporting. The Project Coordinator implemented an Action Control System, in which all Action Items (AIs) from official Milestone/Review meetings (starting from the Kick-Off) are recorded and their status is continuously tracked. Such recording of AIs is performed as well for all meetings and teleconferences, and the status of AIs is regularly followed-up by the Coordinator and communicated to the consortium. No "Project Anomaly Reports and Recovery Action - Plans" were necessary so far.

MEETINGS & TELECONFERENCES

Official project/review meetings as well as consortium-internal administrative and technical meetings are normally organised by the Project Coordinator GAF. For all meetings, minutes are drafted by the Coordinator and distributed to the participants. For the official Review meetings there is a dedicated Deliverable with confidential status, which contains: "*D11.1 - Agendas and Minutes of Meetings*" [AD06].

In terms of official meetings, the **Kick-Off (KO) Meeting** was held on 20 January 2017 in Munich, with participation of the EC Project Officer, key stakeholders and all consortium partners. The **Interim Progress Meeting 1 (IPM1)** was carried out on 19 October 2017 at REA premises in Brussels. On 5 September 2018 the **Periodic Review Meeting (PRM) - End of phase 1** took place again at REA in Brussels. The next **Interim**

Progress Meeting 2 is scheduled in July 2019). The aim will be to present progress on Milestones, Deliverables and key achievements versus the project plan, and provide a deep insight into the progress of all WPs.

Regular **consortium-internal progress meetings** are mostly carried out as **teleconferences** every 4 – 8 weeks as required, where administrative issues are clarified, the project progress of all partners and relevant WPs is assessed, and further work is planned and coordinated. **Four technical meetings** have been held as physical meeting: from 2-3 May 2017 at DLR in Oberpfaffenhofen (day 1) and GAF in Munich, Germany (day 2), from 4-5 October 2017 at Joanneum Research premises in Graz, Austria, and from 19-20 November 2018 at GAF in Munich. A further physical meeting was carried out on 4 September 2018 in Brussels. Several WP-internal Telecons and phone calls have been carried out in addition, according to the WP development needs. A summary of all meetings and teleconferences involving the full consortium until the Interim Progress Meeting is displayed in Table 4:

Table 4: List of Meetings and Teleconferences

NAME OF MEETING	TYPE OF MEETING	DATE	PLACE	PARTICIPANTS
Kick-off preparation	Teleconference	16 Dec 2016	NA	All consortium partners
Internal Kick-Off	Meeting	19 Jan 2017	Munich, GAF	All consortium partners
Official Kick-Off	Official Kick-Off Meeting	20 Jan 2017	Munich, GAF	All consortium partners, EC REA, stakeholders
Progress Teleconference 1	Teleconference	8 Feb 2017	NA	All consortium partners
Progress Teleconference 2	Teleconference	7 Apr 2017	NA	All consortium partners
Technical Meeting 1	Meeting	3 – 4 May 2017	Oberpfaffenhofen, DLR (day 1); Munich, GAF (day 2)	All consortium partners
Progress Teleconference 3	Teleconference	22 Jun 2017	NA	All consortium partners
Progress Teleconference 4	Teleconference	25 Jul 2017	NA	All consortium partners
Progress Teleconference 5	Teleconference	15 Sep 2017	NA	All consortium partners
Technical Meeting 2	Meeting	4 – 5 Oct 2017	Graz, Joanneum Research	All consortium partners
Interim Progress Meeting 1	Review Meeting	19 Oct 2017	Brussels, EC REA	All consortium partners, EC REA, reviewer, stakeholder
Progress Teleconference 6	Teleconference	7 Dec 2017	NA	All consortium partners
Progress Teleconference 7	Teleconference	2 Feb 2018	NA	All consortium partners
Progress Teleconference 8	Teleconference	23 Apr 2018	NA	All consortium partners
Progress Teleconference 9	Teleconference	16 May 2018	NA	All consortium partners
Progress Teleconference 10	Teleconference	25 May 2018	NA	All consortium partners
Progress Teleconference 11	Teleconference	14 Jun 2018	NA	All consortium partners
Phase 2 preparation	Teleconference	17 Jul 2018	NA	All consortium partners
Progress Teleconference 12	Teleconference	30 Aug 2018	NA	All consortium partners
Technical Meeting 3	Meeting	4 Sep 2018	Brussels, EC REA	All consortium partners
Periodic Review Meeting	Review Meeting	5 Sep 2018	Brussels, EC REA	All consortium partners, EC REA, reviewer
Progress Teleconference 13	Teleconference	14 Nov 2018	NA	All consortium partners
Technical Meeting 4	Meeting	19-20 Nov 2018	Munich, GAF	All consortium partners
Progress Teleconference 14	Teleconference	07 Dec 2018	NA	All consortium partners
Progress Teleconference 15	Teleconference	17 Jan 2019	NA	All consortium partners
Progress Teleconference 16	Teleconference	28 Feb 2019	NA	All consortium partners
Progress Teleconference 17	Teleconference	04 April 2019	NA	DLR, JR, SIRS, GAF
Progress Teleconference 18	Teleconference	28 May 2019	NA	DLR, JR, SIRS, UCL, GAF
Technical Meeting 5	Meeting	11 July 2019	Brussels	All consortium partners
Interim Progress Meeting 2	Review Meeting	12 July 2019	Brussels, EC REA	All consortium partners, EC REA, reviewer, stakeholder

Additionally, numerous **stakeholder and user meetings** took place in the framework of WP 21 and WP 51, either as physical meetings back-to-back with other events, or as dedicated physical meetings, teleconferences or webinars addressing previously defined topics, e.g. for the user requirements analysis (WP 21, see chapter 2.4.1) – cf. *"D21.1a - Service Evolution Requirements Report*" [AD09], or for stakeholder interaction (WP 51, see chapter 2.4.14) – cf. "*D51.1c - Stakeholder Consultation Report*" [AD22].

German and French **National Copernicus Meetings/Fora** were attended by GAF and SIRS, respectively, and ECoLaSS was presented there. Further **Copernicus Meetings** and Copernicus conferences/fora organised by the EC or EEA upon invitation or suggestion of the EC, e.g. the CCI+ Information Day, the EEA Land Monitoring & CLC+ Workshop, the Copernicus for Agriculture - Industry Workshop, the Copernicus Event "20 years Baveno Manifesto", etc., have been attended until the first half of the second Reporting Period. The follow up of the CLMS H2020 projects took place in Spain, and ECoLaSS was presented in the IACS Workshop event the following day by invitation of the EC. A more complete and updated list can be found in the WP61.2 (Issue 2) [AD26].

REPORTING

The Project Coordinator is responsible for the reporting duties in ECoLaSS, following GAF's ISO 9001:2015 certified QM procedures. Reporting activities and uploads of Deliverables are carried out via the System for Grant Management (SyGMa) of the EC's Research Participant Portal. Specific types of reporting are highlighted in the following:

Deliverables: 43 deliverables have been uploaded (see Table 3). For a complete list of all project deliverables refer to AD05.

- **Interim Progress Reports:** The present document is the second of the two Interim Progress Reports which are to be provided upon the two Interim Progress Meetings (M9 and M27), with Financial Figures and Use of Resources descriptions provided as a separate Annex. These reports follow the same structure and similar contents as the Periodic Reports at M18 and M36.
- **Periodic Report:** There are/will be two Periodic Reports, which are to be provided upon the Periodic Review Meeting (M18), and the Final Meeting (M36). The Periodic Review Report comprises three parts:
  - Part A is to be delivered via SyGMa. It includes **(i)** a publishable summary, containing the context and overall project objectives, an explanation of the work carried out, the main results achieved so far, the progress towards the objectives of the project, the expected economic and societal impact, and the project's website address (URL); **(ii)** web-based tables covering issues related to the project implementation (e.g. work packages, deliverables, milestones, risks, publications, dissemination, patents (IPR), innovation, SME Impact and Gender).
  - Part B provides information on the status of the work carried out in the various WPs. This contains an overview of finalised deliverables and achieved milestones, a summary of the administrative and project management efforts including risk management, a summary of scientific and technical coordination, and explanations of the work carried out by all Work Packages during the corresponding reporting period. An update of the project impact assessment is provided together with an update of the plan for exploitation and dissemination of the results, and a follow-up of recommendations from the previous Interim Progress Meeting.
  - The Financial Report, which is carried out via web-based tables on the EU participant portal.
- **Agendas & Minutes:** During all meetings, minutes are drafted by the Project Coordinator and are shared with all participants a few days after the meeting for their review and comments. The minutes provide a record of discussions, decisions, and AIs on the topics discussed. Typically, relevant Annexes and the meetings' presentation slides form part of the minutes. The update of

D11.1 is to be provided as project follow-up material from the next Review Meeting preparation.

- **Project Anomaly Reports:** There were no unexpected or unforeseen events that could not be handled and would have required filing a Project Anomaly Report.

LEGAL ASPECTS

DLR is the responsible partner for the project webpage (updated according to the General Data Protection Regulation -GDPR-) and Twitter account, such as website disclaimer, legal notice and privacy policy for the ECoLaSS website and the project's Twitter account.

ETHICS ASPECTS

Ethics requirements are being observed throughout the project by the ECoLaSS Project Coordinator and the Scientific Coordinator. Due to political reasons and the access to reference data, the demonstration site in the DRC has been exchanged with another site in South Africa (Western Cape, see Figure 5). As this also includes possible changes regarding the Ethics Aspects, this was taken care of as part of a separate document that was submitted to the PO on March 4th 2019: Technical Note Update on ethics issues [AD 28].

RISK ASSESSMENT & MITIGATION PLAN

Relevant risks for successful implementation of the ECoLaSS project are continuously monitored, and mitigation measures are put in place, if required. Whereas some previously recognised risks have become obsolete (and have consequently been set to very low risk), some additional delays and risks are observed, which however appear to be generally manageable.

The risk analysis and mitigation are constantly undertaken by the Coordinator as an action under WP 11 and kept up-to-date throughout the project's lifetime, supported by all partners through timely communication of foreseeable or materialising project risks. This fosters optimising resource allocation and project implementation procedures throughout the project's lifetime.

The following table (Table 5) compiles and reassesses the risks already identified and analysed in the Grant Agreement and Project Management Plan, and updated in the first Interim Review Report and First Periodic Technical Report., plus the evaluation of risks linked to ongoing tasks in phase 2 (updates marked in grey), towards the last Interim Progress Meeting (IPM2).

Table 5: Updated relevant risks for successful implementation of the ECoLaSS Project

DESCRIPTION OF RISK (+ LEVEL OF LIKELIHOOD)	RELATED WPS[1] (PART.PORTAL)	RELATED WPS[2] (PROJECT STRUCT.)	PROPOSED RISK-IMPACT & MITIGATION MEASURES
Operational Risks			
Availability of VHR1 data for future time steps from DWH may prove insufficient, particularly in case of new acquisitions (very low risk/deprecated)	4, 6-10, 11-15	22, 31-35, 41-45	Impact: In the first 9 project months, VHR1 data availability had been limited due to delayed access to the DWH. New image acquisition options were therefore restricted towards the end of the growing season 2017. The granted quota for new image acquisitions could not be fully utilised in 2017. Mitigation Measures: More archive VHR1 data were ordered, largely compensating. These data proved fit for purpose. Data orders for 2018 were nominal. No further impact on successful implementation of all project tasks.
Shortage of suitable HR EO data availability (S1-3, L8) due to satellite failure (e.g. Sentinel B-units), delayed launch, long commissioning phase, high cloud cover, or data hub issues (very low risk)	All WPs	All WPs	Impact: Limited time series availability/density; restrictions in realistic scenario assessment of future operational service implementation. Data hub issues for S-1 retrieval resulted in delays in pre-processing tasks. Mitigation Measures: Exploitation of other constellation scenarios (Sent.1-3, with/ without B-units, S-1 for closing optical acquisition gaps, Landsat-8) to reduce data shortage risk, applying flexible data processing methods. Alternative other satellite data envisaged (AWiFS, PROBA-V, etc.) Due to S-3B products still being in the commissioning phase in particular the SYN product, the S-3 data are not readily available for HR land gap-filling applications. Furthermore, the temporal resolution of S-3 data is currently not sufficient to complement S-2 time series, which are outperforming expectations. To test project goals of optical HR/MR data integration an alternative use of PROBA-V data is being tested (see Technical Note [AD27]). Pre-processing finished now (no further issues expected).

Restricted/delayed access to appropriate national in-situ/ancillary reference data (low risk)	4, 6-10, 11-15	22, 31-35, 41-45	<u>Impact:</u> Reduced quantity and quality of training areas and validation datasets. <u>Mitigation Measures:</u> The consortium's extensive Copernicus Land heritage and established contacts with national in-situ hosting entities facilitate access to appropriate reference data. Data access via CORDA is well established and being used. Test/demo sites have been selected based on established contacts and data availabilities, so that no major restrictions are expected. Issues encountered had been a delayed access to LPIS data (i) in Central demo site (German Fed. State of Bavaria), solved in M28, and (ii) for French part of the demo site West where data were finally not available for 2017, which was mitigated producing the agricultural prototype in the French part with LPIS 2016 as well as with EO data 2016 (only Sentinel-2A) in phase 1. LUCAS 2018 data were recently released (M28) and have been used for training/validation. Issues related to reference data scarcity/density are addressed by tailored integration of complementary sources to build fit-for-purpose samples. Furthermore, ECoLaSS is providing feedback to data providers (such as ESTAT) and the EC/JRC.
Procedural Risks			
Overall time plan delays (medium risk)	mainly 11-20	41-45; 51-53; 61-62	<u>Impact:</u> By the end of project phase 1 there was an overall deliverable delay of about 2 months, due to technical challenges in implementing Task 4 demonstrators and prototype products, and knock-on delays of Task 5+6 Deliverables. This in turn resulted in Task 2 Deliverables delays in phase 2. <u>Mitigation Measures:</u> Task 5&6 missing Deliverables were submitted before the end of 2018, which has allowed a seamless start of the 2nd project cycle without major delays. Task 2 Deliverables have been issued in late February except for D21 (coming later, to include CLMS' latest developments and incorporate H2020 sister projects' conclusions), and upcoming reports related to the technical tasks (Task 3) are being drafted. On the basis of the experiences in phase 1, the agreed larger overlap between Task 3 and Task 4 results in a more efficient/consistent workflow and documentation: Ensuring that methods developed and tested in test sites perform adequately also on large scale avoids unexpected issues at later stages in Task 4. For all final Deliverable versions, the final goal is to foster quality of results and maximize project impact. Quality control procedures, consistency, interconnection between WPs as expressed in the Pert diagram, and improvements from the first issues taking into account the reviewer s comments are being applied. In any case, final project deadline for tasks completion and Deliverables submission will be respected.

Political risks & Ethical issues			
Temporal and/or thematic misalignment of the project with EEEs' (EEA & JRC) planning for operational Copernicus Land services (low risk)	6-10, 17-18	31-35, 52-53	<u>Impact:</u> Project results would not fully reflect all relevant stakeholder requirements for long-term CLMS service evolution 2020/2021+, specifically if upcoming only during the last stages of the project. <u>Mitigation Measures:</u> Regular coordination with key stakeholders and systematic identification of their requirements, including anticipation of evolving product needs and portfolios, are core activities during project life cycle. Upcoming product/tender specifications (i.e. new/updated HRLs, CLC+) and evolving general service requirements were taken into account as far as foreseeable and coincident with project objectives. Respective Copernicus and EEA work programmes are continuously screened for that purpose. One particular case that is worth mentioning is related to the HRLs 2018 (kicked-off in Jan. 2019), where some optional elements may be included such as "grassland biomass removal frequency and timing", which could potentially overlap with the ongoing investigation of grassland use intensity in the second ECoLaSS reporting period. Anyway, so far, this option hasn't been drawn in the HRL. Moreover, it is considered that the ECoLaSS work on this research issue will rather benefit the potential operational implementation, in any case.
Lack of active stakeholder (e.g., the JRC) and user engagement in support of the project (low risk)	3-5, 16-18,	21-23, 51-53	<u>Impact:</u> In the first project phase, the involvement of JRC, being the key stakeholder of the Global CLMS Component, had been positive and responsive, albeit in different mode than anticipated, i.e. mostly through side-meetings at other occasions, rather than dedicated consultations. Although there was a specifically good exchange with JRC on a future agricultural service, the direct engagement of JRC's Global CLMS group had been limited in the first Reporting Period due to continued other obligations of JRC. <u>Mitigation Measures:</u> Two dedicated meeting between JRC's Global CLMS group, EEA, DG GROW, REA and CLMS-related H2020 projects (incl. ECoLaSS) on 15/11/2018 and 9/04/2019 were conducted. Given the previous experience, the facilitation of REA appears crucial. This currently good exchange will be further followed up in the final Task 5 assessments.

Lack of alignment/agreement on respective CLMS components' perimeters between the EEEs (medium risk)	17-18	52-53	Impact: In case that major shifts in the EEEs' responsibilities for the CLMS main components (i.e.: EEA for the continental/local CLMS and in-situ, JRC for global CLMS) should be agreed and implemented in the near future, specifically the ECoLaSS Task 5 activities could be impacted. Particularly the outlining of an Integration Plan into the CLMS Service Architecture (in WP 53) would have to take into account any respective new developments, potentially on short notice towards project end. In any case, there would be no impact on the technical assessments in Tasks 3+4. Moreover, since ECoLaSS is in its final stage, it is quite unlikely that any potential changes to the EEEs' roles would become effective before the start of the next MFF (2021). Mitigation Measures: As such are decisions to be taken on a political level, the project doesn't have any means to mitigate this risk. However, from the perspective of industrial operational implementation feasibility, the ECoLaSS project is advocating that service implementation be coordinated by the respective thematically and operationally most competent entity/-ies.
Unstable political situation in African demo site requires modification of test sites (high risk)	7-9, 11, 14, 15	32- 34, 41, 44, 45	Impact: A key driver for the demo sites selection had been ground-truth data availability for the development of a HR crop area and crop status layer based on Sentinel data time series with pan-European and global perspective. In the initially planned Democratic Republic of Congo (DRC) demonstration site, the unstable political situation has caused unpredictable collaboration conditions of the JECAM teams (which serve as input data to ECoLaSS) with national partners, as well as big challenges in field data collection. Therefore, input data availability could not have been ensured for this site. This implies also implications on the status of the project's Ethics assessment. Mitigation Measures: In phase 2, the (DRC) site was exchanged by the South Africa (Western Cape) site, and the Mali site was extended to a much larger area (above 120 000 km^2), still ensuring a large crop and field size diversity, and covering also grassland and natural vegetation as well as high crop diversity, in particular with regards to the forage crops and perennial crops. The larger extent of the Western Cape demonstration site also partially compensates the cancellation of the DRC demonstration site in terms of Sentinel tiles to process. A Technical Note has been submitted with the update of the Ethics section Part B-Ethics_5.1 of the Grant Agreement as required by REA [AD28].

Financial risks			
Potential overspending of available project resources	1-20	11-62	Impact: There was an overspending of human resources by the end of phase 1 (i.e., 144 PM instead of 116 PM) reported for GAF, JR and SIRS, which represents an increase of approximately 20% compared to the original planned PMs, if assuming a linear expenditure over the project's lifetime. In turn, UCL and DLR faced an according underspending in phase 1. Mitigation Measures: On the one hand, it is usually the case that the set-up and first stages of a project require a relatively larger amount of resources (i.e. a non-linear distribution), and the overspending will be partially compensated in Phase 2. Although the partners involved in the more preoccupant overspending have still significant contributions in the technical tasks during phase 2, the project developments are largely on track and less effort will be required to fulfil the tasks ahead. This is true also for reporting and in the case of GAF for coordination tasks, as all mechanisms of management, quality control, templates and procedures are already well established. This is proven in Annex 1 which contains the financial figures associated to staff resources: it can be verified that the overspending has been reduced significantly to 18 PMs instead of the 28 PM reported by the end of phase 1. In any case, the overspending is not considered to have a significant impact on the project outcomes, as, even in case of remaining overspending, the project team is both bound and committed to fulfilling all its contractual obligations. Every partner is responsible to financially cover their respective overspending apart from the cofounded budget share, if such should persist until project end. It is a common understanding that H2020 project are innovation invest actions, not pursuing economic immediate benefits.

Human workforce risks			
Transition losses with the handover of the Project Coordinator position (very low risk)	1+2; all WPs	11+12; all WPs	Impact: The handover of the Project Coordinator position from Mr Markus Probeck to Ms Linda Moser could have created a discontinuity in the project progress and/or the consortium's performance. Along the same line, the handover from Ms Linda Moser to Dr Eva Sevillano Marco was subject to the same potential risk of discontinuity in project management. Mitigation Measures: As in the previous case, the handover has been long prepared. Ms Moser having the experience of being in the handover receiver position, and present in the project since the outset, together with Mr Markus Probeck carefully provided an overlapping period and supervised personally Dr Eva Sevillano in the uptake of the Project Management duties. Dr Eva Sevillano in turn is well acquainted with European research projects, tasks and partnerships. Furthermore, the previous Project Coordinator Mr Probeck remains available to work and support on the project. The risk of any losses is therefore considered minimal.
Staffing issues (medium risk)	6-10, 11-15, 19	31-35, 41-45, 61	Impact: Due to unforeseeable cases of long-term sickness leave, parental leaves, force majeure and staff changes, there have been related delays and struggles to meet the envisaged time plans of some Work Packages, and a reduced ability to respond to project needs. Mitigation Measures: Replacement staff has been organised and has been trained, so that the current delays are expected to be recovered at the beginning of phase 2. Apart from the Project Coordination take over, there have been several staff reallocations for UCL and DLR. Contact lists have been updated, technical contact lists for thematic topics and responsibilities have been defined and communication channels are open. An overlap between staff in case of long-term leaves has been taking place (e.g., at DLR and GAF). Overall, the Project Coordinator is closely following up new staff in the project to clarify procedures, management and technical doubts.

[1] Sequential WP name, as specified in the EC Participant Portal
[2] WP names corresponding to project structure (Tasks) as have been kept in the WP title;
Highlight = Update of the Risk and Mitigation Plan with respect to the First Technical Report

2.3 Technical/Scientific Coordination (WP 12)

WP 12 deals with the technical and scientific coordination of all Tasks and WPs, ensuring application of state-of-the art methods and overall project consistency, quality control of document Deliverables and prototype datasets, as well as formulating Very High Resolution (VHR) data requirements towards the European Space Agency (ESA) Data Warehouse (DWH), as cross-cutting activities all throughout the project development.

This section documents conducted technical and scientific coordination activities as part of WP 12 Scientific Coordination. Sub-section 2.3.1 deals with overall scientific coordination measures, whereas sub-section 2.3.2 addresses specifically the management of quota and use of VHR data accessible via ESA's DWH mechanism.

2.3.1 Scientific Coordination Measures and Activities

In this section, measures of overall scientific coordination of the methodological developments are explained, the benchmarking procedures – to be applied for all method and prototype developments – are described in detail, the selection of test sites and prototype sites is illustrated, data management and data sharing procedures are described, and the Scientific Coordinator's support to dissemination measures is explained, as well as the approach to overall quality management.

ADAPTATIONS TO THE SCIENTIFIC CONCEPT

In the Horizon 2020 Call for Tenders EO-3-2016: Evolution of Copernicus services, which led to the present ECoLaSS project, the requirement for "Improved permanent grassland identification methods" had been identified as relevant topic, separately from existing HRLs, probably due to a previous HRL 2012 product called "Natural Grassland (NGR)" that had shown issues in thematic accuracy, and had therefore not been continued by EEA, leading to the need of a new definition of the grassland theme. Shortly after the abovementioned H2020 tender, however, the EEA Call for Tender for "Copernicus Land High Resolution Layer Updates 2015" was published, comprising also a newly defined HRL Grassland 2015. A consortium, including amongst others the ECoLaSS partners GAF and SIRS, was awarded the new production of the HRL Grassland (GRA) 2015, under the lead of GAF.

As this development re-confirmed the belonging of the HRL Grassland to the set of thematic LC/LU Layers of the Continental CLMS component, from an ECoLaSS point of view, developments towards an improved HRL GRA (previously described in WP 43 "Improved Permanent Grassland") are being addressed synergistically with the HRLs Forest (FOR) and Imperviousness (IMP) as part of WP 42 "Incremental Updates of HR Layers", in terms of incremental updates of the GRA prototype in project phase 2. In turn, WP 43 addresses new methods for additional, further-reaching thematic characterisation of different types of grassland as well as use categories and intensities.

TEST- AND DEMONSTRATION SITES:

The EO-based processing activities of Tasks 3 and 4 are carried out in selected Test- and Demonstration (Prototype) Sites in Europe (related primarily to the pan-European CLMS component), see Figure 4, and partly Africa (global CLMS component), see Figure 5.

The methodological developments (Task 3) are investigated in small **Test Sites** with good access to specific in-situ data, and representing the spread of biogeographic regions in Europe (Source EEA: *http://www.eea.europa.eu/data-and-maps/data/biogeographical-regions-europe-3#tab-gis-data*).

Test Sites are located in France, Belgium, Sweden, Germany, Austria, Bulgaria and Greece and are being used to test the methodological developments (see sections 2.4.4 – 2.4.8):

- The test site in **Sweden** is dominated by forests. In some central parts and in the South, larger agricultural areas are included. The forest land is interspersed with lakes and smaller water bodies, peat bogs and grassland.
- The test site in **Germany/Austria** is dominated in the North by cropland areas, mixed with grassland (pastures). The Southern part, covering the Alpine Foreland, is dominated by forest cover and grassland, including extensively used grassland and wetland areas. Furthermore, the test site covers parts of the Swiss and Austrian Alps with mountain-specific vegetation zones.
- The test site in **Belgium** comprises areas of dense agriculture and intensively used grassland, as well as a fragmented mixture of grassland and broadleaved forests, which poses a challenge to grassland classification. Two major cities and a full gradient of imperviousness degrees is represented in the site.
- The test site in **France** comprises large urban agglomerations (such as Toulouse) as well as natural grassland and intensively used grassland areas which are mixed with cropland. Towards the South, the site comprises highly mountainous landscapes.
- The **Bulgarian/Greek** test-site covers parts of the Continental, the Alpine and the Mediterranean biogeographic regions. The Alpine part is constituted by the Rhodopian Mountains which reach up to about 2000m in the centre, and which are forest-covered to a high degree. The test-site includes various semi-natural grassland areas and pastures, with cropland mainly in the North and South.

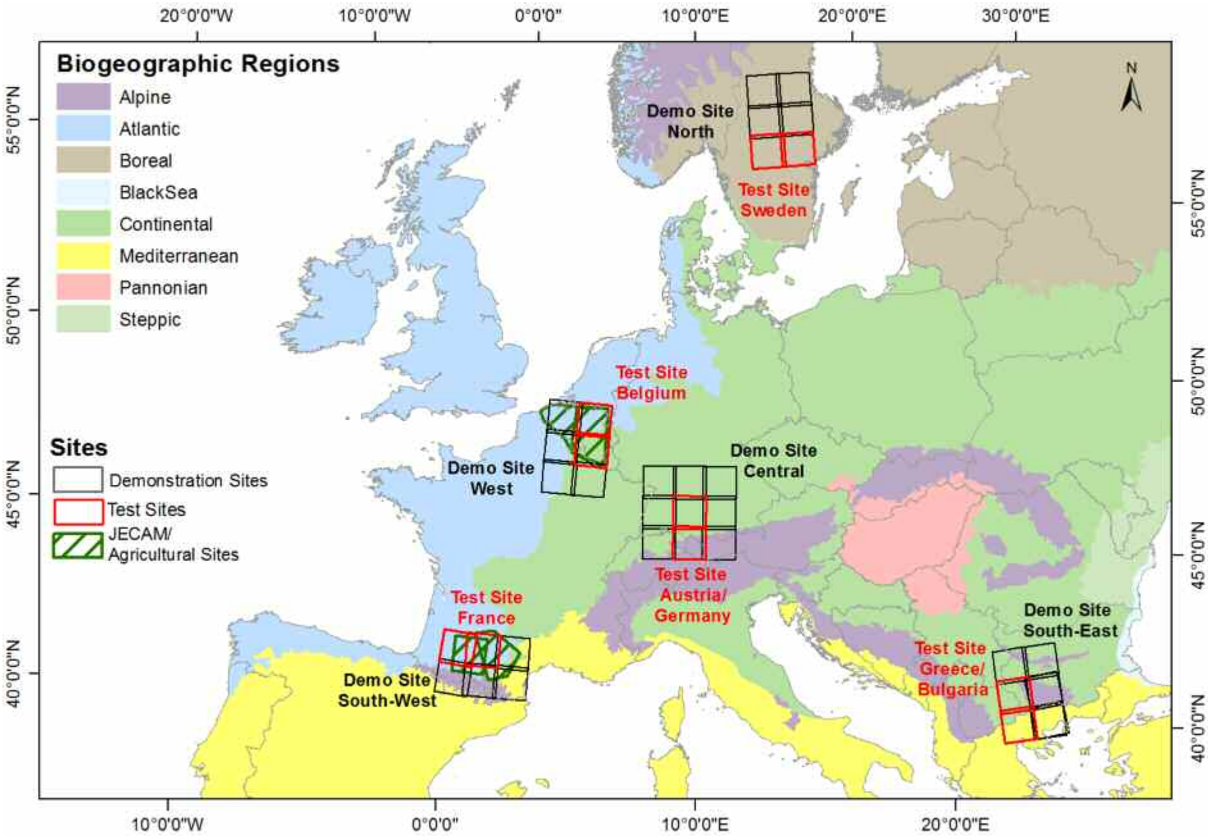


Figure 4: ECoLaSS Test- and Demonstration- Sites in Europe

Five larger **Demonstration Sites** (approx. 60,000 km² and 90,000km² respectively), which incorporate the areas of the test sites, and serve for demonstrating the proposed candidates for Copernicus Land Service evolution in terms of roll-out to a larger scale (Task 4). These selected Prototype Sites cover the most important environmental zones (Source: EEA) of Europe and the member states of the EEA-39:

- The Demonstration Site "**North**" is located in the Boreal zone in the North of Europe;
- The "**Central**" site is in the Continental and Alpine Central European region (Germany, Austria, Switzerland, Italy);
- The "**West**" site is in the Atlantic and Steppic region (Belgium, France);

- The "**South-West**" site represents a landscape gradient from the Atlantic biogeographic region in the North over the Alpine region of the Pyrenees, to the Mediterranean region in the South and East (France, Spain, Andorra);
- The "**South-East**" site is in the Mediterranean, Continental and Alpine South-East (Serbia, Macedonia, Greece, Bulgaria and Kosovo).

It should be mentioned that, compared to the initial Grant Agreement, the number of European Demonstration Sites has been increased to five, in order to better reflect the regional diversity and the individual specificities of individual CLMS products under investigation, across Europe. In turn, it has been agreed to reduce the sizes of 4 of the demonstration sites to 60,000 km² (six Sentinel-2 granules) each (instead of previously 90,000 km²) in order to allow keeping the focus of the project efforts on thematic developments rather than on data pre-processing and handling in a non-yet operational processing environment/infrastructure situation. Following the reviewer's recommendation from the Interim Progress Meeting 1, one site remains a large site with 9 Sentinel-2 granules (approx. 90,000 km²) for which the consortium has chosen the "Central" demonstration site. This has been part of the Amendment to the Grant Agreement from 9 February 2018.

With respect to the global perspective, three **African Sites** (see Figure 5) distributed across the continent have been selected to cover a wide range of land cover/use diversity. With respect to the Grant Agreement, a shift of two African sites was agreed for the second project phase, on the one hand due to political reasons, and on the other hand due to the value of scientific outcomes. The updated status regarding the African sites shift, field data collection and associated Ethics compliance description are described in the **Technical Note: "Update on ethics issues"** (modification to the **Ethics section Part B-Ethics_5.1 of the Grant Agreement**) [AD28], as agreed with the EC Project Officer.

In particular, it was decided to cancel the Democratic Republic of Congo (DRC) demonstration site Kisangani, due to the unstable political situation related to the ever postponed election (currently foreseen for December 2018). This political context makes any collaboration with national partners rather unpredictable and the field data collection challenging. Therefore, the Mali site was extended to a much larger area (above 120 000 km²) than already completed for the current project phase.

Furthermore, it was proposed to move the large South African demonstration site from the Free State province to the Western Cape province. The agricultural context of the Western Cape is more challenging due to the more fragmented landscapes and its higher crop diversity, in particular with regards to the forage crops and perennial crops. The larger extent of the Western Cape demonstration site also partially compensates the cancellation of the DRC demonstration site in terms of Sentinel tiles to process.

Therefore, the current Africa sites for the second project phase are:

- The **Mali** site is representative of many semi-arid regions, and has been enlarged to a demonstration site of 120,000 km²;
- The **South Africa** site Western Cape site covers a very fragmented landscape with high crop diversity in particular with regards to the forage crops and perennial crops.
- The **South Africa** site Free State was only used for WP41 in project phase 1 and the related work has been extended using the same datasets.

A key driver for the selection of the ECoLaSS Test and Demonstration Sites was the need for availability of ground truth data for the development of a crop area and crop status layer based on Sentinel data time series with pan-European and global perspective. Therefore, the sites comprise four **JECAM** (Joint Experiment for Crop Assessment and Monitoring) test sites located in Belgium, France, Mali and South Africa. The selection of these sites in different biogeographic regions ensures a large crop and field size diversity, and covering also grassland and natural vegetation.

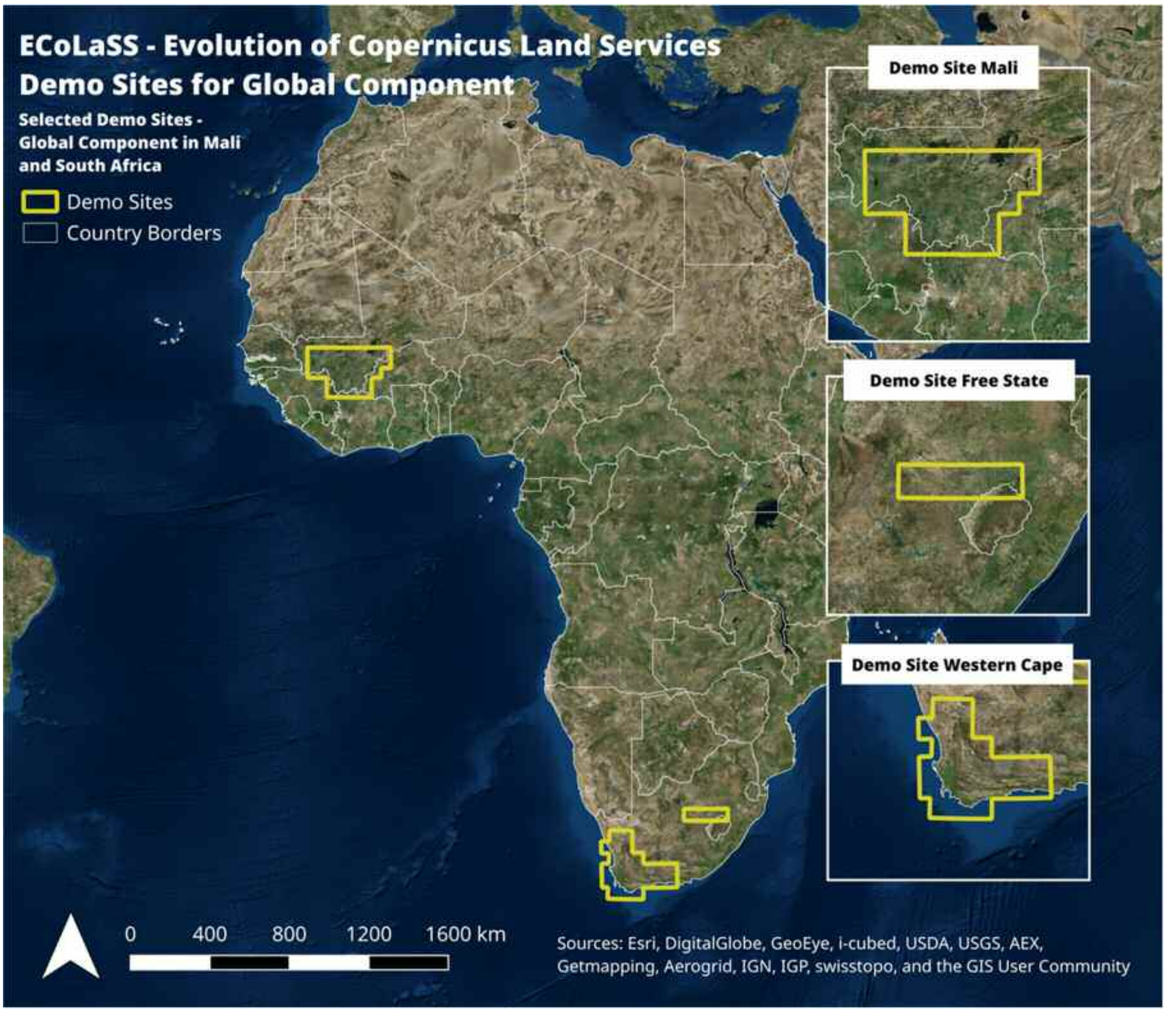


Figure 5: ECoLaSS test sites in Africa

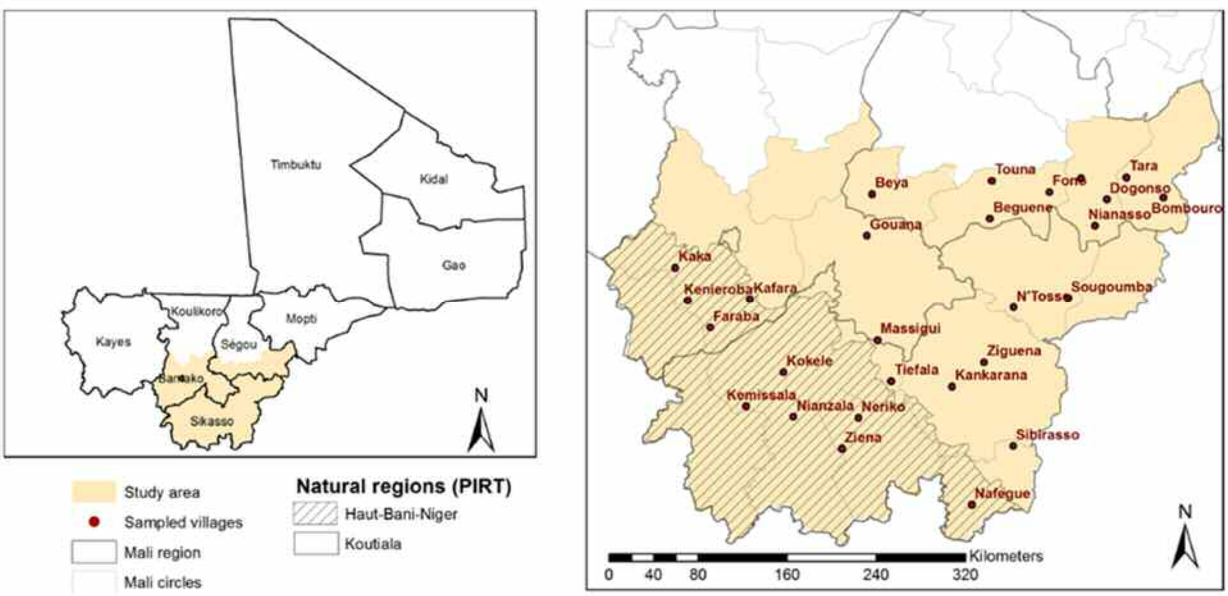


Figure 6: Mali Study region.

The Mali study region (light yellow in Figure 6) covers the Sikasso's region and part of the Segou's and Koulikoro's administrative regions. Field data were collected by the Malian JECAM site team in 2017 around 29 villages spatially distributed over the study region (presented in red). A high rainfall gradient from North to South characterizes the study region.

SCIENTIFIC COORDINATION OF METHODOLOGICAL DEVELOPMENTS

The coordination of the development and prototyping in Tasks 3 and 4 is particularly complex. Besides the fact that partners are involved in many Work Packages, which requires good coordination by the Task 3 WP Leads, the activities in Task 3 are highly interlinked with Task 4 and therefore, had to be well defined and adjusted in advance. This definition was carried out with particular thematic and coordination support of WP 12. From phase 1 developments and the review meetings and comments, in agreement with the PO and observing the project reviews recommendations, the Scientific Coordination decided on a better alignment with ongoing technical activities. This is done by speeding up remaining pre-processing and time-series preparation tasks to enable parallel cross-check of methods implementation in both test and demonstration sites classifications and change detections, specifically targeting multisensor integration (e.g., optical/radar contributions) and the alternative to Sentinel-3 as explained in the related Technical Note (AD-27). Although this generates a shift in Task 3 reports submissions, the larger overlap between Task3/Task4 is taking place with the aim of keeping up with high quality contents in the reports and optimization of workflows (i.e., budget control, avoid redundancies and mismatch between tests/demos methods applications).

The Scientific Coordinator is providing centralised coordination in this respect, whereas the coordination of each WP stays with the respective WP Lead. Action items lists are constantly cross-checked and updated in each progress teleconferences. In addition, in phase 2 the WPs leaders set up regular thematic topics split teleconferences with more specific targets. The Scientific Coordinator follows up all teleconferences and reviews the corresponding Minutes and Action Items derived, integrating them into the general action items list.

During the Interim Review Meeting 1 and confirmed in the Periodic Review Meeting, it was recommended to have each prototype implemented in three demonstration sites by the end of project, and that the Central demonstration site be the site to implement all prototypes. The distribution of prototypes, demonstration sites and contributing partners – in line with WP participation and budget – has been agreed as displayed in Table 6.

Table 6: Selection of Prototypes and corresponding Demonstration Sites

Prototype	North (SWE)	Central (D, A, SUI)	West (BEL)	South-West (FRA)	South-East (GRE, BUL…)	Mali	S-Africa
Indicators/ Variables		Phase 2 (UCL, SIRS, DLR)	Phase 1 + 2 (UCL, SIRS, DLR)				Phase 1 + 2 (UCL)
Impervious ness		Phase 2 (SIRS)		Phase 1 + 2 (SIRS)	Phase 2 (SIRS)		
Forest	Phase 1 + 2 (GAF)	Phase 2 (GAF)			Phase 2 (GAF)		
Grassland		Phase 2 (GAF)	Phase 1 + 2 (JR)		Phase 2 (DLR)		
Agriculture		Phase 1 + 2 (GAF)	Phase 1 + 2 (UCL, SIRS)			Phase 1 + 2 (UCL)	Phase 2 (UCL)
New LC/LU		Phase 2 (SIRS, GAF)	Phase 2 (GAF,SIRS)	Phase 1 (SIRS, GAF)			

Plan for prototype phase 2.

Benchmarking Procedure

Benchmarking is applied primarily in Task 3 and Task 5 WPs and documented in the respective Deliverables, in cases where there is more than one potential candidate method, input data, algorithm, software, hardware configuration, etc.

In order to harmonise the benchmarking work throughout the project, a generic benchmarking procedure has been defined, following the concept described below, which is followed for each individual benchmarking exercise where applicable. Suitable criteria have to be defined in each case to (qualitatively or quantitatively) perform the benchmarking and subsequent selection process.

This general procedure shall be considered for each Task 3 Deliverable report where applicable – i.e., for the second issues of Task 3 Deliverables due between M26 - M35 (Mar 2019 - Nov 2019).

1. **Introduction**: Description of the need and the procedure for benchmarking in the subject matter
    - *What is the background in the project (e.g. wider context of Task / WP / processing chain in relation to the subject matter*
    - *Why is there a need to benchmark and (potentially) decide for only one method?*
    - *Brief generic overview of all following steps of Benchmarking and the expected outcome*
2. (Generic) description of the **candidate methods*** to be benchmarked
    - *highlighting the origin / purpose / history / current use of the candidate methods**
    - *generically describing basic characteristics / specifics of the candidate methods* – without going into detailed numbers*
3. Selection and description of **benchmark criteria** to be applied
    - *Briefly describing the selection process (who decides on the criteria, based on which experience (project, literature…)?)*
    - *List of the selected benchmark criteria & individual justification of their selection (why is it relevant?)*

- *Description of each benchmark criterion (how will it be applied, what is the expected range?)*

4. **Implementation** of the Benchmarking
    - *Explanation of the applied system of (relative or absolute) "marks" to be given to the candidate methods* in relation to the benchmarking criteria (e.g. from +++ to - - -)*
    - *Filled matrix of "marks" for candidate methods* vs. all benchmarking criteria*
    - *If appropriate, additional matrix line with overall mark, as a summary/average of the individual marks, per candidate method**
5. Summary and **Conclusion**
    - *Discussion / interpretation of the outcome of the Benchmarking (e.g. is there a clear result, or two equally suited methods, etc.?)*
    - *In case the result should be inconclusive (e.g. two methods* resulting equally good):*
        - i. *Discussion whether the benchmarking method / criteria were appropriate / complete*
        - ii. *Discussion whether the Benchmarking needs to be repeated at a later stage (e.g. because further developments / information / experience will become available)*
        - iii. *Or: Discussion whether both methods* can/should be used*
    - *Discussion of implications & Recommendations for the project*

* or data, algorithms, software, hardware configurations, …

DATA MANAGEMENT AND DATA SHARING

Two tools for document management and data sharing were set up:

- A MS Sharepoint-based **Teamsite** was set up by DLR for facilitating the exchange of project documents. This central storage and collaboration space also allows to jointly work on and edit documents (e.g. MS Word, MS Excel), and versioning is supported as well. This reduces exchange of documents per email between the consortium partners.
- One **FTP** was set up by SIRS and one by GAF for the storage & exchange of pre-processed satellite data and derived products. These FTPs allow a fast and cost-efficient exchange of high volume data for all test sites and demonstration sites. At present, all pre-processed data for the tests and demosites is uploaded for data sharing within the consortium. Another FTP is used for the delivery of the prototype datasets (raster products) to EC (Deliverables P41.2, P42.2, P43.2, P44.2, P45.2).

SUPPORT TO DISSEMINATION ACTIVITIES

A part of WP 12 Scientific Coordination is also the support to dissemination activities. This was provided by the Scientific Coordinator for jointly creating the first ECoLaSS conference contribution and poster, and many further project presentations, posters, videos, conference papers, flyers etc. in the following. Moreover, the Scientific Coordinator has supported the website layout and contents, and is actively participating in dissemination activities on Twitter. Dissemination activities, e.g. participations in workshops and conferences, are jointly coordinated and updated via the Teamsite or FTP.

QUALITY MANAGEMENT

The ECoLaSS Project Management Procedures are based on GAF's certified ISO 9001:2015 Quality Management (QM) System. This stringent framework covers all aspects of the project implementation and management cycle. Amongst others, the following procedures are regularly carried out by GAF in order to assure an overall high quality and consistency of the project outcomes:

- Quality Assurance of all deliverables and reports in terms of completeness, scientific/technical content, layout and formatting
- Ensure the use of corporate colours on webpage, poster, flyers, proper logos and references, acknowledgments, etc.
- Make sure that social media communication is carried out in a conform way
- Quality control of prototype datasets and INSPIRE conform metadata (towards the end of project phase 1 and now towards project end)
- Common document naming for all Deliverables, structured in the following way: "Number(system)_Number(title)-Name_IssueX_MX", e.g., for the present Deliverable this is: "*PeriodicReport_Issue 1_M18"*.

2.3.2 Quota Management and Data Acquisition within the ESA DWH Mechanism

The ECoLaSS consortium has requested a quota of 13,200 km² of additional VHR Earth Observation data from Copernicus Contributing Missions in 2017. These additional VHR1 data are essential for methodological testing in the framework of improving the existing High Resolution Layers on Imperviousness, Forest and Grassland, and the new layer on Agriculture. In terms of VHR1 data use 2017, the focus is on four test sites: Sweden (North), France, Belgium and Mali.

The abovementioned quota had been accepted by ESA and was subsequently granted to the project. The quota for optical VHR1 archive data orders was slightly exceeded whereas the quota for new acquisitions was not fully exploited for the acquisition year 2017 (Table 7). The main reason for that is that the DWH access for ECoLaSS could be established only at the end of August 2017 where the growing seasons relevant for forest, grassland and agriculture had almost reached their final stages. Since there were sufficient cloud-free VHR1 data in the archives to select from, this did however not create a bottleneck.

Ordering and provision of satellite data is performed through the ESA DWH mechanism, providing eligible users with free and open access to space-based Earth Observation data.

Detailed information on the planned use of this data for the year 2017 in relation to the project objectives as well as deviations from the assigned quota are documented in the Deliverable "*D12.1a-DWHuseFor2017_M9*" [AD07], and updated information were provided in the Deliverable "*D12.1b-DWHuseFor2018_M21*" due at M21, alongside with the planned use for VHR data 2018.

Table 7: Overview of the total assigned and consumed quota 2017 for ECoLaSS

Dataset ID	Description	Assigned Quota 2017 [km²]	Approx. consumed quota 2017 [km²]
D2_MG2b_ECOL_011a	Archive_standard_Optical_VHR1	3,200	3,700
D2_MG2b_ECOL_012a	New acquisition_standard_Optical_VHR1	10,000	2,800

For the second project year (2018), the project has requested again an overall quota of 13,200 km² (Table 8), as documented in the Deliverable "*D12.2a_DWH-RequestFor2018_M9-M21*" [AD08]. The acquisition of VHR data of 2018 could be officially completed in late 2018. The approximately consumed quota 2018 were updated in the Deliverable "*D12.1b-DWHuseFor2018_M21*" due at M21. The final numbers can be found in **Fehler! Verweisquelle konnte nicht gefunden werden.**. Within the production of the prototypes of Task 4, additional VHR data have been used for various steps in the processing/production workflow.

Table 8: Overview of the total assigned and consumed quota 2018 for ECoLaSS

Dataset ID	Description	Assigned Quota 2018 [km²]	Approx. consumed quota 2018 [km²]
D2_MG2b_ECOL_011a	Archive_standard_Optical_VHR1	4,000	0,692
D2_MG2b_ECOL_012a	New acquisition_standard_Optical_VHR1	9,200	4,607

2.4 Work Package Progress

Whereas WP 11 and WP 12 were already described in section 2.2 and 1.1, respectively, the following sections present the Work Package progress of the recently concluded WPs 21-23 although still in place linking to Task 5 and Task 6, and ongoing 31-35, 41-45, 51-53 and 61-62. Objectives, ongoing work in progress, first results and plans for the coming months are explained.

2.4.1 Assessment of Service Evolution Requirements (WP 21)

The WP 21 "Assessment of Service Evolution Requirements" collects and analyses the evolving user and stakeholder requirements towards the Copernicus Land Monitoring Service for the long-term (2020+) perspective, but records also more short- to mid-term requirements which are found on the way.

Table 9: WP 21 – Assessment of Service Evolution Requirements

Work Package Number	3	**Lead Beneficiary**		GAF		
Work Package Title	WP 21 – Assessment of Service Evolution Requirements					
Short Name of Participant (Participant Number)		**GAF (1)**	SIRS (2)			
Person/Months per Participant		**2.90**	2.30			
Phase 1	**Start Month**	1	**End Month**	8		
Phase 2	**Start Month**	19	**End Month**	21		
Objectives: To collect and describe the evolution requirements of Copernicus Land Monitoring Services in view of a potential post-2020 implementation, by analysing the state of the art, product specifications, identifying challenges, shortcomings and lessons learned from current and upcoming operational land monitoring services.						

The first round of user requirements analysis – documented in the Deliverable "*D21.1 - Service Evolution Requirements Report*" and integrated into the final issue – was one of the first activities at the beginning of the project, at an early stage of the first 18-month project cycle. Since this activity is typically very time-intensive and requires coordination of schedules and meetings of different users and stakeholders, it has been agreed after the Interim Progress Meeting 1 to extend the second project phase of WP 21 from three to six months duration.

The first requirements were collected by conducting a number of phone and face-to-face interviews with key representatives of European institutions as well as key national users and stakeholders that are in charge of implementing or coordinating CLMS related activities. The synthesis report from this WP contains a compilation of all responses from user and stakeholder interviews, extended by information from additional sources such as relevant concept notes, reports or relevant stakeholders' workshop presentations on the topic.

The Annexe to the *"D21.1a - Service Evolution Requirements Report"* contains the detailed interview records, and has been agreed to become a separate (confidential) Deliverable.

In both phases, the work carried out has primarily been a qualitative analysis, featuring questions with possibilities for open responses. The second round of analysis (which was planned in the second project phase between M19 and M24 and has been extended to include further interactions from the third round of WP51.1c and the second CLMS H2020 projects collaboration) provides an update to the first deliverable, comprising a larger number of users and stakeholders and focusing on specific topics of interest. For instance, in the IACS Workshop, Agriculture-related requirements were noted (e.g., phenology based intraseasonal crop monitoring, crop types mapping, change detection, high resolution and closer to near real time local field level surveillance, etc.). However, it must be kept in mind ECoLaSS scope addresses large scale mapping (i.e., Pan-European and Global Components) and although it responds to the H2020 call requirements, during the implementation it has been confirmed that some issues remain regarding the Agriculture Service development requirement, suchlike the definition of a representative pan-European crop types legend. Albeit providing a consistent prototype on the basis of testing in biogeographically diverse zones, it has been found that adaptations to local conditions are advisable for a more accurate local scale monitoring. More specific farmer-oriented applications should result from tailored solutions (e.g., CAP payments EO monitoring support).

In phase 2, two webinars (Figure 7) were distributed addressing respectively the DGs and the NRCs, explaining phase 1 findings and providing guidelines for the requirements questionnaire in the frame of ECoLaSS, as additional tools to gather requirements, including a shortened multiple choice questionnaire (Figure 8). Additionally, relevant external sources were crosschecked, like the EC NextSpace study. In this study, requirements voiced demands for high resolution soil moisture indicators products at 20 m spatial resolution on a monthly basis aimed at ecosystems monitoring and land resources management, HR snow cover, lakes, ice and glaciers, which are not within the scope of ECoLaSS. Other specific requirements that are already addressed in ECoLaSS include Imperviousness high resolution land cover change and grassland phenology products (e.g., number of cuts/grazing events per season).

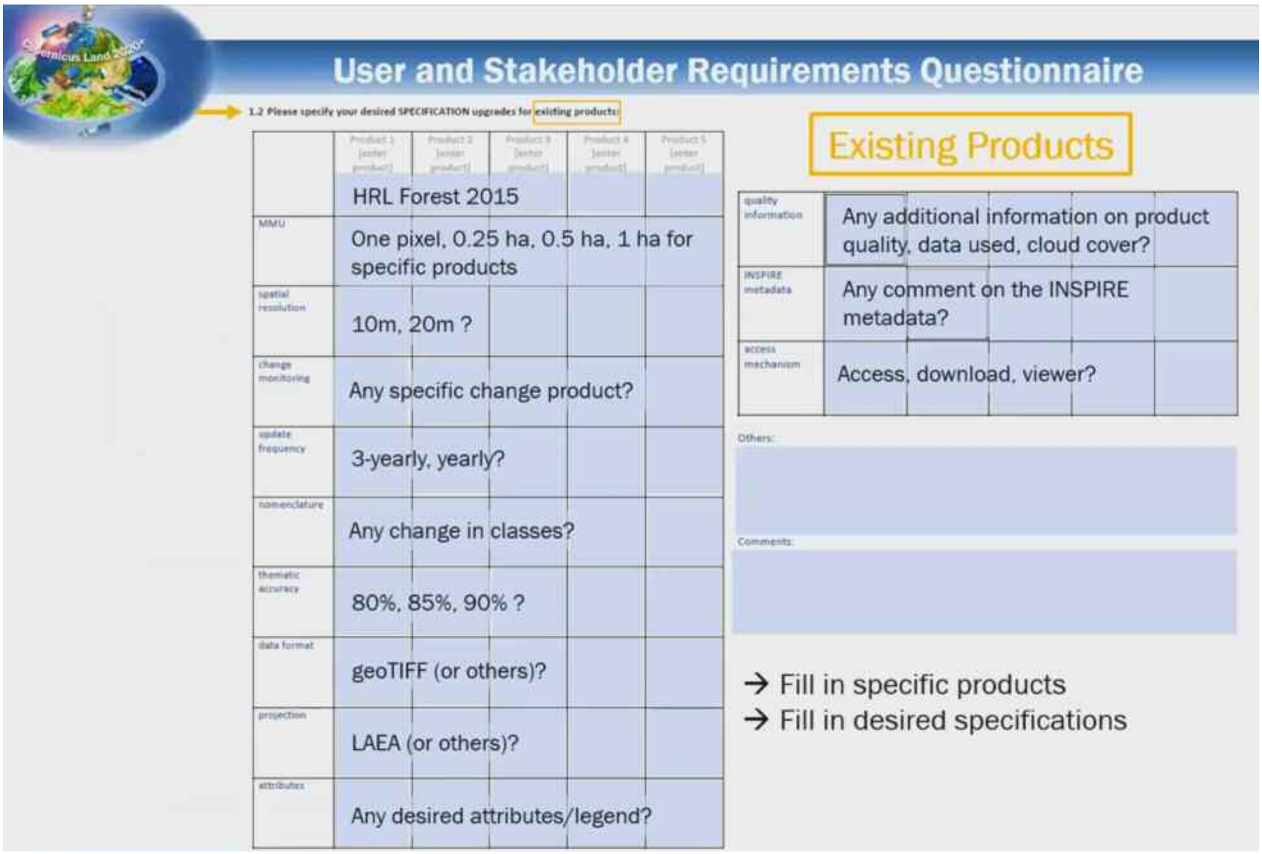


Figure 7: Webinar screenshot.

User and Stakeholder Requirements Questionnaire

-Technical Specifications for Copernicus Land Service Evolution-

Organisation:
Department/Unit:
Contact person:

1. Evolution of Existing Products

1.1 Based on the current Copernicus Land product specifications[1], for which existing PRODUCTS do you consider an improvement/evolution as necessary, and why? (you may address more than one product)

PAN-EUROPEAN COMPONENT

- ☐ HRL Imperviousness
- ☐ HRL Forest
- ☐ HRL Grassland
- ☐ HRL Water and Wetness
- ☐ CORINE Land Cover
- ☐ Image Mosaics
- ☐ EU-DEM
- ☐ EU-Hydro

Reasons:

LOCAL COMPONENT

- ☐ Urban Atlas
- ☐ Riparian Zones
- ☐ Natura 2000

Reasons:

GLOBAL COMPONENT

- ☐ Vegetation Products (if specific ones state below under "Reasons")
- ☐ Water Products (if specific ones state below under "Reasons")
- ☐ Energy Products (if specific ones state below under "Reasons")
- ☐ Cryosphere Products (if specific ones state below under "Reasons")

Reasons:

[1] http:\\land.copernicus.eu

Figure 8: Shortened multiple choice questionnaire sample extract.

WP21 considers recent developments regarding Copernicus Land services as well as future plans, although it is clear that most recent requirements cannot be fulfilled in the remaining months of ECoLaSS. All in all, the results of the first user requirements analysis show that the methodological and prototypical developments investigated by ECoLaSS largely concur with the perception and future plans of the key users and stakeholders in terms of Copernicus Land Service evolution. In phase 2, these findings were confirmed although additional updates were also noted that now are out of scope at least within the ECoLaSS objectives and scheduling: tendency towards better alignment between the continental and global components, and the time series exploitation towards a combination of real time monitoring component built on phenology variables and land cover components, like the CLC evolution and HRLs products consistency (status and change layers included), cross-cutting generic products and phenology layers that might fit broader purposes. The finalisation of WP21 integrates as well the collaboration with other CLMS H2020 projects. Task 2 reports were shared with the SENSAGRI/MULTIPLY/EO4AGRI/NIVA/SEN4CAP projects in phase 1 although a second interaction is ongoing in phase 2. Prior to the follow-up Exchange meeting of Copernicus projects related to agriculture in the context of IACS that took place in Valladolid (Spain) 9th of April in 2019 the updated user requirements materials were recirculated and some relevant conclusions fitting into WP21 were embedded to close Task 2.

The publication of the ITT for the High Resolution Layers 2018 production on 17 July 2018 confirms that the developments of ECoLaSS go into the right direction towards next-generation services 2020+. The HRL 2018 product specifications largely comply with those from 2015, targeting mainly an evolution to 10m spatial resolution and different derived products (such as a new built-up product for the HRL Imperviousness 2018). Some optional elements mentioned like “grassland biomass removal frequency and timing” could overlap with the planned investigation of grassland use intensity in the second ECoLaSS reporting period. It is therefore being closely observed in subsequent tests.

At this point in the project lifetime, congruity between phase 1 and phase 2 main findings makes it still fully valid that ECoLaSS focuses on the pan-European and Global Component aspects, as these are partially closely related and potentially converging on the longer run, taking into account the respective needs of the key user and stakeholder community. Indeed, there is generally substantial interest in use of the High Resolution Layers, particularly when equivalent information is not available at national level. However, some users indicated that there is still a lack of awareness about the HRLs, hampering their uptake and use. National users showed particularly high interest in products of the Local CLMS Component, clearly related to a higher spatial resolution of the products, better fulfilling the information needs on a regional level and also perhaps because these products are thematically closer to those already available locally. There is a general trend towards increasing interest in Copernicus (Sentinel) satellite data, which was repeatedly mentioned by several users. Nonetheless, depending on expertise level, not completely realistic assumptions on satellite-application potentials especially regarding timely production, near real time and very high resolution at large scales were noticed. As such, shorter update frequencies and change products (incremental updates) specifications were mentioned. 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. Concerning new services, the pan-European Agricultural Service as well as a Phenology Layer are still the most frequent demands.

Additionally, a general requirement for an easier and standardised access to data, products and documentation, via a unified access portal, was repeatedly stated and still in place, including multi-layer online visualisation and/or evaluation tool for the products.

In phase 2 of the ECoLaSS project, the Service Evolution Requirements Assessment, including the User Requirements Analysis, has been updated and refined, on the basis of phase 1 implementation and connected to Task 5 interactions as well. Further EC DGs and national users have been contacted as part of WP 51 and the analysis of their filled questionnaires has been ingested into phase two of WP 21. More national Member State users are included through the interaction with EIONET for which one of the abovementioned webinar together with a reduced questionnaire were used, targeting mainly technical specifications for improved and new Copernicus Land Monitoring services. These materials were distributed with the help of EEA. The second analysis cycle targets in this manner more specific aspects in accordance to the identified needs in phase 1, that ultimately led to the update of the respective Deliverable.

2.4.2 Assessment of EO and Other Data Requirements (WP 22)

WP 22 is on the “Assessment of EO and other Data Requirements” and is as such considering the outcomes of WP 21 “Assessment of Service Evolution Requirements“ and is of relevance for WP 23 “Assessment of Service Infrastructure/Architecture Requirements”:

Table 10: WP 22 – Assessment of EO and other Data Requirements

Work Package Number	4	**Lead Beneficiary**	SIRS			
Work Package Title	WP 22 – Assessment of EO and other Data Requirements					
Short Name of Participant (Participant Number)		GAF (1)	**SIRS (2)**			
Person/Months per Participant		3.60	**2.90**			
Phase 1	**Start Month**	1	**End Month**	9		
Phase 2	**Start Month**	19	**End Month**	24		
Objectives: To assess, monitor and document the requirements for EO and other data availability as input for future Copernicus Land operational services (2020 and beyond) by monitoring the effective implementation of the Sentinel satellites deployment, the third-party missions as well as the in-situ activities.						

WP22 aims at a comprehensive assessment of EO and other data requirements to make sure that the general requirements expressed as part of WP 21 “Assessment of Service Evolution Requirements” are realistic and can be supported by a sustainable provision of relevant input data to ensure the service operational conditions in the near and more distant future. Therefore, the objectives of this WP are to:

- Assess current available EO, reference and in situ data and their usability for the evolution of Copernicus Land Services
- Follow and analyse the evolution of new and upcoming satellite/sensors
- Define data requirements relevant for future Copernicus land services 2020+

A first deliverable of WP22 was produced: “*D22.1 - EO and other Data Requirements Report*” that represents the first iteration of WP22 deliverable at the end on month 9 of the project only considering the outcome of WP21 in terms of user requirements.

The second deliverable of WP22 has been produced: “D22.1 - EO and other Data Requirements Report” [AD10] that represents a new iteration of WP22 deliverable at the end on month 27 of the project considering the outcome of the second WP21 iteration in terms of user requirements as well as all deliverables from phase 1, related to Tasks 3, 4 and 5. Lessons learnt from the first implementation of the prototypical services envisaged over the demonstrations sites have been integrated and first conclusions on the availability of EO data from the newly launched Sentinel satellites (i.e., Sentinel-2B, Sentinel-3B) have been drawn.

A detailed review of the status of Copernicus EO and other data was re-assessed, outlining the shortcomings of the current provision and the consequence this might have for future services. A new assessment of the current and future offering in terms of EO data was made, including the Sentinel constellation based on available documentation and in light of the results of the first phase of prototyping and the assessment of future mission evolution was also done primarily based on the participation to relevant meetings. This was confronted to the needs identified as part of WP21 to assess any critical gaps and potential mitigation measures as outlined below:

- There is still a lack of a reliable geometric reference dataset hampering the use of the Copernicus VHR dataset for calibration and validation of the thematic classification associated with the production of the HRLs, or alike products, at pan-European level. This could be resolved in part by improving the quality of the pan-European EU-DEM, since it shows room for enhancement regarding the data consistency, a higher spatial resolution as well as a higher vertical accuracy.

- The specifications of the upcoming VHR_IMAGE_2018 data with 2-4 m spatial resolution will pose a limitation in terms of information content and discriminability of landscape features. The largely contained Planetscope data will not allow to identify the "quasi/ground truth" calibration information needed for all HR Layers, e.g. it will not be possible to reliably characterize individual tree crowns vs. canopy gaps for the HRL Forest's Tree Cover Density and Dominant Leaf Type products. Although a higher-precision DEM for Europe may be produced by ESA in the course of 2019, it will come too late to support a better geometric consistency of the upcoming VHR_Image_2018 dataset. However, future generations of Copernicus services may greatly profit from it.
- The S-2A and S-2B satellites cannot be envisioned as the sole providers for image coverages for the future HRLs production, over the pan-European countries. As already assessed during the previous runs of those productions, the use of Landsat-8 and S-2 required a non-negligible amount of complementary EO data, in particular ResourceSat-2 and SPOT-5 images, to fill gaps due to the dense cloud presence over Northern Europe. The Figure 9 illustrates the HR MS coverage which was used for the production of the HRL2015, which included Sentinel-2A, Landsat 8, ResourceSat-2 and SPOT-5 data. However, it should be noted that S-2 twin satellites are outperforming in terms of revisit time and spectral quality as demonstrated during the production of HRL prototypes in phase 1 – even though geometrical inaccuracies remain. The integration of S-1 data and PROBA-V, in particular for the creation of new products such as the phenological and crop type layers, will be tested during the second phase.
- As underlined in the Technical Note [AD28], the S-3 twin satellites are not performing at the same standard as the S-2 satellites, in particular in terms of aerosol optical thickness (AOT), quality flags, and cloud screening, and will be replaced for the current study by PROBA-V time series images in the processing chains, in particular for the phenological products creation.

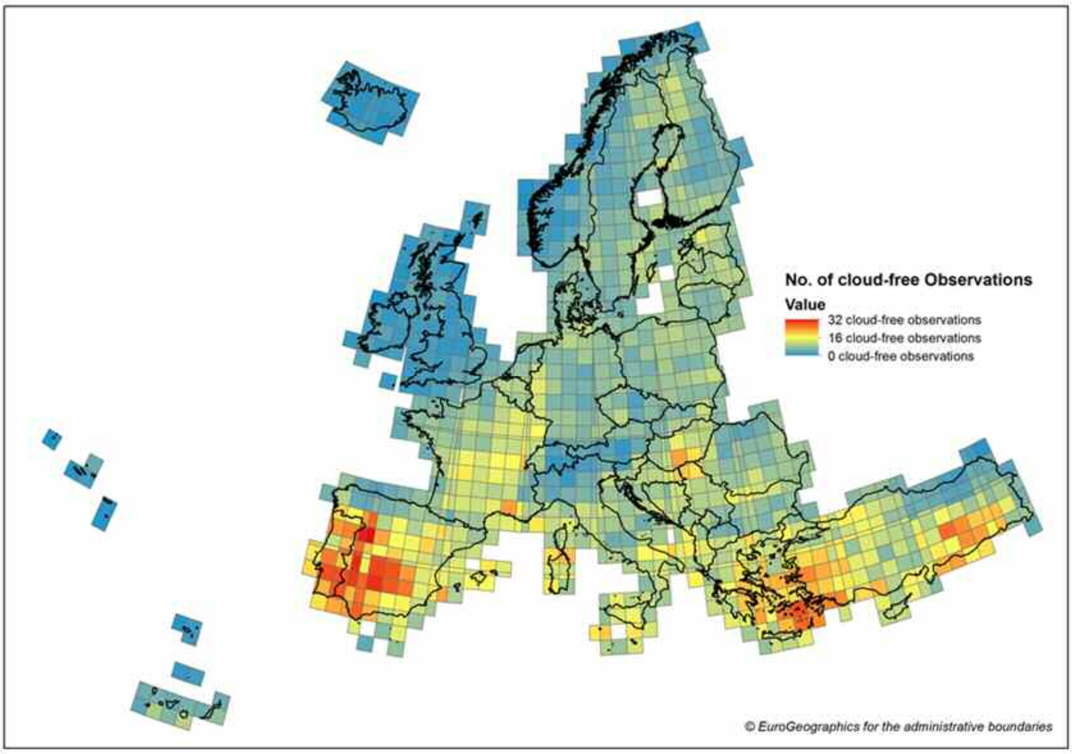


Figure 9: Number of cloud free observations for HRL2015 production per MGRS tile

Note that Figure 9 includes ResourceSat-2, SPOT-5, Landsat 8 and Sentinel-2A over the 2014-2017 period

- Supporting in situ data for training and validation of thematic data are not homogeneous. One of the more obvious examples is that of the Land-Parcel Identification System (LPIS) which could provide reliable training and validation data for the production of the HRL grassland and a future potential crop layer, but its availability at pan-European level is still far from complete despite the INSPIRE Directive. The use of LUCAS dataset is being explored in the second ECoLaSS phase as a basis for a crop mask layer.

- The level of pre-processing for Sentinel-2 imagery using Sen2Cor is currently still not fully sufficient for a large-scale operational production thus hampering the implementation of automated processing chains based on dense time series. Specifically, small and scattered clouds, as well as thin cirrus clouds, their associated shadows and cloud fringe areas, are not always consistently captured. At the very least, cloud masks have been improved, but work remained to be done in order to use the Sentinel-2 time series images at Level-2A “as is”. The ESA software for Sentinel images pre-processing SNAP now proposed an algorithm called IDEPIX. As of now, this algorithm still confuses urban areas with clouds, and cloud shadows are not flagged properly, as displayed in Figure 10. Multi-temporal detection algorithms such as the one implemented in MAJA have been tested in the final iteration of WP32 deliverable [AD13] and have been demonstrated to be solid alternatives.

Figure 10: Example of S-2 images pre-processed in SNAP over the North of France.

On the right, in blue, the partial cloud mask provided with the image. On the left, in yellow, the masking of opaque cloud obtained with the IDEPIX algorithm in SNAP. Red borders mark the fringe of the opaque cloud, while purple flags are supposed to spot cirrus. As can be seen, urban areas are falsely considered as clouds, while cloud shadows are not yet distinguished.

The analysis of critical gaps and the provision of mitigation measures have been reviewed following the first demonstration of future CLMS service candidates as part of Task 4 in phase 1. The consolidation of EO and other data requirements will be re-assessed at the end of the project, in particular through the deliverables of WP52 and 53, which tackle the issues of feasibility for each prototype for future operational implementation

2.4.3 Assessment of Service Infrastructure/Architecture Requirements (WP 23)

WP 23 on the "Assessment of Service Infrastructure/Architecture Requirements" builds on WP 21 and 22:

Table 11: WP 23 – Assessment of Service Infrastructure/Architecture Requirements

Work Package Number	5	**Lead Beneficiary**	DLR			
Work Package Title	WP 23 – Assessment of Service Infrastructure/Architecture Requirements					
Short Name of Participant (Participant Number)		GAF (1)	SIRS (2)	JR (3)	UCL (4)	**DLR (5)**
Person/Months per Participant		1.70	1.20	0.66	1.00	**3.60**
Phase 1	**Start Month**	1	**End Month**	10		
Phase 2	**Start Month**	19	**End Month**	24		
Objectives: To assess currently available and upcoming IT architectures in terms of their capabilities for processing large volumes of EO data in order to minimise Input-Output operations within and across systems, recommend strategies for easy integration of prototype products into the future Copernicus Land service infrastructure.						

The launch and operation of the meanwhile complete constellation of the Sentinel 1, 2 and 3 Earth observation satellites (with their A and B units) have resulted in a sharp increase of freely available high-resolution remote sensing data for global land and ocean monitoring services. Together with already existing data sets (e.g. Landsat) users face the challenge of dealing with massive data sets.

Users therefore have to decide whether to process data locally or remotely using cloud services. In order to stay flexible and avoid unnecessary and costly data transfer traffic, processing techniques increasingly favour solutions that move software to data, that is, to cloud-processing services. This opens the way for collaborations with partners and keeps stakeholders independent of hardware and service providers.

Approaches taken by different users and organizations are highly diverse and rapidly evolving, especially since the appearance of readily available commercial processing platforms (e.g. Google Earth Engine, Amazon Web Services), which solve the problem of data discovery, access and organization. Since the operational full availability of the five Data and Information Access Services (DIAS) from mid-June 2018, also genuine European platforms are now available, which compete with the other big IT provider platforms as well as among each other. This increased competition is expected to be highly beneficial for platform users in terms of constantly growing data offers (including non-Copernicus EO data and in-situ data), increased availability of, often open-sourced, big-data software solutions, as well as decreasing prices.

As a first step and in the previous absence of the DIASes, WP 23 undertook a survey and study, successfully highlighting common strategies as well as fundamental differences between the ECoLaSS partners' data handling and processing infrastructures, as a proxy for the heterogeneity also found between the DIASes. This was documented in the report *"D23.1 - Service Infrastructure/Architecture Requirements Report"* [AD11], which summarized state of the art paradigms and developments in EO data processing, analysed the service architecture, infrastructure and requirements of each member of the consortium and addresses assessments for future developments regarding hardware, software and platform infrastructure and the overarching orchestration. Also described are areas of cooperation and interaction that were identified during the practical work and the study.

As requested by the M9 interim review report, the deliverable D23.1 was updated with developments regarding the DIAS platforms and other EO data initiatives in Europe such as the TEP and RUS Service portals. It also provided checklists of system requirements that were later used for deliverable D23.1b to (i) identify points of interaction; (ii) make recommendations for streamlined collaboration; (iii) set up platform tests and (iv) document solutions. Finally, the additions included some initial estimates regarding general processing and data transfer for typical EO computations. The document was re-submitted in December 2017.

With submission of D23.1b, particular attention was paid to evaluating the current usability, but also limitations of the DIASes, which have the potential to provide users with data and hardware resources that are superior to many local processing platforms. The DIAS platform developments were found to be progressing very fast, and with GAF and DLR, two of the ECoLaSS partners are involved with the developments of the ATOS-led DIAS "Mundi". This facilitates testing of ECoLaSS processing chains on the Mundi platform, which is the most familiar one to the consortium, and also provides the presumably best trade-off between required input data and cost for the kind of services aimed for. But also the other four DIASses, i.e. "Sobloo" (led by Airbus), "CreoDIAS" (led by CloudFerro), "ONDA" (led by SERCO) and "WekEO" (led by EUMETSAT, ECMWF and Mercator Ocean), have been closely reviewed and their capabilities and commercial conditions investigated. Project partner Joanneum Research plans to implement selected tools from their in-house developed software suite IMPACT on the CreoDIAS platform.

Even though all DIAS centres now offer similar services, significant differences regarding completeness of functionalities, services and data availability were found. In particular, challenges that remained were:

- Incomplete archives or rolling archive strategies, which render retrospective or long-term time-series analysis impossible. Users requiring more than the last two years of data have very a limited choice of providers.
- Incomplete data discovery functionality. Search APIs so far, were found to be insufficient for automated, large-scale processing.
- Differences in data archive structures, search APIs and software availability, were found to complicate the portability of processing chains from one DIAS to another. Each DIAS requires a notable number of adaptions in the user code-base before it can be used, which is counter to EC's and ESA's ambition to enable users to seamlessly switch between services.

Besides that, it can be stated, that for the time being, the DIASes are still striving towards full operational data availability and maturity. This rapid evolution, however, puts current and future users in a tricky position as they need to keep track of and adapt to changes frequently, which is unsustainable for operational processing. Therefore, it was concluded, that it is vital that the DIASes reach operational maturity in short time, since otherwise, other, already more established platforms like AWS and Google, are likely to marginalise the European-led DIASes in the long run.

Within project phase 2 a number of hands-on tests are being considered by consortium members to evaluate the practical and most-recent usability of the DIASes for operational production (e.g., JR is currently implementing tools and testing its potential to generate training samples of grassland management events through visual interpretation in CREODIAS).

2.4.4 Sentinel-1/2/3 Integration Strategies (WP 31)

WP 31 is on "Sentinel-1/2/3 Integration Strategies" and builds on the experiences gathered in WP32, WP33 and WP34 regarding the complementarity of the different sensors.

Table 12: WP 31 - Sentinel-1/2/3 Integration Strategies

Work Package Number	6	**Lead Beneficiary**			DLR	
Work Package Title	WP 31 - Sentinel-1/2/3 Integration Strategies					
Short Name of Participant (Participant Number)		SIRS (2)	UCL (4)	**DLR (5)**		
Person/Months per Participant		2.90	2.00	**3.02**		
Start Month	2	**End Month**		31		
Objectives To investigate S-1/2 complementary information integration techniques for improved LC/LU updates, crop area and improved grassland services; to identify alternative strategies for using S-1/2 time series indicators in classification / post-classification approaches; to explore the potential of and define S-2/3 fusion approaches.						

Monitoring of land cover/land use (LC/LU) change and seasonal dynamics of vegetation and crops requires temporally and spatially high resolution EO data. Currently, this requirement cannot be satisfied by one EO sensor alone (Gao et al., 2015). On the one hand, frequent cloud cover in optical imagery can limit the availability of a complete time series for the classification; while on the other hand, speckle noise as well as geometric and radiometric effects due to topography in SAR imagery can increase the uncertainty und result in poor classifications (Joshi et al., 2015). Therefore, data fusion approaches have been developed over the past decades to use the advantages of different sensors in LC/LU classifications. In general, fusion approaches are developed for the integration of different spectral and spatial resolutions from two or more sensors to the effect of including data into high spatial resolution as well as preserving the high spectral and temporal resolution properties of the sensors.

According to the desk study within WP31, the following integration strategies are possible and reasonable in relation to the objectives of ECoLaSS:

- Multi-sensor-temporal approach for classification and change detection analysis (integration of Sentinel-1 and Sentinel-2)
- Multi-sensor-spatial-temporal approach to enhance temporal high resolution time series data (i.e. fusion of Sentinel 2 data with a higher temporal resolution sensor). As lined out in the Technical Note "Proposed Substitutes for Sentinel-3 data" [AD27], Sentinel 3 is not suitable yet for this kind of analysis. While no currently available high temporal resolution sensor can fill this gap entirely, substitute analyses are being performed based on PROBA-V data. Nevertheless, given the high quality of the Sentinel 2 time series themselves, only moderate added value through this fusion combination is expected.

Depending on the type of land cover (e.g., urban, grassland, etc.), specific fusion approaches need to be evaluated. First, it is of utmost importance to perform all necessary image correction and pre-processing steps (especially dealing with sensor specific effects) to provide the best single data geometry and radiometry as image fusion is generally performed on pixel level (Pohl & Van Genderen, 1998). As multi-sensor data can vary in their spatial and temporal resolution, the pre-processing of the data has to be adjusted with respect to the specific needs and field of application, including sensor specific steps such as calibration, speckle reduction (SAR) or atmospheric correction (optical), and geocoding as well as resampling to a common pixel size. A major challenge considering the fusion of optical and SAR imagery is to ensure an accurate co-registration, since errors lead to artefacts and misclassifications (Pohl & Van Genderen, 2015). Different pre-processing approaches both for optical and SAR data have been benchmarked in [AD13].

In order to increase the impact of the work accomplished in Task3 and Task 4 prototype developments, it was agreed upon that, following the summary of the state of the art approaches in data fusion in [AD12], the second issue thereof should summarize the approaches developed and tested within ECoLaSS to derive improved and novel CLMS products, with particular focus on the data requirements regarding Sentinel 1 and Sentinel 2 as well as the potential for classification improvements through their combination. To this end phase 2 of WP31 has been rescheduled to be conducted alongside all other Task 3 and Task 4 WPs with a subsequent wrap-up phase until M35. Moreover, the benchmarking and practical testing has been moved out of this WP and is accomplished directly in the other WPs, leaving space for WP31 D31.1b to become a collective summary of the ECoLaSS experiences for next generation CLMS products (see recommendation #10 in section 5).

In the Task 3 and Task 4 prototype developments, the information gained from both Sentinel 1 and Sentinel 2 is used in parallel for the classification as they record complementary characteristics of the land surface. While optical data are affected by the physical-chemical characteristics of the surface (such as leaf structure or pigmentation) SAR data represent the geometric and dielectric properties of the surface (Woodhouse, 2006). Through their multi-spectral bands ranging from visible to near infrared wavelengths, optical data provide information on diverse land covers. SAR data on the other hand are usually acquired in a single frequency for each sensor and interact with the structural characteristics of the surface depending on the wavelength, incidence angle of the sensor, as well as roughness and moisture content (Joshi et al., 2016).

Here, two different methods are used for the integration of the S-1/S-2 data: (a) the fusion on feature level: bands and indices from S-1 and S-2 are stacked into one dataset, which is the target of the classification; and (b) the fusion on decision level: classification of individual land cover classes is performed based on S-1 data or S-2 data individually and the results are fused based on decision rules on the post-classification level. Therefore, sets of indicators and metrics derived from time series of SAR and optical data are currently being used in the literature, which can also be derived from S-1 or S-2 data. The following indicators from optical and SAR data have been identified based on the state-of-the-art analysis of being useful and improving the thematic classification results: NDVI, NDBI, MNDWI, NDMIR, NDRB, as well as NDGB derived from S-2 data and the backscatter coefficient in the available polarisations (VH, VV) and polarisation ratios VH/VV derived from S-1 data. The first qualitative assessment showed that the complementary information derived from S-1 data in addition to those from the optical data of S-2 are promising in helping to distinguish between urban areas and bare soil. In Figure 11, this specific false colour composite makes residential urban areas appear in a pink to purple colour and industrial areas in a light yellow to light green colour, whereas base soil appears in a light blue-purple colour (a detailed view gives upper close-up on the right). Despite the possibility to distinguish between urban and bare soil, also a sub-classification of urban areas seems possible as one can clearly discriminate between these two classes. Also, forests and agricultural/grassland areas can be visually distinguished better using the fused data sets, which can be seen in the lower close-up on the right side of Figure 11, where forests can be clearly identified through their orange colour compared to agricultural/grassland areas which are visible in all different shades of darker blue.

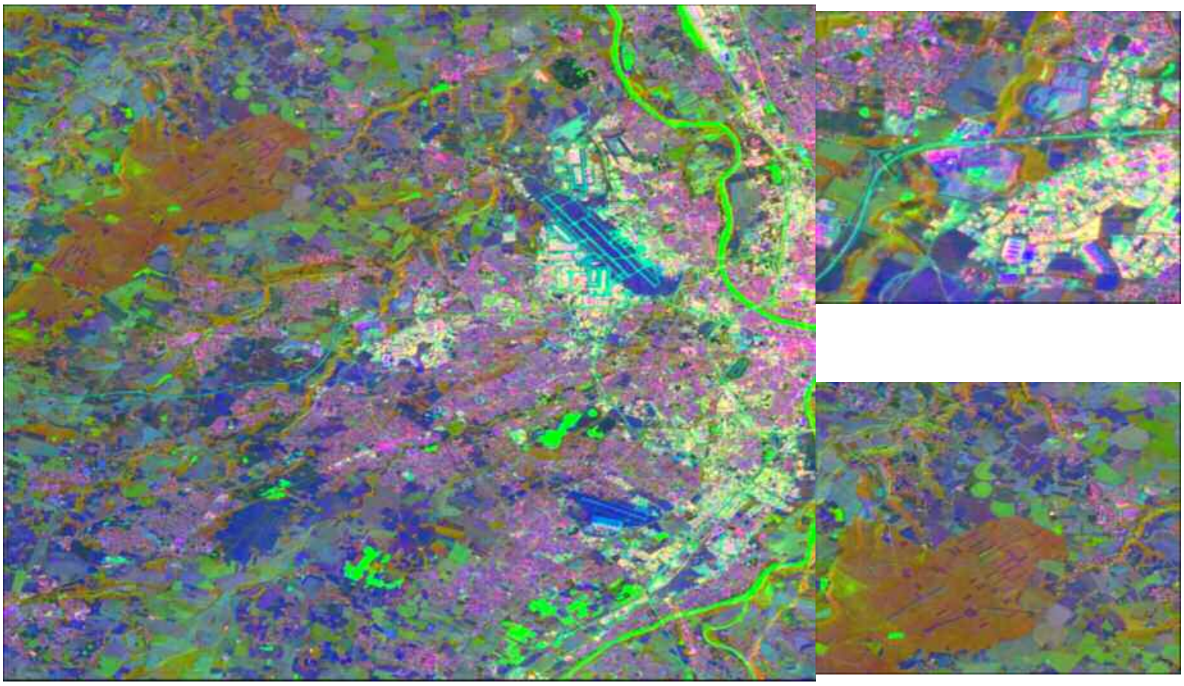


Figure 11: False colour composite of bands R: S-1 VV MEAN, G: S-2 MNDWI MEAN and B: S-2 NDBI MEAN 2017 West of Toulouse

With respect to the fusion of S-2 and S-3, S-3 daily surface reflectance (S-3 synergy product combining SLSTR and OLCI observations) is required to fill the gaps in S-2 time series. However, since operational, dense Sentinel-3 time-series and the corresponding atmospheric correction tools were not available in due time, the integration of Sentinel-2 and Sentinel-3 in the project has been discarded. Instead of Sentinel 3, analyses based on established PROBA-V data are being performed. Nevertheless, a benchmarking for spectral and textural time series metrics/variables has been performed solely on S-2 imagery.

The statistical metrics (extrema, standard deviation and median) derived from the five most significant bands contain the most complete information, therefore lead to the best results regarding the spectral separability of targeted classes, as assessed over the training data. The combination of two classical spectral indices, the NDBI and NDVI and their statistical metrics, gives the next best results compared to the statistical metrics directly derived from a selection of the most meaningful bands. The spectral separability of the five test classes (namely: cropland, forest, grassland, urban, and water) is still achieved, despite a clear reduction of the spectral information. The use of those combinations of statistical metrics and spectral indices to feed various kind of classification were explored in more detail in the WP33 and 34 reports.

The major drawback of optical observations is the impossibility for any sensor to permeate opaque clouds, whose presence can greatly vary from one AOI to the other. The fusion of S-2 and S-3 or PROBA-V data has the potential to bring down the revisit time from five days (for S-2) to one day, helping to densify the time series (Sylla et al., 2014). However, as noticed in current HRL projects, supplemental observations (from other sensors or on an extended span of several years) often have to be required in order to fill the gaps left by clouds. Within WP32 a review of such gap filling approaches for Sentinel 2 was conducted. Quantitative analyses and benchmarking of harmonic regression for the creation of synthetic gap-free time series showed some potential for forest areas, but notable errors remained, especially during spring [AD13]. To monitor slow changes, such as the urban growth, temporal metrics derived from spectral indices, such as extrema, standard deviation and median of the NDBI and NDVI, computed over a year, seem to be qualitatively as satisfactory as full datasets of raw images to characterize the land cover image by image, before proceeding to fusion on decision level. Nonetheless, to follow crop and grassland evolution in the landscape, future research will need to investigate in further details temporal techniques, such as temporal interpolation, to create composites based on the previous and following cloudless images in the time series, or trend modelling, that fill gaps as well as discriminate outliers, or diminish the effect of random noise.

These findings were presented in the first issue of the deliverable “*D6.1 : D31.1a - Methods Compendium: Sentinel-1-2-3 Integration Strategies”* [AD12], which was delivered at M15.

The second issue of the deliverable “*D6.2: D31.1b - Methods Compendium: Sentinel-1-2-3 Integration Strategies”* shall incorporate the results gained during the prototype development in WP33, WP34, and WP35 and has therefore been agreed to be delivered on M35. Particular focus therein, is being given to a more detailed analysis on the usefulness of the integration/fusion methods shall be performed for the single HRL classification.

2.4.5 Time Series Preparation (WP 32)

WP 32 is on "Time Series Preparation" and serves as input to WPs 33 "Time Series Analyses for Thematic Classification, 34 "Time Series Analyses for Change Detection" and 35 "Time Series Consistency for HRL Product (incremental) Updates", as well as Task 4:

Table 13: WP 32 – Time Series Preparation

Work Package Number	7	**Lead Beneficiary**		JR		
Work Package Title	WP 32 – Time Series Preparation					
Short Name of Participant (Participant Number)		**JR (3)**	DLR (5)			
Person/Months per Participant		**4.33**	3.92			
Phase 1	**Start Month**	3	**End Month**	14		
Phase 2	**Start Month**	19	**End Month**	26		
Objectives: Provide methods for precisely and considerately pre-processing of SAR and optical time series imagery.						

The aim of WP32 – Time Series Preparation is to find robust methods for fully automated pre-processing of SAR and optical time series data streams, which are a prerequisite for all further processing tasks. The quality of the pre-processing procedure determines the thematic quality and accuracy of subsequent information extraction processes. Considering the number of scenes to be processed and the resulting data size, an automated and rapid processing chain is essential, especially for near real-time scenarios.

SENTINEL-1 PRE-PROCESSING

The benchmarking for SAR time series pre-processing is focusing on the a) radiometric calibration, b) implementation of spatio-temporal noise filtering tools optimized for Sentinel-1 time series and the c) interferometric coherence estimation.

Radiometric Calibration

SAR intensity values can be processed to different radiometric calibration levels to correct backscatter differences related to local incidence values and thus make data from different orbits comparable. As shown in phase 1, flattened gamma nought imagery shows the best results for terrain correction and for the similarity of imagery from different orbits. When incidence angles are too steep the values are still unreliable (i.e., areas with large incidence angles above 70° should be eliminated).

Speckle Noise Reduction

Noise reduction is an important pre-processing step regarding SAR imagery based land cover classifications. In addition to multi-looking, which is already applied to GRD images, SAR speckle filtering can be used to reduce speckle noise in SAR imagery. Common SAR speckle filters including the Lee filter, Frost filter, Kuan filter, Gamma-Map filter and multiresolution speckle filters are benchmarked. However, with common speckle filters geometric detail is lost due to blurring effects. Multitemporal SAR filters are better suited for high resolution land cover classification with full resolution, e.g. 10m resolution for Sentinel-1/Sentinel-2. They preserve the radiometry while reducing noise and sharpening the image. The calculation of seasonal means further reduces noise and enhances class separability. Seasonal means and seasonal statistics further reduce speckle noise and should be used as input regarding SAR data classification of the HRL land cover classes.

Interferometric Coherence Estimation

Interferometric coherence is a measure of decorrelation and can be used to separate different land cover classes. For vegetated areas decorrelation is very high and short-term coherence is required to map differences among vegetated areas. In the second issue of WP32, examples of coherence products generated for the Belgium demosite are shown, considering time windows performances in different land cover categories assessments, proving their potential usefulness in LU/LC classifications and change monitoring.

Short-term coherence seems to be of interest for agricultural applications (bare field conditions) and possibly grasslands, e.g. detection of mowing events or differentiation of intensive versus extensive grassland. Longer coherence time intervals could be of interest for medium resolution detection of urban built-up areas. Whether coherence data adds significant additional value for HR land cover classification compared to using only filtered GRD backscatter data is being investigated further in the thematic classification chains. The project partner JR optimised the inhouse-developed RSG software suite to facilitate the automated calculation of coherences over time. However, calculating these products on the pan-European level for an entire year or more will consume huge time and processing resources, therefore an operational application at the pan-European level can only be recommended in cases where thematic classifications demonstrate significant benefits.

SENTINEL-2 PRE-PROCESSING

The generation of spatio-temporally consistent, dense optical time series requires fully automated pre-processing. The benchmarking of optical time series pre-processing concentrates on testing of best suited algorithms and their application in test sites and the development of new methods as well as the implementation of prototype methods. The benchmarking for optical time series pre-processing was therefore, focusing on (a) atmospheric correction (b) cloud, cloud shadow and snow masking (c) topographic normalisation and (d) geometric consistency.

Atmospheric correction

In order to obtain the Bottom-of-Atmosphere reflectances for Sentinel optical data, several processors like Sen2Cor (processor for Sentinel-2 Level-2A product generation) and MAJA (MACCS-ATCOR Joint Algorithm) are available. The analysis shows that, for the most part, atmospheric correction performed with Sen2Cor works consistently when Dark Dense Vegetation (DDV) pixels are present in the granule. Small over-correction in comparison with the AERONET sunphotometer measurements is observed by Louis et al. (2016), which may result from false aerosol parameters because Sen2Cor estimated higher aerosol optical thickness compared to the reference data. Doxani et. al, 2018 compared within the ACIX initiative the surface reflectance products from several different processors (CorA, FORCE, iCOR, LaSRC, MACCS, S2-AC2020,GFZ-AC and Sen2Cor). The overall analysis shows that FORCE, LaSRC, MACCS and Sen2Cor managed to estimate the reflectance quite well in comparison to AERONET corrected data.

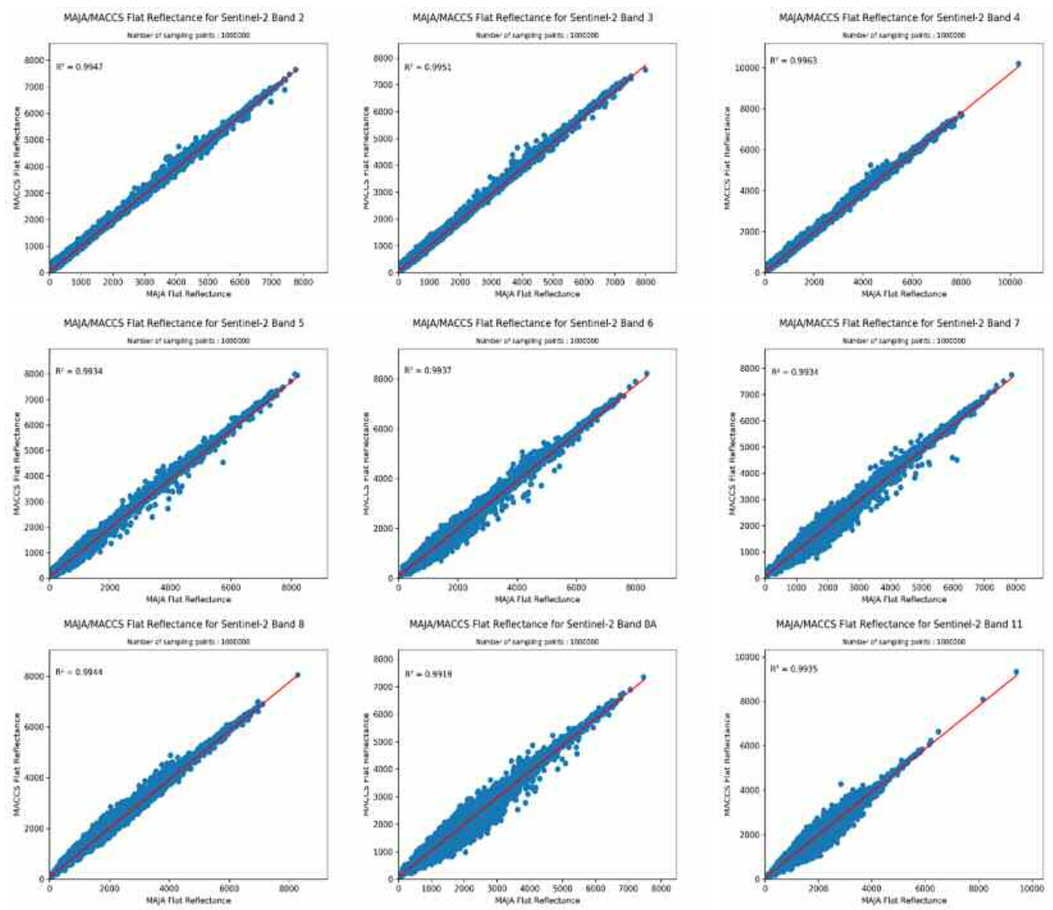


Figure 12: Scatterplots for each Sentinel-2 band comparing surface reflectance values from MAJA and MACCS.

In the African sites (Mali, South-Africa), MACCS algorithm was used for the S2 preprocessing. MAJA is an evolution of the MACCS which includes also ATCOR in a MACCS-ATCOR Joint Algorithm. The impact of this algorithm evolution on the surface reflectance has been assessed in detail for the different bands (Figure 12). Only slight differences can be observed between the surface reflectance values obtained from MACCS versus MAJA. The atmospheric correction of band 2 and 3 is very slightly reduced. The dispersion around the 1:1 line tends to increase with the wavelength till the band 12 (not shown here but very similar results than the band 11). These differences can be related to either an improvement of the haze detection and a better aerosol retrieval, or to an enhanced cloud and cloud shadow screening.

Cloud, Cloud Shadow and Snow Masking

A significant improvement of current methods for the classification/masking of clouds, cloud shadows and snow is required for enabling a fully automated generation of highly accurate masks in near-real time. Whereas current methods, such as implemented in the Sen2Cor (Louis et al., 2016b) or LEDAPS software (Home et al., 2013), classify each scene separately, improved methods such as MAJA exploit the additional information provided by time series. The Sen2Cor processor scene classification algorithm generates a classification map based on spectral threshold tests applied to the cirrus band and band ratios like NDVI and NDSI (Fletcher, 2012; Müller-Wilm et al., 2013). The MAJA processor uses the multi-temporal cloud detection (MTCD) method to detect clouds, cloud shadows and to estimate the optical properties of the atmosphere (Rouquié et al., 2017). The algorithm detects areas covered with clouds, cloud shadows, snow and water based on multi-temporal data sets and generates corresponding masks (Donadieu and L'Helguen, 2016). The so-called Fmask (Function of mask) approach uses Top of Atmosphere (TOA) reflectance and Brightness Temperature (BT) to detect clouds and cloud shadows (Zhu et al., 2015). The major input for cloud detection for Landsat data was a thermal band which does not exist for Sentinel-2. Nevertheless, the new cirrus band of Sentinel-2 has been found to be useful for cloud detection especially for thin cirrus clouds (Zhu et al., 2015). In the second issue of WP32, a visual comparison between MAJA, Fmask and SEN2COR Level-2 cloud masks and cloud shadows outputs is shown. In general, the service providers implement different cloud and cloud shadow masking workflows in their software environments, which include also post-processing steps to improve the masking results.

In the phase 1 for the African sites (Mali, South-Africa), MACCS algorithm was used for the S2 cloud and cloud shadow screening. The impact of this algorithm evolution on the reflectance screening performances has been assessed specifically. The results are visually illustrated at the Figure 13. Overall MAJA appears therefore much more conservative than MACCS which might not detect thin clouds and haze and their respective shadows. The improvement highlights the significant progress in cloud screening with regards to the previous algorithm like MACCS or Sen2Cor separately.

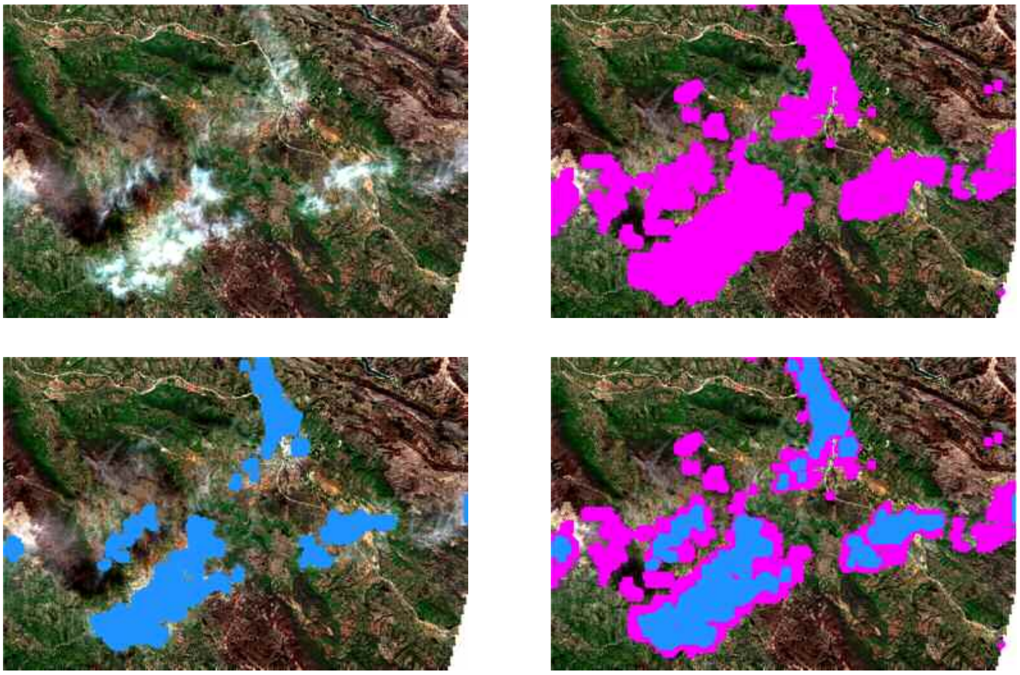


Figure 13: Cloud screening differences between MACCS (blue) and MAJA (magenta) in particular with regards to the cirrus detection much improved in MAJA.

Sentinel-2 image acquired on the 12-04-2017 over the 34TFN tile.

Topographic Normalisation

Semi-empirical topographic normalisation approaches are using Digital Elevation Models (DEMs) that provide terrain elevation, slope inclination, exposure and other information to describe surface geomorphology (Balthazar et al., 2012). In the benchmarking the topographic correction of the Sen2Cor processor is compared with the one of the Minnaert correction (each using the 90m SRTM). Corrections with elevation models of different spatial resolutions have been performed. The comparison shows that there is no significant difference between the Minnaert correction and the rugged terrain algorithm, both using the SRTM 90m elevation model. Nevertheless, the comparison between the Minnaert correction results based on the different elevation models implies that the resolution of the elevation model determines the quality of the topographic normalisation. In general, it is recommended that a topographic normalization should be applied in hilly to mountainous terrain, using the DEM with the highest spatial resolution.

In the analysis of the various DSMs (see the second issue of WP32 for further details) it has to be stated that the spatial resolution of the global freely available DSMs is limited to a best resolution of ~30m. A highly accurate DSM from LiDAR with 1m spatial resolution gives the most sufficient correction results. As a compromise, the Euromaps DSM with 5m spatial resolution offers an alternative to the rather expensive product of LiDAR DSM. In comparison with the LiDAR DSM only minor differences can be recognized, which occur only in extreme terrain locations, e.g. ridges or deep valleys.

Geometric Consistency

It is essential to analyse the overall data quality of the input data and the initial geometric shifts and radiometric differences between image data from the same sensor (e.g. from neighbouring orbits) and from different sensors if for example Sentinel-2, Sentinel-1 and Sentinel-3 data will be combined.

For the ECoLaSS prototyping it was suggested not to include a specific linear co-registration approach in the current ECoLaSS Sentinel-2 pre-processing chain because co-registration to a global reference image is applied by ESA operationally in near future; In fact, during the test phase used for algorithm development, the observed linear shifts are not so critical to require a co-registration procedure.

Noise Reduction and Gap Filling

The applicability of the harmonic regression method for gap filling and noise reduction has been investigated. The underlying assumption of the approach is that the temporal trajectory of a given spectral band over the course of the year can be captured by a model featuring a sum of trigonometric functions of different frequencies and a trend component. Therefore, the bottom-of-atmosphere (BOA) reflectance is modelled independently for each pixel as a continuous function of time. Consequently, synthetic images can be produced for any point in time in order to fill gaps in the time series. The concept of harmonic regression has been successfully applied by Verbesselt et al. (2012), Zhu et al. (2014), or Brooks et al. (2014).

The applicability of the harmonic regression method for gap filling in forest areas and different orders of the harmonic regression function have been benchmarked and implemented in the Central demosite. A harmonic model has been trained using Sentinel-2 images from 2016 and 2017. Synthetic images based on the model have been created for several target dates in 2018 and compared to actual imagery acquired at the same date. Results showed that the forecast quality is reduced in spring. Due to the deterministic nature of the regression model, shifts in the timing of the green-up can result in larger errors and higher-order models are even more affected: RMSE values are quite similar regardless of the model order and that there is no general tendency showing that higher-order models achieve a lower RMSE. The highest RMSE values occur during the vegetation green-up in April and May, where also the phenological dynamics are highest. Both the steep increase of NIR reflectance as well as shifts in the timing of the green-up are problematic and forecasts based on regression models can be subject to large errors. The other seasons beside spring are represented more accurately.

Generic Pre-processing chain applied on test sites and demonstration sites

The following granules (Table 14) were processed for the corresponding four European test sites and two African test sites and demonstration sites.

Table 14: Test sites and corresponding demonstration sites including Sentinel-2 granules

Test sites	Defined test-site granules	Partner responsible for pre-processing	Demo sites	Defined demonstration site granules	Partner responsible for pre-processing	Biogeographic regions
European						
Sweden	33VVF 33VWF	DLR	North	33VVH, 33VWH, 33VVG, 33VWG, 33VWF	DLR	Boreal
Austria/ Germany	32UNU 32TNT	GAF	Central	32UMV, 32UNV, 32UPV, 32UMU, 32UNU, 32UPU, 32TMT, 32TNT, 32TPT	GAF	Alpine/ Continental
Belgium	31UFR 31UFS 31UES 31UER	JR	West	31UFR, 31UFS, 31UES, 31UER, 31UFQ, 31UEQ	JR	Atlantic /Continental
France	30TYP 31TCJ	SIRS	South-West	30TYP, 30TYN, 31TCJ, 31TCH, 31TDJ, 31TDH	SIRS	Atlantic
Greece/Bulgaria	34TFM 35TFL	UCL	South-East	34TFN, 34TGN, 34TFM, 34TGM 35TKG, 34TFL, 34TGL, 34TKF	UCL	Mediterranean /Alpine/ Continental
African						
Mali	29PRP 29PTU	UCL	Mali	29PPQ, 29PNQ, 29PMP, 29PRM, 29PRP, 29PRQ, 29PPP, 29PLP, 29PMN, 30PUA, 29PRR, 30PTT, 29PPM, 29PQN, 30PTA, 30PTS, 29PNS, 30PTU, 30PUV, 29PMQ, 29PLQ, 29PMR, 30PTV, 29PQR, 29PLR, 29PQM, 30PVA, 29PPR, 29PMS, 30PUU, 29PNN, 29PQQ, 29PPN, 29PNR, 29PNP, 29PNM, 29PRN, 29PQP, 30PVV	UCL	semi-arid regions
South Africa	35JMJ 35JNJ	UCL	South Africa	34JBL, 33HYC, 34HDH, 34JCL, 34HFG, 34HFH, 33HYB, 34HFJ, 34HGJ, 33JYG, 34HBG, 34HBK, 34HGH, 33HYD, 34HDG, 34HCG, 34HDJ, 34HEG, 34HBJ, 34JBM, 34HBH, 34HDK, 34HEH, 34HCK, 33HYE, 35HKC, 33JYF, 34HCJ, 34HCH, 34JCM, 34HEJ	UCL	natural landscapes combined with subsistence agriculture

WORKFLOWS AND PRE-PROCESSING DATA VOLUME

Pre-processing of Sentinel – 2 time series:

To assess the required infrastructure, necessary to process high volume of optical Sentinel-2 data streams several Software packages can be used depending on the user needs. Which package should be used depends on location area, thematic application and the available software environment. Figure 14 gives a general overview of the pre-processing workflow including necessary and optional pre-processing steps regarding Sentinel-2 optical time series data. Further following optional pre-processing and post-processing steps were applied by the consortium partners depending on the test site and the demonstration site.

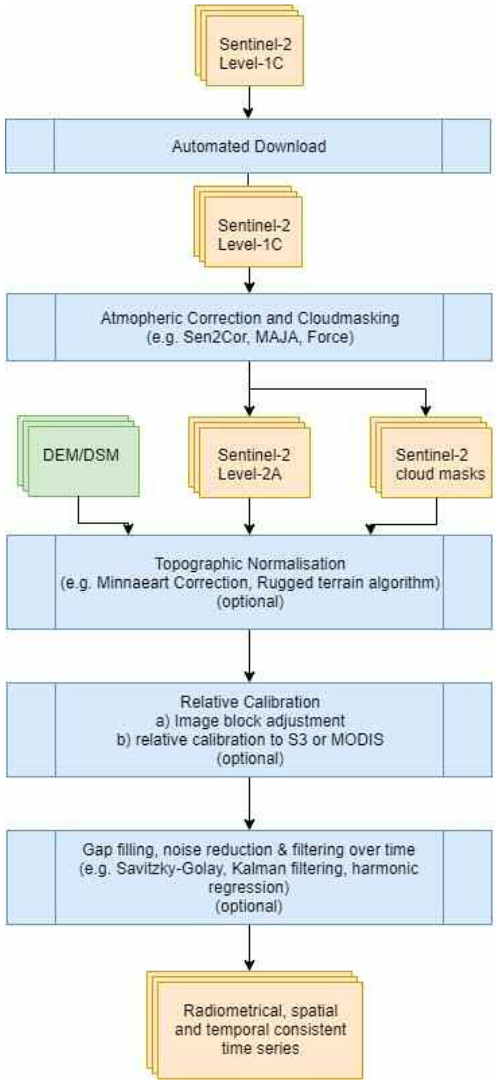


Figure 14: Generic pre-processing of optical time series – workflow.

Pre-processing of Sentinel-1 time series:

The pre-processing is based on Level-1 products in Interferometric Wide swath (IW) mode and Level-1 Ground Range Detected (GRD). This mode has been chosen because the IW is the main acquisition mode over land. An automated processing chain for Sentinel-1 data pre-processing has then been implemented by each partner using SNAP or the Remote Sensing Software Package Graz (RSG) module "Space Suite", which is an in-house development of the project partner JR. It comprises the following optional processing steps:

- automated SAR image download by defining the spatio-temporal extend
- automated preparation of digital elevation data (SRTM-V4)
- automated download and update of precise orbit files
- merge of GRD tiles from same orbit and same acquisition day
- clip of image extent according to the sites
- calculation of local incidence angle map
- radiometric calibration
- radiometric terrain corrections,

- image registration in image geometry
- multi-temporal speckle filtering
- calculation of temporal image stack statistics (see WP33)
- orthorectification to LAEA or UTM
- coherence calculation

Table 15: Sentinel-1 and -2 data amount and volumes for the demonstration sites in phase 1.

Demo sites	S1 no. images	S1 processed data volume	Time frame	S2 no. images	S2 processed data volume	Time frame
North	1092	166 GB*	01.01.2017 - 30.11.2017	577	671 GB	01.01.2017 - 30.11.2017
Central	243	2.24 TB	01.10.2016 – 14.11.2017	641	1.19TB	01.10.2016 – 14.11.2017
West	704	2.3 TB	01.01.2017 – 11.11 2017	410	1.4 TB	01.01.2017 – 15.11 2017
South-West	785	1.8 TB	01.01.2017 – 15.11.2017	320	523 GB	03.01.2017 – 14.11.2017
Mali	NA	NA	NA	1811	3.5 TB	01.04.2017 – 31.12.2017
South Africa	NA	NA	NA	56	123 GB	07.10.2016 – 22.04.2017
SUM	2824	6.5 TB	NA	3815	7.4 TB	NA

*The data has been compressed to LZW. Therefore, numbers are way lower than compared to other demonstration sites.

Table 16: Sentinel-1 and -2 data amount and volumes for the demonstration sites in phase 2.

Demo sites	S1 no. images	S1 processed data volume	Time frame	S2 no. images	S2 processed data volume	Time frame
North	498	484 GB (compressed)	01.01.2017 - 30.11.2018	908	1.9 TB (Compressed)	01.01.2018 – 11.11.2018
Central	291	1.9TB	01.01.2018 – 31.12.2018	1068	4.54 TB	01.01.2018 – 31.12.2018
West	733	2.5 TB	15.11.2017 – 15.11.2018	702	2.1 TB	15.11.2017 – 15.11.2018
South-West	665	2.6 TB	01.01.2018 - 15.11.2018	479	686 GB	01.01.2018 - 15.11.2018
South-East	1966 (*)	14.9 TB (*)	01.01.2017 – 31.12.2018	1681(*)	722.75 GB(*)	01.01.2017 – 31.12.2018
Mali	318 (*)	2.24 TB (*)	01.04.2018 – 31.12.2018	2905(*)	1.61 TB(*)	01.04.2018 – 31.12.2018
South Africa	266 (*)	1.93 TB (*)	01.04.2017 – 30.11.2017	2138(*)	1.07 TB(*)	01.04.2017 – 30.11.2017
SUM	**4737**	**26.56 TB**	NA	**9881**	**12.62 TB (*)**	NA

(*) can change after the finalization of the pre-processing.

For the Sentinel-1 radar data an overall number of 7561 scenes and a processed data volume of about 33 TB, have been processed covering the test and demonstration sites (in Task 3 and Task 4). For the Sentinel-2 optical data an overall data amount of 9881 scenes and a processed data volume of approx.12 TB, has been processed covering the test and demonstration sites (in Task 3 and Task 4), for details see Table 15 and Table 16).

Pre-processing of PROBA-V time series:

In order to replace the Sentinel-3 time series, PROBA-V 330 m time series of daily surface reflectance (S1) were acquired. This dataset corresponds to the collection 1 version of all PROBA-V S1 images acquired from the 1st January 2018 to the 31st December 2018. The collection 1 dataset provided an enhanced cloud screening for the 1 km and the 330 m time series but not appropriate for the 100 m dataset. The full 2018 330 m time series of S1 images have been composited into 52 weekly composites using the mean compositing algorithm (Vancutsem et al., 2007) averaging all the valid cloud free pixel values recorded during a given week. This algorithm was benchmarked again in the phase 1 of ECoLaSS.

SUMMARY

Regarding the pre-processing of Sentinel-2 optical data streams the main software packages have been compared (MAJA, Sen2Cor, MACCS and FORCE). In general, all software packages have advantages and drawbacks.

Concerning Sentinel-1 data sets a conversion of db to DN is recommended. The conversion from db to DN reduces the file size by 50% and facilitates multi-temporal metric calculation from SAR image stacks. The DN based land cover classification results are slightly more accurate than db based classification results. Using flattened gamma nought SAR backscatter data is recommended if data from different orbits is combined, and to eliminate areas with large incidence angles above 70°. For ECoLaSS pre-processing, our analysis concludes that multi-temporal SAR filters should be applied to pre-processed gamma nought data in DN processing unit. Seasonal means and seasonal statistics further reduce speckle noise and should be used as input regarding SAR data classification of the HRL land cover classes. Which seasonal statistics provide reliable features for classification depends on the thematic application and is therefore assessed in detail in WP 33. If the benefits are only small, it is recommend not going through the additional effort of processing SLC data and InSAR coherence.

For further details, please refer to the second issue of the deliverable of WP 32 [AD13], *"D7.1_D32.1a-MethodsCompendiumTimeSeriesPreparationReport_Issue 12_M14M28.pdf"*.

2.4.6 Time Series Analyses for Thematic Classification (WP 33)

WP 33 is on "Time Series Analyses for Thematic Classification" and builds up on pre-processed data from WP 32 and methods for integrating Sentinel-1 and -2 data from WP 31:

Table 17: WP 33 – Time Series Analyses for Thematic Classification

Work Package Number	**8**	**Lead Beneficiary**		**UCL**	
Work Package Title	**WP 33 – Time Series Analyses for Thematic Classification**				
Short Name of Participant (Participant Number)		**GAF (1)**	**SIRS (2)**	**JR (3)**	**UCL (4)**	**DLR (5)**
Person/Months per Participant		**4.70**	**2.90**	**4.83**	**5.00**	**4.95**
Phase 1	**Start Month**	**4**	**End Month**	**14**		
Phase 2	**Start Month**	**19**	**End Month**	**27**		
Objectives: **To develop a framework for times series analysis for thematic classification based on Sentinel multi-sensor constellation.**						

This WP aims at developing a framework for times series analysis for thematic classification based on Sentinel multi-sensor constellation. Build on the availability of calibrated and atmospherically corrected surface reflectance or backscattering coefficient time series (provided by WP32) it aims to support the development of various prototypes products: HRLs (Imperviousness, Forest layers), Grassland, Crop type, and new LC/LU products.

A general common workflow has been adopted by all the partners for each thematic application. The main activities consist in (1) identifying the best strategy for time series production based on optical S2 imagery; (2) identifying indicator based on backscattering and coherence S1 images; (3) testing different automated reference sampling approaches; (4) developing temporal metrics; (5) analysing the best curve fitting and filtering method from multi-annual optical and SAR series for land surface phenology; (6) studying the methods for phenological metrics estimation; (7) studying the S1/S2 fusion possibility at biophysical variable level, (8) investigating different algorithm for time series classification; and then (9) validating the classification.

FOREST

According to the outcomes of WP 33, the Random Forest (RF) classifier has been selected as the best rated classification algorithm in terms of processing time and achieved accuracy. Spatio-temporal input features that capture important time series properties and patterns are used. An automated reference sampling approach has been applied to derive the necessary sample basis for the classifier. The use of Sentinel-2 data from the spring period was expected to provide the best ratio of high classification accuracy and lowest processing cost according to the tests carried out in WP 33. First, a 10m Tree Cover Mask (TCM) is calculated from time series features derived from Sentinel-2. This mask is subsequently intersected with a seamless and independently derived leaf type layer to create the improved DLT status layer.

After some sobering results of the phase 1 TCM classifications in the demonstration site North due to an insufficient data situation within the selected spring period, the utilization of Sentinel-1 SAR data has been reconsidered in phase 2 to improve the tree cover detection. The integration of SAR data for TCM generation has reduced the number of commission errors significantly. This is especially the case for agricultural areas (hops, vineyards, maize fields), moors and wetlands. In this context, SAR data contributes to a reliable tree cover detection, which is mandatory for a reliable map-to-map change approach of the Incremental Update Layer 2017-2018. With respect to the DLT classification, the influence of SAR time features within a combined S-1/S-2 approach plays a minor role only. In general, the integration of SAR data in the classification process show high processing costs in terms of processing time and storage costs. Consequently, a well-balanced usage of SAR data for status layer generation is recommended for an operational service on continental or global scale. This can be addressed by an elaborated stratification approach of the production area.

New time features derived from Sentinel-1 SAR data and from the Sentinel-2 spectral bands (B02 to B12) have been calculated and analysed towards their importance in the Random Forest classifications of both, the TCM and the DLT. In total, 234 features (compared to 160 features in phase 1) were available to feed the machine learning algorithm: 182 features for the Sentinel-2 indices and bands, and 52 features from the Sentinel-1 single bands and indices. SAR time features derived from the VH polarisation (e.g. VH_p025, VH_p010) turned out to have a high importance in the tree cover detection followed by features derived from the Sentinel-2 bands B02 and B03 as well as NDVI and NDWI features. With respect to the DLT classification, SAR features show no benefit for the leaf type discrimination. Here, band-specific features from Sentinel-2 dominate clearly over all other derived features. Worth mentioning is the dominance of features derived from the SWIR band (B11). Figure 15 presents the top 20 ranking of the time feature importance for the TCM and DLT classifications of the Central test site for the reference year 2018.

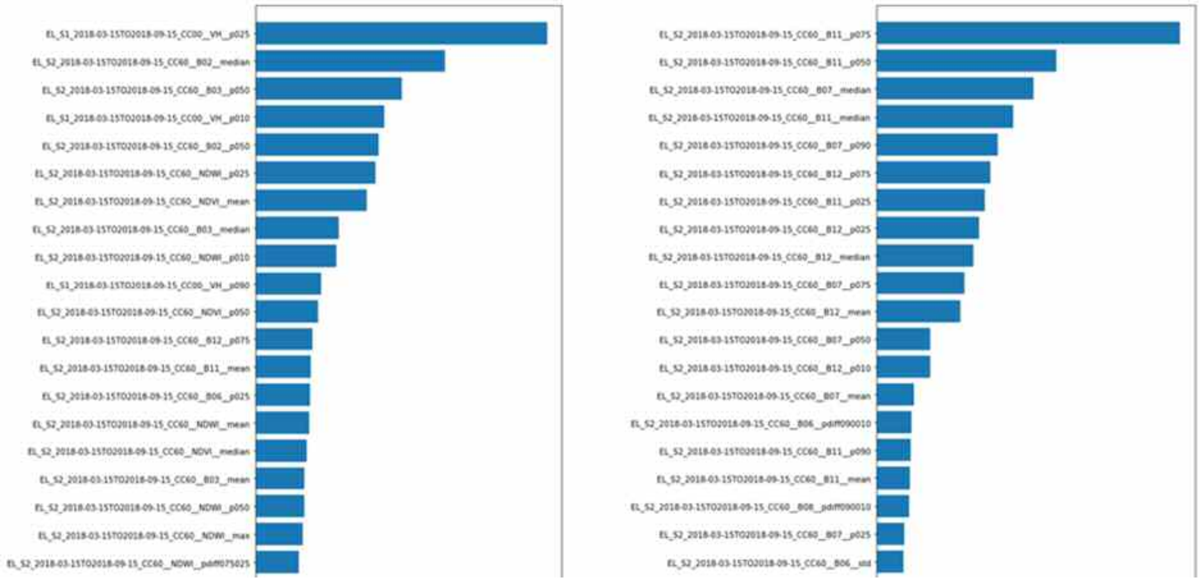


Figure 15: Top 20 time feature ranking for combined S1/S2 TCM 2018 (left) and the DLT 2018 classification (right)

In parallel to the new feature calculation and analysis, two different feature selection methods have been tested. The first one is based on the statistical analysis of variance of the features and the target class to be classified. The process comprises the comparison of the mean values in every feature for the land cover class “forest” vs other land cover classes (urban, water, grassland, and cropland), using an Analysis of Variance and a post-hoc analysis (Tukey test). The features selected under this feature selection scheme are those with a significant statistical difference between forest and other land cover classes. In the case of the Dominant Leaf Type the statistical analysis was made on the mean values of two classes (broadleaved and coniferous), using a Student’s t-test.

The second feature selection method is the K-Fold Cross Validation. This is based on a stratified k fold sampling integrated in the machine learning package. This sampling method splits the training and test dataset into a number of k-folds. It clones the classifier by every iteration and produces accuracy figures and a new training and test set. The algorithm finally yields a combination of the features with the highest accuracy. This subset of features is used for the classification process.

In terms of processing costs (processing time), the variance analysis seems to be superior to the K-Fold feature selection, as it provides similar model accuracy figures by using significantly less features. A significant influence of the feature selection method on the overall accuracy figures (retrieved by LUCAS 2018 points) could not be observed.

Next to the spring period (15th March to 15th June), which has been rated as the observation period providing the best ratio of classification accuracy and lowest processing cost in phase 1 of ECoLaSS, an extension of the time window ranging from 15th March to 15th September has been tested. Increasing the time window is drastically increasing the data volume and processing time (and logically also the production costs) but has a positive effect on the achieved overall accuracy figures (retrieved by LUCAS 2018 points) of the TCM, which is in the magnitude of 2 to 4 percentage points. This is mainly due to the increased data availability and a potentially higher rate of data acquisitions without or with less cloud cover. From this perspective, and due to the ever-growing requirements and expectations on user side, an extended time window for classification seems to be a good compromise. However, the strongest influence on classification accuracies can be observed by the quality of the samples. In ECoLaSS, a multi-stage sampling approach has been applied: automatic reference sampling (separately for TCM and DLT) based on a sample layer generated from the HRLs 2015, outlier detection with visual validation of the samples and split of the sample dataset into training and validation dataset, initial classification and re-sampling based on omission and commission errors and subsequent iteration loops. A subsequently performed validation with 800 LUCAS 2018 points confirmed very high overall accuracies for both, the TCM as well as the DLT classification.

In addition to the aspects listed above, phase two has also concentrated on the generation of a continuous-scale (0-100%) Tree Cover Density (TCD) product at 10m spatial resolution using optical Sentinel-2 data. The pixel-based TCD product provides information on the proportional crown coverage per pixel in percent, whereas tree cover density is defined as the „vertical projection of tree crowns to a horizontal earth's surface". Two different approaches have been used to generate the status layer Tree Cover Density 2018 using a linear regression estimator: a mono-temporal classification using a "best-of" scene approach and a multi-temporal classification using band-specific time features for defined time windows.

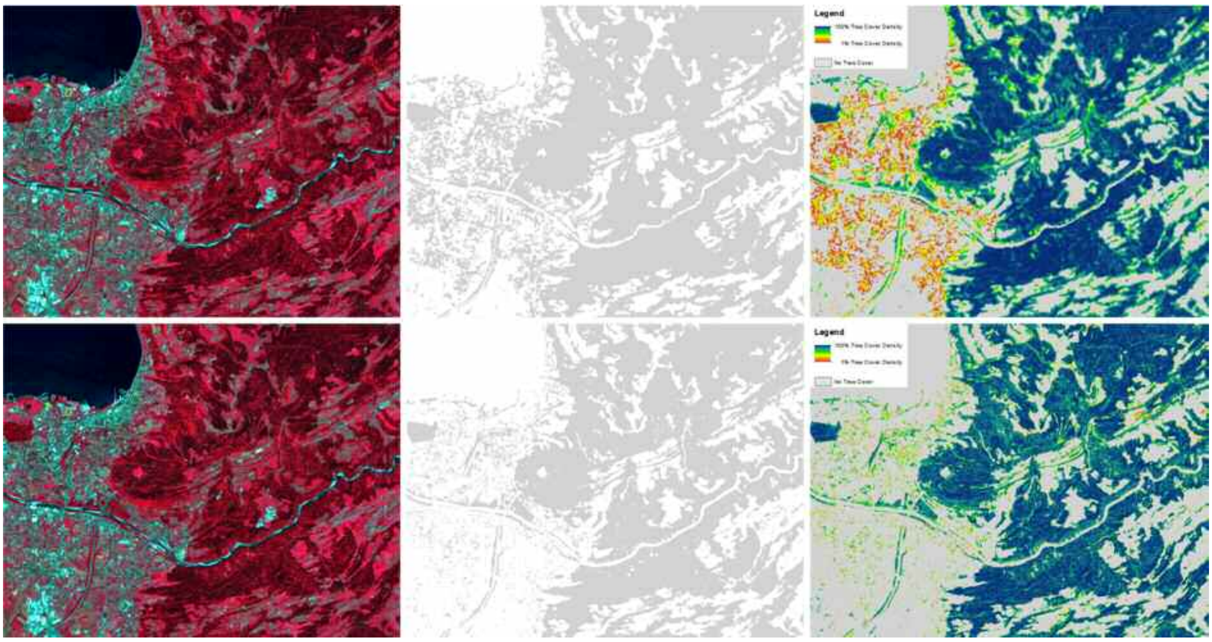


Figure 16: Comparison: TCM&TCD 2015 products with the improved TCM&TCD 2018 status layer.

TCM&TCD 2015 (above) and TCM&TCD 2018 (below) in 10m spatial resolution. *Produced using modified Copernicus Sentinel data [2016/2018].*

Band-specific spatio-temporal features (each 10m & 20m band) have been tested for a multi-temporal TCD classification. Whereas most of the features show no suitability for the classification, results of the mean and median features provide promising results. Classification results have been compared with results derived from the Copernicus Sentinel-2 Global Mosaic (S2GM - https://land.copernicus.eu/imagery-in-situ/global-image-mosaics/) and a mono-temporal "best-of" scene acquired in summer 2017.

The following observations have been made in the evaluation process of the feature-based TCD:

- Length of the selected time window for feature computation is crucially to avoid cloud gaps
- Inadequate cloudmasks lead to artefacts in the TCD classification
- Overcorrections in the topographic normalization (performed by Sen2Cor) lead to significantly lower TCD values than may be realistically the case
- High agreement with results obtained from the mono-temporal Sentinel-2 scene
- Much less artefacts compared to the classification derived from the S2GM

Main issues are referred to the topographic normalization of the input satellite data and the quality of the derived cloudmasks. Some further research and improvements are necessary to compensate these effects in the multitemporal TCD classification.

IMPERVIOUSNESS

Regarding the thematic field of Imperviousness, the performed analysis in phase 1 shows better results for the following set of parameters:

- a mono-temporal approach, image-by-image;
- the use of an active learning or SVM classifier;
- the input being all data available (or subset based on the best available cloud-free images) with both sensors Sentinel-1 and Sentinel-2.

The results (Figure 17) are not fully compliant with the actual specifications (both 90% user and producer accuracies), although nearly meet the threshold. It should be noticed that very few post-processing (mostly manual enhancement) has been applied and the results can be easily increased. The active learning algorithm shows great classification performances whilst being very computational efficient, thus substantially reducing processing time overall and dealing with large dataset. The Support Vector Machines (SVM) classifier shows interesting results as an alternative method.

The approach based on both sensors Sentinel-1 and Sentinel-2 shows the interest to use data fusion. The mono-source approach, based on one HR sensor, Sentienl-1/2, doesn't seem in fact sufficient. The optical time series, in particular, is not dense enough to take advantage of the phenology of inter-yearly and intra-yearly seasonal dynamics. Further investigation is currently ongoing to better integrate the S-1 datasets over the test sites and enhance the results of the classification based on those SAR images. Several statistics over the year as well as at a monthly frequency are being tested and at the same time, will be expanded over the demonstration sites, since results from phase 1 highlighted a discrepancy between the test site scale, at which the SAR classification slightly improved the optical classification, and the demonstration site scale, where results from S-2 classification overperformed.

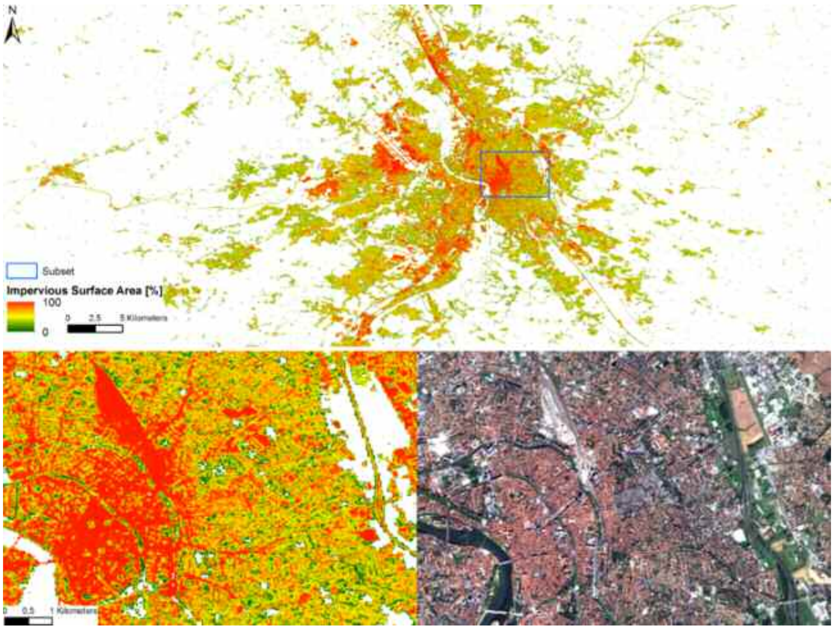


Figure 17: Subset of Imperviousness Layer compared with Sentinel-2 imagery.

GRASSLAND

For the thematic field of Grassland, the aggregated classification result with SAR and optical combined datasets are quite encouraging. After the visual interpretation of all classifications, it can be observed that using optical data only more confusion between grasslands and cropland are present, whereas using SAR data only more misclassifications between grassland and roads are present. The combined approach shows more homogenous patches than using SAR data only (see Figure 18 and Figure 19).

Figure 18: Aggregated (MMU 0.09ha) SAR + optical grassland classification with random forest and selected features for 2016. (grassland in green)

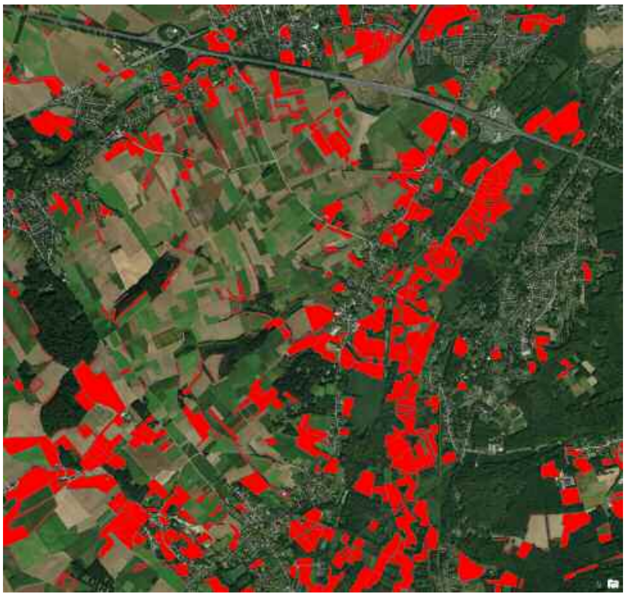


Figure 19: LGP grassland areas (2016) over Basemap VHR data.

Based on the applied tests and the experience of consortium partners from other projects, we recommend to apply the supervised random forest based approach within the demonstration sites in Task 4. A main requirement however is the precise pre-processing of the dense time series including a topographic normalisation for hilly to mountainous terrain. For SAR time-series the application of multi-temporal filtering on gamma naught corrected imagery is recommended (see [AD13]).

In the test areas in Central, it has been noted that the addition of S-1 results in a much higher accuracy, diminishing confusion with other classes suchlike plantations, that otherwise cannot be excluded when using only S-2. This is relevant as in fact the overall accuracy values obtained are misleading while the visual inspection demonstrates the combined approach performs best (Figure 20).

Figure 20: Comparison of S-2 only approach with combined S-1&S-2 approach in grassland mask

In this figure, on the centre a DigitalGlobe image shows the actual land cover. On the left, grassland mask resulting from applying only S-2 features and on the right, the combined approach using S-1+S-2 features showing better distinction between tree covers and grasslands. In addition, the contribution of coherence to grassland use intensity is being tested in several AOI in Central and West, as this a very particular application that needs to be approached in locally controlled areas for parameter tuning.

In phase 2, further, the discrimination between extensively and intensively used grassland with SAR and optical time series features is investigated. Training samples are generated based on the LUCAS samples through an outlier detection and an independent visual interpretation with Sentinel-2 time series data and additional VHR data if available. The use of temporal trajectories, seasonal statistical features and phenological features is investigated regarding the intensity to achieve the optimal set of features/indices per biographic region/elevation stratum.

AGRICULTURE

The time interval algorithms are strongly affected by undetected clouds/cloud shadows as well as confusion with bright surfaces in the cloud mask. These algorithms present many artefacts and data gaps due to the short compositing period and the interval between images available in the time series. In phase 1, it was demonstrated that feature-based algorithms are more appropriate as they achieve more spatial consistency and very few data gaps thanks to the use of the entire time series as input. To avoid potential artefacts derived from the presence of unmasked cloud cover pixels, time periods were selected to guarantee a sufficient number of imagery to minimize the distortion that extreme values would pose to the statistics.

Concerning Agriculture classification an initial set of criteria to evaluate the best compositing method for crop recognition (cropland-CL, crop type-CT) and crop growth monitoring (CG) have been selected. The benchmark is performed on Central (Germany) and Belgium site and show promising accuracies and high potential of time series and derived time features for crop mask extraction and crop type monitoring. In Central tests, LUCAS data from 2018 constitute the main part of the sample base and additional samples for forest, grassland, water and urban areas have been taken from HRL2015. The availability and representation of crop and specifically crop types samples is essential for the model training and significantly impacts the performance and quality. Preliminary results from the tests in Central point out to the fact that the added value of using S-1 data is dependent on density of optical time series: e.g., due to the positive data situation on the test tiles in 2018 – high number of optical and cloud free imagery – the additional benefit of using S1 is low in test areas. This fact is also represented in the accuracy figures for the experiments with S-1 and S-2 only.

The Crop Type Mask was calculated basing on LPIS data from Baden Württemberg and InVeKoS data from Austria (referring to the tiles 32TNT and 32UNU). A newly arranged Crop Type class aggregation which is suitable to be used in a Pan-European context and at the same time adaptable to regional conditions to a certain extend has been used for the classification approach. The Crop Type Legend is oriented towards the LUCAS class structure (aiming at the potential of LUCAS data being a source of information available in most EEA countries). It comprises the most common crop types for the crop groups of winter and summer cereals, vegetables, dry pulses and legumes, industrial crops, root/tuber crops, fodder crops and permanent crops (seeTable 18).

Table 18: Class aggregation for Crop Types test in the Central site for phase 2

Structure: the left column of crop group refers to the similar crop structure of LUCAS; the next column of crop classes is a sub-structure to the crop groups, and might be used as a quite generic structure, suitable for a Pan-European context; the column on the right reflects the class structure used for the Crop Type Classification in ECoLaSS. This class structure is a quite generic in view of a homogeneous pan-European crop type map production, while at the same time reflects the regional situation on the test site.

Land cover mask	Crop Group		Crop classes		class	ECoLaSS Crop classes classification for CTM classname	code
Crop mask	1	Cereals	11	Winter cereals	1	winter wheat	111
					2	winter barley	112
					3	winter rye	113
					4	winter oats	114
			12	Spring/summer cereals	5	summer wheat	121
					6	summer barley	122
					7	summer rye	123
					8	summer oats	124
			13	Maize	9	Maize	131
			14	Rice	999		
	2	Vegetables, dry pulses,	21	Vegetables	10	vegetables	211
			22	dry pulses/legumes	11	peas and beans	212
					12	lentils	213
					13	legumes	214
	4	Industrial crops	41	Soybeans	14	soya beans	411
			42	Sunflower	15	sunflowers	421
			43	Rapeseed	16	rape seed	431
			44	Other oleaginous, fibre, biofuel, and	17	oleaginous+fibre crops	441
	5	Root/ tuber crops	51	Potatoes	18	potatoes	511
			52	beet crops	19	beet crops	521
	6	Fodder crops	61	Temporary grasslands (<5 y.) +	20	temorary grassland	611
	7	Permanent crops	71	Grape vines	21	wine growing	711
			72	Olives groves	999		
			73	Other permanent crops	22	fruit trees/orchards	731
						shrub fruits	731

A first run combining S-1 and S-2 data (using the same technical workflow as for the Crop Mask) provides an OA of 86% and a F1Score of 0.86. The detection and differentiation of the different classes gives promising results. However, there is room for improvement by using a stratification approach for the demosite to take into account the shifted vegetation period of the alpine region in comparison to the area in the North of the demosite. This is applicable only on the demosite as it is related to a better fit to differentiated local conditions that are not significant in the test area. This is one example where the across-scale approaches might differ, and that are being tackled in parallel in phase 2 between Task 3 and Task 4 subactivities. With the provision of the LPIS data of Bavaria and the larger region, the number of samples will be high enough to work with this approach.

The next figure (Figure 21) shows the Crop Type Mask 2018 for a region in southern Baden-Wurttemberg, displaying the crop types for the 2018 data. In both layers, there are overlaps of the grassland layer and the class agrarian/fodder grass of the Crop Layer which is inevitable for a layer based on a one year period.

Without a dense time series covering historical data, natural and permanent grassland cannot be distinguished from agrarian grassland and temporary grassland being ploughed regularly.

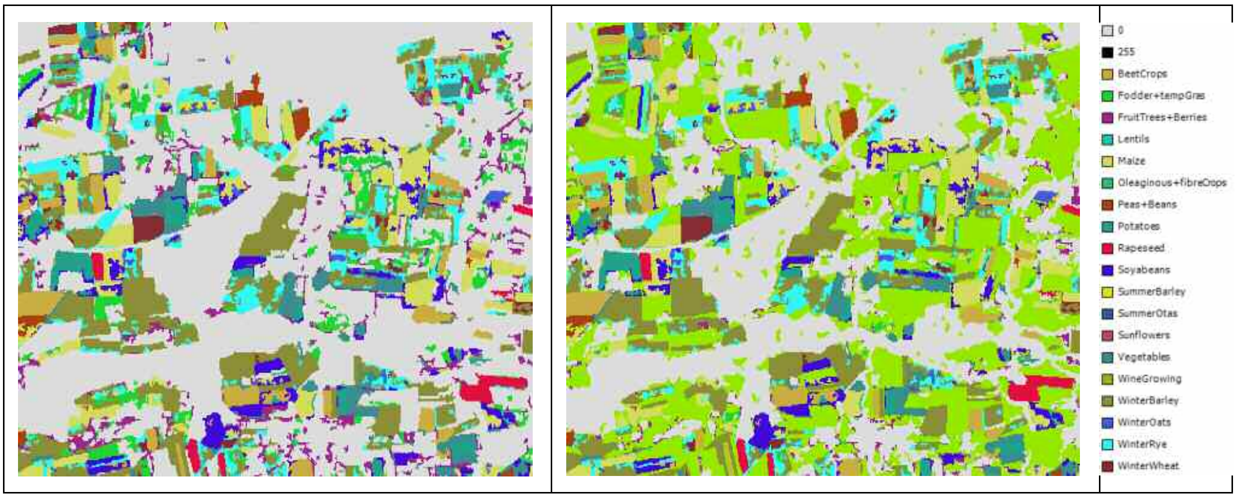


Figure 21: Crop Type Mask of the year 2018 (tile 32TNT).

South Baden-Wurttemberg, crop types/non-cropland on the left and various crop types/non-cropland as well as the grassland layer 2018 on the right.

More testing should be done when it comes to the differentiation of similar crop types, as well as regional diversity for implementation of future agricultural HRL.

NEW LAND COVER PRODUCTS

Concerning the new land cover products, the same methodology is used in phase 2, only several other algorithms are being tested over the South-West and Central test sites. The time series has been densified thanks to the use of both S-2A and S-2B datasets for 2018. Regarding the sampling method, only LUCAS points and pan-European databases such as HRLs 2015 or CLC 2018 have been used – no sample has been drawn from the LPIS datasets, whose only 2016 and 2017 years are available at the moment.

Several issues are currently being addressed such as:

- The selection of a strong and robust segmentation algorithm has been anticipated as a major difficulty and a comprise is being sought to create a multi-scale segmentation that would not be time and resource-consuming
- The refinement of the sampling datasets used to better represent the various classes of the latest version of the CLC+ nomenclature.
- The fusion algorithms to merge the softbone, the hardbone and the raster classification need to be explored in more details.

Further details are described in the first issue of the deliverable of WP 33 [AD14], *“D8.1_D33.1a-MethodsCompendium_TimeSeriesAnalysisForClassification_Issue1_M14.pdf”*.

2.4.7 Time Series Analyses for Change Detection (WP 34)

WP34 on "Time Series Analyses for Change Detection" is closely connected to WP 33 "Time Series Analyses for Thematic Classification" and WP 35 "Time Series Consistency for HRL Product (incremental) Updates":

Table 19: WP 34 – Time Series Analyses for Change Detection

Work Package Number	9	**Lead Beneficiary**		JR		
Work Package Title	WP 34 – Time Series Analyses for Change Detection					
Short Name of Participant (Participant Number)		GAF (1)	SIRS (2)	**JR (3)**	UCL (4)	DLR (5)
Person/Months per Participant		3.90	2.90	**5.60**	3.00	4.95
Phase 1	**Start Month**	4	**End Month**	14		
Phase 2	**Start Month**	19	**End Month**	27		
Objectives: To explore and set up a methodological approach for automated change detection based on optical and SAR Sentinel time series to be used as input for the local, pan-European and Global Components of the Land Monitoring Service.						

This work package aims to explore and set up a methodological approach for automated change detection based on optical and SAR Sentinel time series to be used for updating of potential future Copernicus Land Monitoring layers such as Imperviousness, Forest or Grassland and potentially, also Agriculture.

A comprehensive state of the art review has been performed for signal anomaly detection in time series based on optical & SAR data, and change detection by fusing signal anomaly detection. Special emphasis was drawn on signal anomaly detection for dense time series for both, optical and SAR data. One major challenge can be seen in data gaps due to high frequency cloud cover and low sun incidence angles in northern regions of Europe or mountainous terrain. Therefore, change detection methods based on SAR, combination of SAR / optical and on the combination of different optical sensors are addressed by the consortium.

CHANGE MONITORING METHODS

Estimating LC/LU-changes from remotely sensed data is a very challenging task, since the reflection behaviour of time series is not only influenced by seasonal, gradual or abrupt changes of land cover, but also from noise that originates from geometric errors, atmospheric scattering, radiometric and topographic effects as well as from cloud effects. The main requirement for setting up state-of-the-art change detection processing chains is the usage of optical as well as SAR time series to allow for a homogeneous full coverage change monitoring. The focus, therefore, is put on fully automated change detection approaches, which are based on dense time series of Sentinel-2 and/or dense time series of Sentinel-1. On a medium to high resolution scale the currently used remote sensing based methods can be generally divided into two categories: a bi-temporal (image-to-image change detection) and a multi-temporal approach (time-series analysis) (Hirschmugl et al., 2017). For image-to-image change detection three different approaches do exist. The first approach is comparing the classification result of each classified image (post-classification comparison), the second approach, the so-called "multi-temporal image stack approach" is putting the images and their spectral bands/indices into a classification algorithm (Hirschmugl et al., 2017; Banskota et al., 2014; Olsson, 2016) and the third approach detect changes solely on the spectral behaviour of the earth s surface (regression based methods or change vector analyses). Regarding time-series based change detection methods the following approaches can be named: threshold based change detection, curve fitting, trajectory fitting including temporal segmentation, and Kalman filtering (Banskota et al., 2014; Hirschmugl et al., 2017).

In the following sections different change detection methods appropriate for the land use / cover categories "Forest", "Imperviousness" and "Grassland" developed and tested in WP 34 will be presented.

A differentiated consideration of the three thematic fields is necessary as their spectral-temporal characteristics and change patterns are fundamentally different in time as well as in space.

FOREST CHANGE/LOSS

In phase 1, examples of delineation of the negative forest change (forest into non-forest) are shown, based on the comparison of forest masks derived from different periods images (pre- and post-change mask). The methodology can incorporate both Sentinel-1 and Sentinel-2 data without significant adjustments.

The detected forest change patches derived from all three input data scenarios (Sentinel-1, Sentinel-2 and combined Sentinel-1/Sentinel-2 data) reveal similar forest-loss areas and show high validation accuracies. The combined usage of Sentinel-1/Sentinel-2 delivers the best detection result, but naturally has the highest processing cost, while the Sentinel-2 scenario gives slightly worse results with about half the cost. The Sentinel-1 scenario leads to overestimation of detected change patches resulting in lower user's accuracy, but overall, can still deliver a useable forest change mask. This is especially important considering the limited availability of optical imagery in areas of frequent cloud cover.

As pointed out in phase 1, whereas the methodology enables the delineation of a forest loss layer independent from the type of sensor, the success of the approach is very reliant on the quality of the reference forest mask, and is not able to determine the exact date of the change due to the use of single features calculated over a longer time period. The combination of the approach with methods that focus on feature dynamics of forest change events within the respective time period may be considered, which is as such not yet part of Copernicus Land products, but is a recommended issue for future investigations.

Another approach that was tested in phase 2 is based on Kalman filtering of time series. Kalman filtering denotes a parameter estimation technique which yields optimal estimates in a statistical sense. In order to apply the Kalman filter, time series models in state space form are required (Harvey 1990). For a time series, the state variables usually represent the series' additive decomposition into trend, seasonal, and long-term cyclical components. The filter can handle uneven temporal intervals between measurements if the underlying model is formulated in continuous time. For example, the seasonal phenology cycle typically encountered in forest can be modelled using trigonometric functions. The ability to make model-based forecasts including confidence intervals is an inherent part of the technique. Thus, the filter predictions can be used to identify abrupt structural change in a time series.

Significant reflectance anomalies can be detected in the Kalman filtering approach, however, no classification of the type of the disturbance is undertaken. In addition to the disturbance indication also the temporal dynamic is captured with the approach. Next figure gives an example from the region Beinheim (coordinates 8°5'51"E 48°50'29"N, Figure 22).

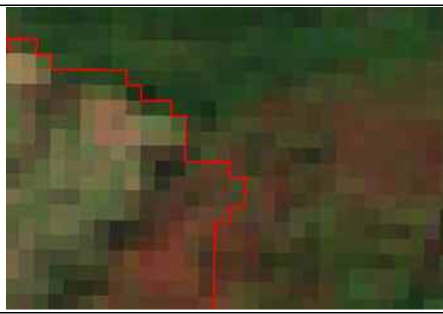
	
Google Earth 2016-08-25	Google Earth 2016-08-25
	
Google Earth 2018-09-17	Google Earth 2018-09-17
	
S-2 2017-10-31	S-2 2017-10-31
	
S-2 2018-09-17	S-2 2018-09-17

Figure 22: Example of disturbance detection with the Kalman filtering approach.

Cloudy areas that remain in the data lead to spectral reflectance anomalies in the time series. To distinguish these anomalies from forest disturbances, the near real time tool confirms detected signature anomalies with a second consecutive observation, before a disturbance is identified. This leads to a temporal time lag depending on the frequency of observations. Please note, that for the annual disturbance maps, more observations are available which lead to a higher accuracy in the identification of disturbances compared to the near real time approach.

Further research will be done to validate the transferability of the methodology to areas of different geographic conditions and seasonal patterns. Besides that, the influence of noise such as speckle effects in SAR data will be further investigated. For example, the integration of SAR coherence could further improve the change detection accuracy.

IMPERVIOUSNESS CHANGE

In the case of the imperviousness change studies a post classification comparison approach based on Sentinel-2 cloud-free images has been developed and validated, and was implemented in the France test site. In the context of the updating of urban areas where classified regions in the first image are already available, the comparison with a new classification of the new image appears more rational than directly classify changes from a pair of images.

The post classification comparison implies post-processing of the layers to attain spatial and temporal consistency based on the reference data. The purpose is to ensure the consistency and comparability between the different dates. Therefore, a post-processing filtering is applied to reduce noise due to single pixels or isolated pixels (small aggregated group of pixels), which are most likely misclassifications in one of the time stamps. Moreover, a contextual analysis based on change probability is applied to take into account the built-up pixels in the 2015 built-up mask in order to establish a probability map of changes. The analysis describes each cell's relationship or membership to a source, or a set of sources based on probabilities. Finally, the contextual analysis results in urban membership estimates, which allow isolating change areas, leading to the change layer, visible in Figure 23. A reference calibration dataset that will be used to determine the relative proportion of actual change versus all the error components is developed. Therefore, stratification is applied to the change areas to assess the new built-up areas for the year 2017 and the omission errors from 2015 (the undetected built-up pixels of 2015) as well as the commission errors from 2017 (the pixels falsely flagged as built-up in 2017). The results obtained from the reference calibration dataset show that 9% of new built-up in the year 2017 have been detected as such, whereas 58% are omission errors in 2015 (therefore undetected built-up in 2015), and 33% are commission errors in 2017 (therefore false built-up in 2017).

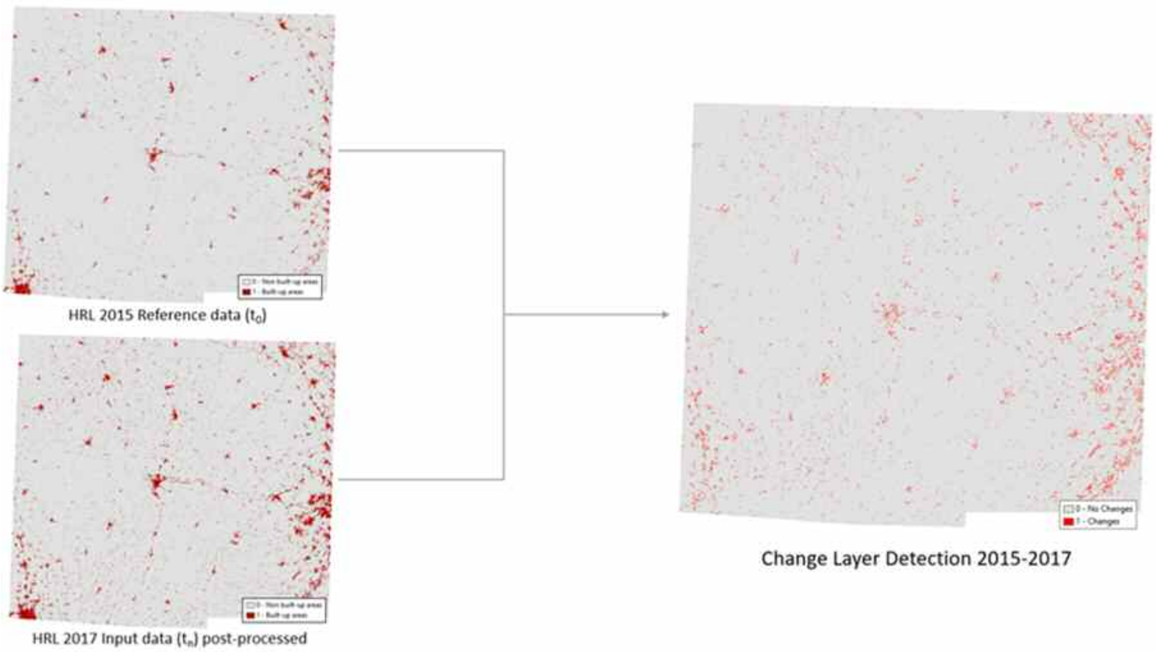


Figure 23: Final change layer for the temporal lapse 2015-2017

The results show that the magnitude of real change is around 10% of the change areas detected. The re-processing of the reference layer – the Imperviousness layer of 2015 – and the new status layer for 2017 needs to be done to ensure that there are no spatial inconsistencies between the layers of the different epochs. There is still a need to ensure the temporal consistency and comparability between the different time intervals. The Impervious areas typically represent less than 5% of the total area and even though the level of omission and commission are still below the set threshold of 10%. The area represented in those 10% errors in the delineation of the built-up mask can still be greater than the actual area of change between the two periods. Although some errors are present in the reference layer, new errors can also appear in the detection of change between two time periods. The change layers' errors can be due, as mentioned before, to the following factors: omission of change, commission errors added for the new period and omission errors detected for the previous period.

The mono-source approach, based on Sentinel-2, doesn't seem sufficient. Indeed, the times series is not dense enough to take advantage of the phenology of inter-yearly and of the intra-yearly seasonal dynamics. The results from the Sentinel-1 based built-up and non-built-up mask is not as good as Sentinel-2 and is therefore not included in the change detection benchmarking. Investigations are currently made to improve the Sentinel-1 based built-up and non-built-up mask results. Further investigation will be explored, including a multi-sensors approach, with the input data from Sentinel-1.

GRASSLAND CHANGE

Testing related to grassland monitoring was applied within the Belgian test site, for which Land Parcel Identification System (LPIS) as well as LUCAS reference data is available. The analysis focused on derivation of temporal metrics from annual dense time-series for two reference years (Figure 24 and Figure 27), which are available from the Copernicus S-1 and S-2 satellites. The multi-temporal features were used to derive grassland probability status maps for both reference years using the random forest algorithm, to further derive the change probability map (Figure 24). The probabilities are combined resulting in a probability difference map which differentiates between grassland increase and decrease. To derive potential changes thresholds (Figure 25) can be applied on the probability difference map derived through iterative accuracy evaluation. Therefore, a reference data set is created to evaluate the changes.

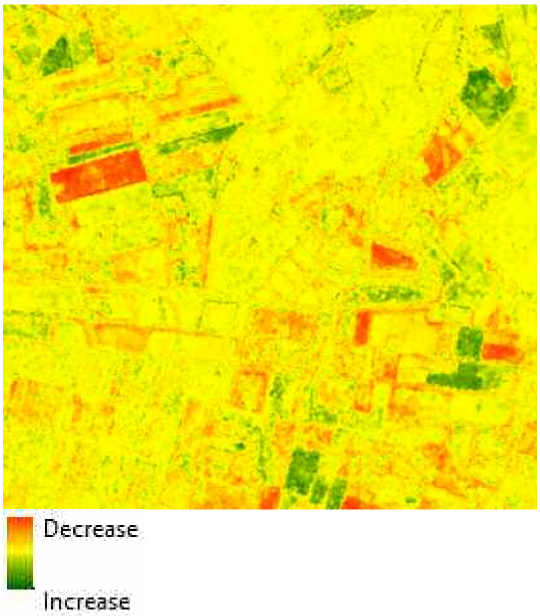


Figure 24: Grassland change probability map

Figure 25: Changes with grassland change probability above 70%. Basis layer: ArcGIS Basemap

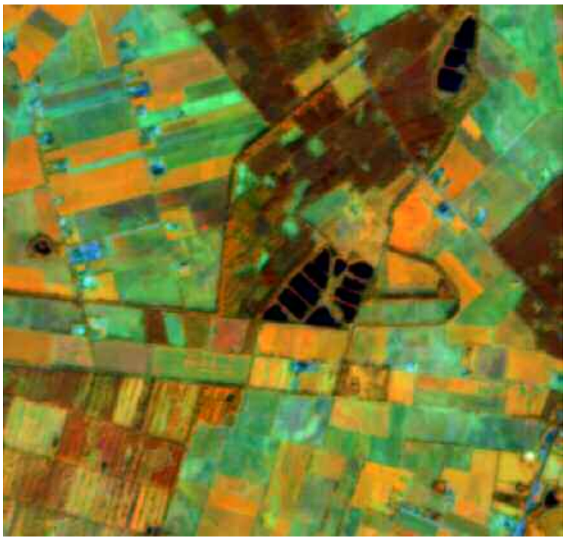


Figure 26: Sentinel-2 Median mosaic from 2016, (B8, B11, B4)

Figure 27: Sentinel-2 Median Mosaic from 2017, (B8, B11, B4)

This approach strongly depends on the availability of dense time series. The annual features used as input for the grassland probability derivation require a sufficient number of observations to distinguish between cropland and grassland respectively to detect changes between these two land use categories. In this case the median feature could have been calculated from observations made at different phonological stages of the year. As alternative method to the application of time series features, methods on signal anomaly detection are developed that are based on statistical analysis of fitted curves describing the spectral behaviour of a grassland pixel in consecutive years. This method was chosen because it is comparatively robust to gaps in the time series which is the main obstacle in change detection applications. Figure 28 shows the time series of Greenness Tasseled Cap index in the years 2015 and 2016, including an OLS curve fit based on a harmonic model using sines and cosines. The harmonic model features a trend parameter as well as three seasonal frequencies. Figure 29 presents the estimated values of the trend parameter (C_0) and the amplitudes of the seasonal components (A_1,A_2,A_3) derived from the OLS fit. While the fitted curves look very different, the overall trend and the amplitudes stay roughly at the same level when their confidence intervals are taken into account. The change of the fitted curves can be explained by phase shifts in the seasonal components.

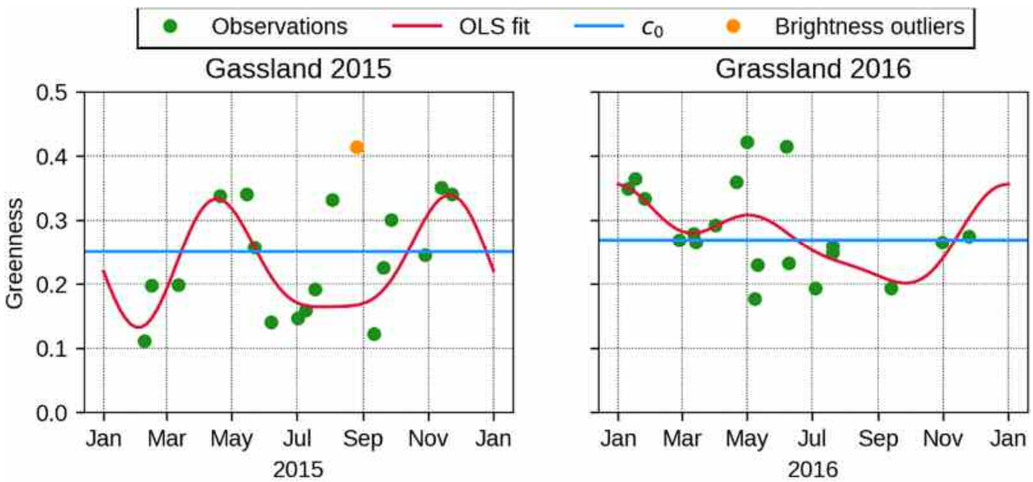


Figure 28: Tasseled Cap Greenness time series of a grassland pixel in consecutive years.

Ordinary least square fitting abbreviated with OLS fit.

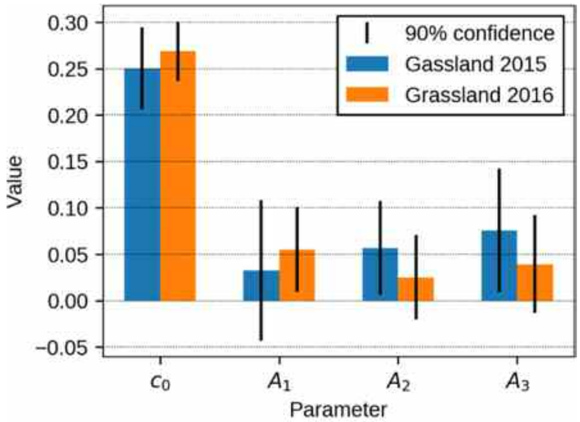


Figure 29: Tasseled Cap Greenness trend (C_0) and amplitudes (A_1,A_2,A_3) of a grassland pixel in consecutive years.

Therefore, further testing is applied on the Belgium test site where signal anomalies are detected separately for the optical and SAR time series stacks.

SUMMARY

As the land cover dynamics heavily depend on the specific land cover, there is no single change detection approach, which can be recommended for application in all thematic fields, covered within ECoLaSS. For example, the temporal characteristics of the reflectance trajectories are different for forests, cropland types, grasslands and settlements. Therefore, the change detection testing and benchmarking was performed separately for different thematic fields. The assessment concentrated on Forest Change/Loss, Imperviousness change, and identification of grassland change into other land cover classes.

The forest change testing investigated the potential of Sentinel-1 and Sentinel-2 data for automated forest change detection to be more flexible in areas of frequent cloud cover. The combined usage of Sentinel-1/Sentinel-2 delivered the best detection result, but has the highest implementation cost, while the Sentinel-2 scenario gives slightly less precision with about half the cost. The current methodology is not able to determine the exact date of the change due to the use of aggregated time features. For the detection of these specific changes, the combination of the approach with methods that focus on feature dynamics (i.e. within-season variation) of forest change events within the respective time period can be considered, which is recommended for future investigations. Further research is also required to validate the transferability of the methodology to areas of different geographic conditions and seasonal patterns. The integration of SAR coherence could further improve the change detection accuracy.

In the case of the imperviousness change studies a mono-sensor approach based on one HR sensor Sentinel-2 has been tested. The results show that the mono-source approach doesn't seem to be sufficient, due to the fact that yet the times series are not dense enough to take advantage of the phenology of inter-yearly and of the intra-yearly seasonal dynamics. There is still a need to ensure the temporal consistency and comparability between the different time intervals regarding the re-processing of the reference layer 2015 – and the new status layer for 2017.

For grassland change detection, a combination of multi-temporal random forest probability estimations based on optical and SAR features have been tested. The current temporal density of optical time-series from Sentinel-2 for the years 2017 and 2016 restricted the applicability of time series methods, as reflectance trajectories depend on the grassland dynamics over the vegetation period such as e.g. mowing events. The results achieved with multi-temporal random forest probability estimations demonstrate their applicability. The work based on denser time series is ongoing, which also allows combining change indicators with the multi-temporal random forest probability estimations.

For all applications, testing and benchmarking of different anomaly detection methods for monitoring land cover changes are ongoing, which range, depending on the application, from object-based methods based on statistical features of different years, change identification by multi-temporal probability estimations and change from annual mapping. Special emphasis will be drawn in phase 2 on change detection methods which carefully make use of the HRL2015 status layer classifications for forest, imperviousness and grassland as inputs to the processing chains, aiming to both minimise the occurrence of change “false positives”, and detecting omission/commission errors in this previous 2015 dataset. This is considered to also open up ways for retrospective corrections (in terms of product outline/masks) in previous HRL time steps as a standard procedure.

For further details, please refer to the first issue of the deliverable of WP 34 [AD15], *“D9.1_D34.1a-MethodsCompendiumTimeSeriesAnalysisforChangeDetection_Issue1_M14.pdf”*.

2.4.8 Time Series Consistency for HRL Product (incremental) Updates (WP 35)

WP35 is on “Time Series Consistency for HRL Product Incremental Updates” and is highly connected to the WPs 33 “Time Series Analyses for Thematic Classification” and 34 “Time Series Analyses for Change Detection”. The results are directly useful for WP 42 “Incremental Update of HR Layers”.

Table 20: WP 35 – Time Series Consistency for HRL Product (incremental) Updates

Work Package Number	10	**Lead Beneficiary**		SIRS		
Work Package Title	WP 35 – Time Series Consistency for HRL Product (incremental) Updates					
Short Name of Participant (Participant Number)		GAF (1)	**SIRS (2)**	JR (3)		
Person/Months per Participant		4.70	**4.70**	3.00		
Phase 1	**Start Month**	4	**End Month**	14		
Phase 2	**Start Month**	19	**End Month**	29		
Objectives: To develop suitable methods for ensuring spatially and temporally consistent incremental updates of HRL products at an appropriate time frequency by defining an appropriate combination between time series-derived classification and change detection algorithms.						

This WP aims to determine the temporal frequency that will be appropriate for HRL product updates, mainly the Imperviousness layer, the Forest layer and the Grassland layer, while harnessing the breakthrough revisit time offered by the Sentinel constellation. Automatically detected changes (as set by the WP34) between two successive layers, should then be classified into eventually new relevant themes.

Spatial and temporal accuracy and consistency of such changes need to be assessed by a suitable method minimizing all types of errors: commission errors as well as omission errors.

The main activities consist in:

1- Proposing a different incremental update frequency for each of the previously mentioned products, tailored to the HRL specific change characteristics and following the conclusions on EO availability drawn from WP32;
2- Testing new methods to correctly identify the automated changes detected in WP34;
3- Testing new methods to ensure the spatial and temporal coherence of those changes along the time series;
4- Testing new methods to assess the accuracy of the thematic label associated with the detected changes in WP34.

<u>IMPERVIOUSNESS</u>

Concerning the **Imperviousness** layer, the changes are mostly toward increase of impervious areas (e.g. the total urban area in the CLC data from 2000-2012 is 2.85% (2000), 3.10% (2006), 3.21% (2012)). The small area concerned with changes in combination with the image availability does not play in favor of increasing the update frequency, particularly when considering image availability in past years. The combined use of S-2 and Landsat certainly improves the cloud free situation and the accuracy of detecting new built-up areas, although the availability of cloud free optical data is still likely to remain critical in cloud prone northern Europe, but the use of S-1 is being tested to improve the situation since it guarantees an image acquisition every 6 days. However, this is currently being tested in WP33 and will be integrated into WP35.

A built-up mask for the year 2018 is being computed as part of WP34 over 3 test sites: the South-West site, the Central site and the South-East site, using the same iterative classification approach, developed in the first phase, that aimed at balancing omission and commission errors and correcting omission errors from the previous layer identified as changes combining S-1 and S-2 data. To determine the built-up changes 2017-2018 and the built-up changes 2015-2018, the supervised classification result for 2018 is combined with the built-up mask from the prototype HRL IMP 2018 over the South-West and the HRL Impervious Status layers for the Central and South-East test sites which was produced during the operational HRL production outside this project. This step reveals 2017-2018 and 2015-2018 built-up changes, with a more precise confidence interval, but it also detects potential omission errors in the built-up mask 2015 and 2017 depending on the test site as well as potential commission errors of the 2018 built-up area.

To avoid any spatial inconsistency between the layers of the different epochs, a densified and optimised reference dataset has been developed to determine the relative proportion of actual change versus all the error components described above. To be valid, this calibration dataset has been selected based on a probability sampling approach – whose focus will be to discriminate between new built-up for the year 2018, omission errors from 2015 and 2017 and commission errors from 2018.

An improved reclassification procedure, involving the combination of Differential Attribute profiles applying SV is then applied, taking full advantage of the increased spatial and temporal resolution of S-1 and S-2, followed by a Post-Classification Comparison (PCC), as depicted in the Figure 30.

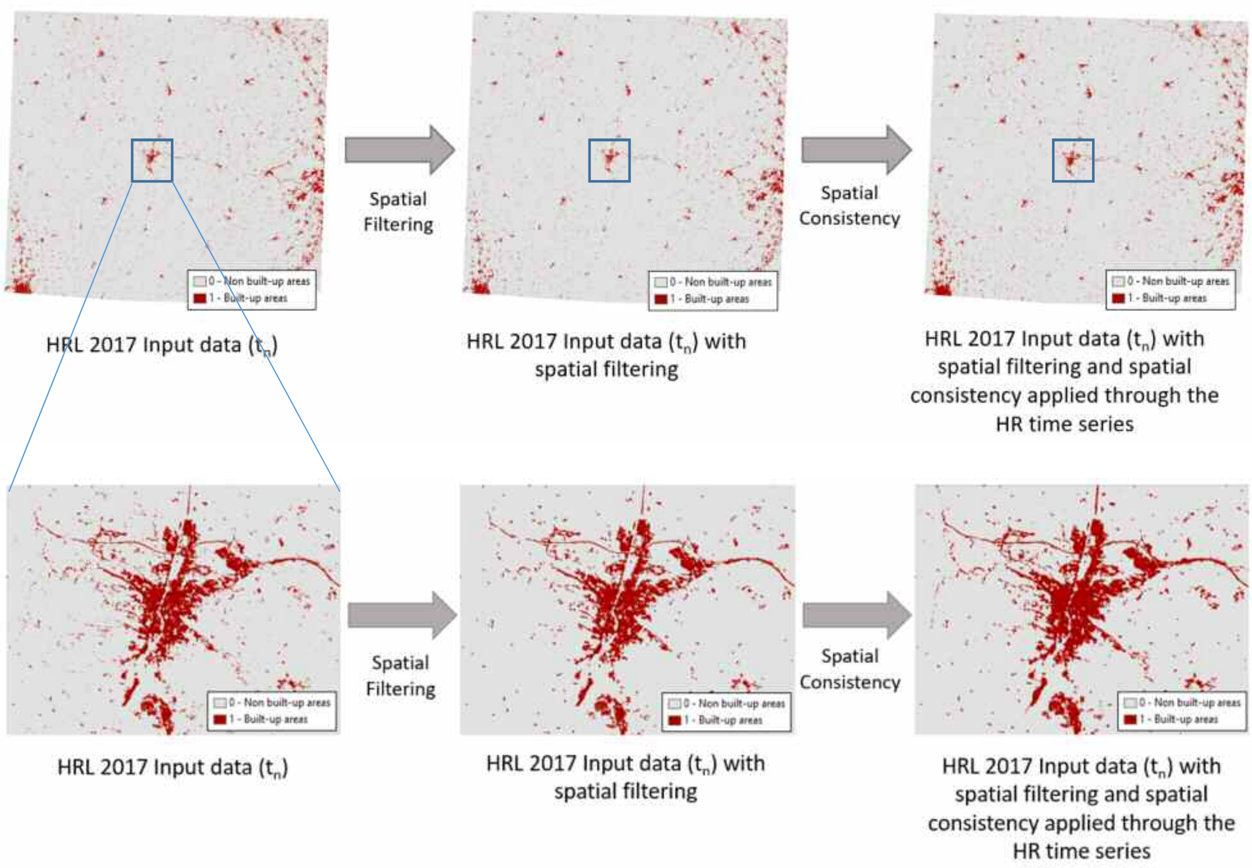


Figure 30: Post-classification processing HRL IMP 2017

The PCC can be decomposed in two steps: a first filtering to remove isolated pixels, which are most likely misclassifications, then a second procedure to ensure spatial and temporal consistency, relying on the reference calibration data. The optimal level of sampling intensity needed for the calibration to apply this method operationally is currently being tested, using the 3 test sites.

Figure 31 shows that a lot of changes are in fact technical changes. Most of the pixels in the 2015-2017 change mask were identified to be omissions due to the change of resolution from mostly Landsat in 2015 to Sentinel 2 (therefore under-estimations) in the reference year 2015 classification and are therefore wrongly detected as change. It is expected that both the Central test site and the South-East test sites will present such misclassifications dating from 2015, but the most interesting part will come from the comparison between the 2017 prototype, based on S-2 spatial resolution at 10 m, and the new 2018 prototype over the South-West test site, which will put the robustness of a yearly update to the test.

Figure 31: Left: S-2 image from 2017 and change mask (WP34)

Right: same image and reclassified change mask (WP35). Red pixels are stable built-up, blue omissions from 2015 and green new built-up from 2017

FOREST

Forest dynamics are more complex with both cases represented, where forest is increasing and decreasing even though the net change is toward increasing forested areas. Forest also covers a much greater area than urban areas by a factor of 6 to 8. Based on several independent databases, e.g. from CORINE Land Cover (CLC) and other studies of the Food and Agriculture Organization of the United Nations (FAO), an increase of the forest area across Europe in the order of magnitude of 1-2% during the last 5-10 years seems to have taken place. Considering the related overall areas, these are significant gains in forest cover, about 30,000 km^2 net change, though theoretically, the area affected by those dynamics could be larger, when considering the areas affected by loss and gain of forest cover. However, breaking the figures down to smaller time intervals, e.g. to one year, it becomes obvious that the extent of annual net increase of forest area is rather small on European extent, i.e. presumably < 0.5% per year. Those studies lead to the conclusion that an incremental update scheme for the HRL Forest may have to follow a two-staged approach:

1. Changes in the extent of tree/forest cover can be monitored in an incremental update cycle of 1 year, capturing primarily rapid (negative) changes (i.e. logging, deforestation, forest damage);
2. Changes in forest characteristics/properties (such as tree cover density, dominant leaf type) as well as typically slower increases in the tree-stocked area (i.e. regrowth, reforestation) can be complemented in the established 3-year update cycle (as is currently the case).

In terms of technical feasibility (i.e. availability of necessary EO data frequencies in combination with state-of-the-art information extraction algorithms), a yearly (or two-yearly) HR Forest Layer update cycle for the whole EEA-39 appears technically feasible, and will be tested in the second project phase.

In phase 1 of ECoLaSS an Incremental Update Layer has been simulated on basis of the Tree Cover Mask 2015 (derived from the 20m Dominant Leaf Type 2015 product) and the newly created improved TCM 2017 (resampled from 10m to 20m), fully based on Sentinel-2 data. Even though the selected approach worked fine, the achieved results were below the expectations due to the completely different lineage and data basis of the masks 2015 and 2017. Although the accuracy could be generally increased by semi-automatic enhancing procedures, such an approach is not in favour in terms of budget and time constraints which are often given in operational projects.

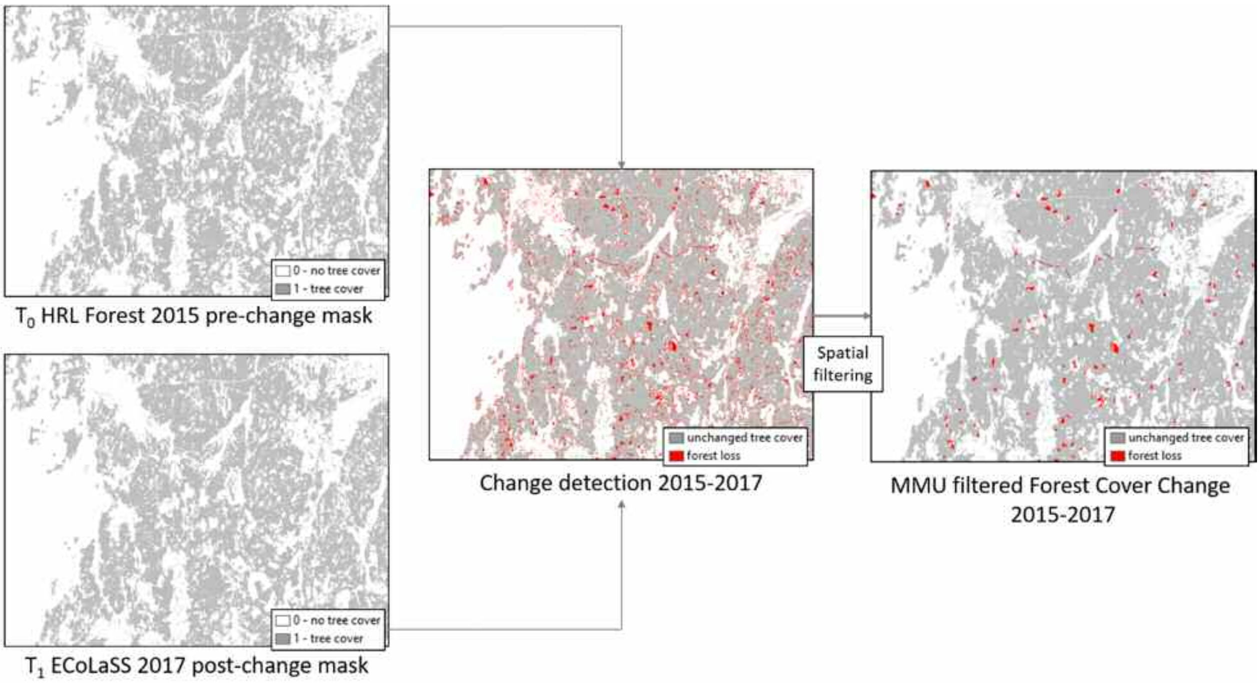


Figure 32: General change detection approach applied to the Forest Incremental Update Layer

In phase 2, full time series of Sentinel-1 and Sentinel-2 data for the years 2017 and 2018 became available. Consequently, a yearly HR Forest Layer update in form of the Incremental Update Layer has been tested in a combined Sentinel-1/Sentinel-2 classification using spatio-temporal features and a subsequently applied change detection approach. Phase 2 results are promising and show much better accuracies than in phase 1.

GRASSLAND

Although the overall area of grasslands seems to slightly increase, as investigated in the available FAOSTAT, EUROSTAT and CLC statistics, the dynamic within the different grassland classes reveals that natural grassland is on decline whereas the area of pasture increases between 2000 and 2012. The trend however also seems to indicate an accelerating decrease rate in the recent few years. Given the knowledge that grasslands are highly valuable ecosystems that need protection, these analyses confirm the need for a dense and accurate monitoring and therefore the need for a reliable data basis.
Changes in grassland are highly dynamic by nature within one growing season – and loss and gain can happen within a short time period induced by extreme weather conditions or by human intervention. These considerations speak in favor of an annual incremental update.
Concerning the implementation of a higher update frequency, several factors are still challenging. Grassland is much more challenging to apprehend as grassland cover is a much more dynamic vegetation type to characterize for which it is often difficult to decouple between phenological changes within a year and long-term trends. Furthermore, the identification of adequate optical EO data acquisition time slots for the accurate detection of grassland calls for regionally adjusted time slots to accommodate varying growing seasons.

SUMMARY

For all three layers, common conclusions can be drawn. For implementing a higher update frequency, several challenges have to be faced:

- Seasonal dynamics of a certain layer (very high for grassland, lower for forest). Potentially high for surrounding land covers (e.g. cropland) to be excluded from the desired layer
- Identification of adequate optical EO data acquisition time intervals
- Differentiation of real changes versus temporary or technical changes;

- Mitigation of certain information gaps (i.e. less dense time series) due to cloud cover, haze or low sun angles in certain geographical regions.

These topics are still open issues and part of the ongoing research.

Based on the parameters EO data availability and magnitude of change it is difficult to draw any conclusions on whether the frequency of updates should be increased or decreased. The real question is more on the ability to improve the accuracy of the detected changes and their labels, i.e. provide an estimate with a greater degree of confidence., and reduce the bias, i.e. ensure that the level of omission and commission errors are equivalent.

For further details, please refer to the first issue of the deliverable of WP 35 [AD16], *"D10.1_D35.1a-MethodsCompendiumHRLTimeSeriesConsistencyforHRLProductUpdatest_Issue 1_M14.pdf"*.

2.4.9 Time Series-derived Indicators & Variables (WP 41)

WP 41 is on "Time series-derived indicators and variables" and builds up on methods tested by the Task 3 WPs [AD12, AD13, AD14, AD15, AD16].

Table 21: WP 41 – Time Series-derived Indicators & Variables

Work Package Number	11	**Lead Beneficiary**		UCL	
Work Package Title	WP 41 - Time Series-derived Indicators & Variables				
Short Name of Participant (Participant Number)		SIRS (2)	**UCL (4)**	DLR (5)		
Person/Months per Participant		3.50	**5.00**	3.23		
Start Month	9	**End Month**		31	
Objectives To implement and demonstrate metrics based on spectro-temporal information.					

In particular, Task 4 WPs target constructing prototypes for (i) using high-volume time series data for providing indicators and variables of high spatial resolution and temporal repeat frequency for Continental and Global Component products and services; (ii) developing incremental update strategies and ensuring time series for improving one of the main pan-European Copernicus Land products, i.e. the current (2012) and future (2015, 2018) HRLs on Forest and Imperviousness; (iii) improved permanent grassland identification targeting the HRL Grassland 2015 improvement; (iv) crop area and crop status/parameters monitoring targeting a potential future Agricultural service; as well as (v) further novel LC/LU products, e.g. as tested in Task 3.

The WP goals are met through developing and applying various approaches on the Demonstration site West. The first approach is proposed to create a phenological product that includes several layers where determination of phenological parameters, such as phenological start of season (PSS), phenological peak of season (PPS), phenological end of season (PES) and phenological length of season (PLS) are required. Hence, robust series of dense multi-year images of Landsat satellite and derived phenological parameters, such as the spectral optical index NDVI, are used for pixel-based unsupervised classification by the K-mean clustering algorithm.

A layer, including 30 classes and called Maximal Phenological Activity (MPA), is produced by the K-mean clustering algorithm for Maximal Phenological Activity. Figure 33 represents the produced image showing the MPA around Antwerp. However, the peak of season is sometimes difficult to determine due to the design of NDVI and, hence, other spectral indices should be introduced. Also, the presence of clouds makes the temporal frequency of a month slightly too long to fully account for the difference in phenological behaviours. As a result, S-2 data which is of much higher frequency, is needed for better capturing the different phenological behaviours through computing maximum NDVI values twice a month or considering alternative vegetation index less saturated at the peak of the vegetation season.

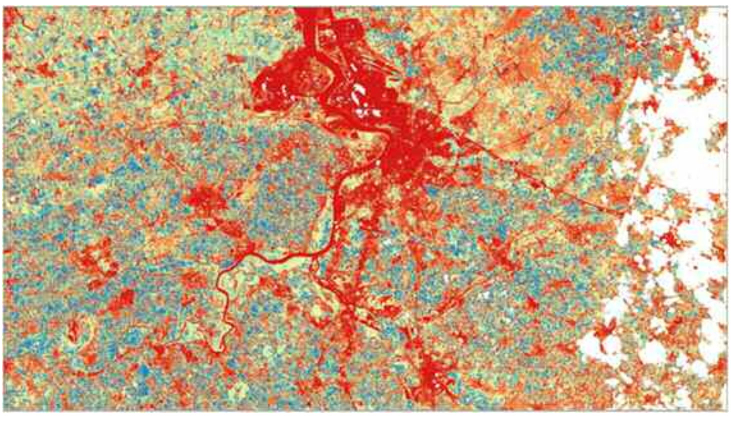


Figure 33: MPA around Antwerp.

K-Means resulting image, with 30 classes, based on the maximal NDVI values for a year. The white dots being no data due to the presence of clouds

The second approach aims at capturing multiannual trends and, as a result, updating potential changes for the specific HRL layers forest and grassland. Hence, a more targeted phenological product has been designed based on detecting marginal behaviour of the statistical metrics computed from S-1 time series. Exploiting the density of S-1 time series, the potential changes in both the Grassland and Forest HRLs are captured by three S-1 time series corresponding to three years. However, the signal sensitivity to various elements other than change would require to develop additional filters.

For multi annual trends, a huge large data set of the backscattering acquired by Sentinel-1 satellite during 2015, 2016 and 2017 was used. Grassland and forested areas are detected for possible update of the HRL corresponding layers where grassland, forest and agricultural areas can be distinguished from each other (Figure 34).

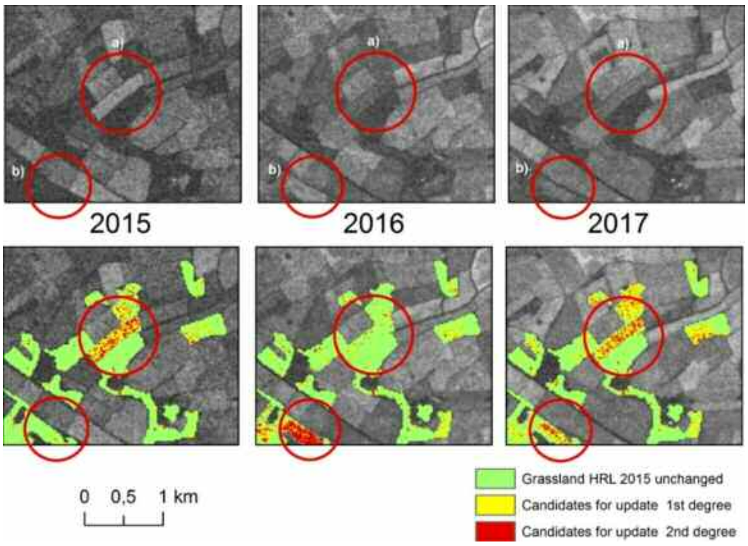


Figure 34: First example of HRL grass updates for three consecutive years.

Above: background layer for visual comparison of surrounding land cover. Below: detected pixels for possible update

The third approach targets assessing crop growth condition by the trajectory of parameters representing photosynthetic activities such as Green Area Index (GAI) and/or Leaf Area Index (LAI). The approach uses the BVnet algorithm employing artificial neuronal networks trained on simulated LAI and reflectance values where reflectance values are simulated by the ProSail radiative transfer model for the Sentinel-2 bands. The analysis is conducted at the field level in relative terms in regards to neighbouring fields of the same crop (within a radius of 3 km). This product allows to identify local marginal behaviour along the season in terms of crop growth cycle, crop development or management practices. An example of quantitative anomaly derived from the comparison between the LAI profile of each field with its surrounding ones provide a wall-to-wall map of the local growth cycle deviation.

The LAI differing over the season based on phenology stage enables detecting the growth conditions of the crops and, hence, distinguishing one crop form another. Figure 35 depicts the LAI anomalies of three main crops of Vallonia region, Belgium where Winter Wheat LAI anomaly shows bell shaped distribution while the majority of Maize LAI anomaly have negative values and Winter Barley anomaly has skewed distributions (to the left). Consequently, the patterns of the local growing conditions for the three crops can be reported.

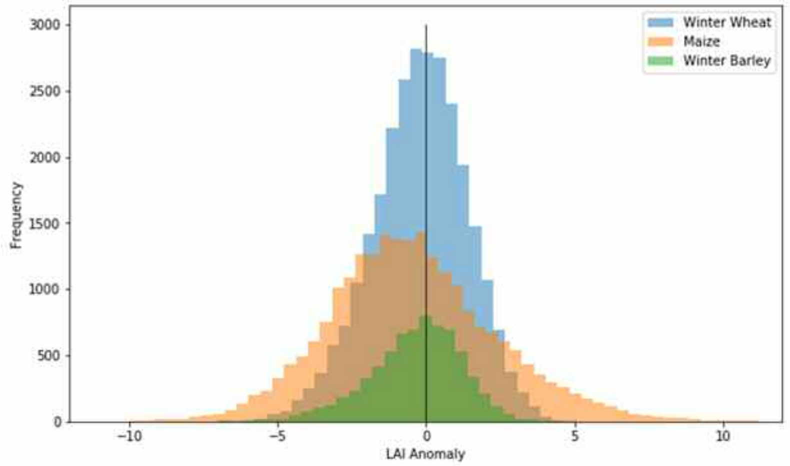


Figure 35: Distribution of the LAI anomalies for the three main crops in 2017

Crops: Winter Wheat, Maize, and Winter Barley. The anomaly corresponds to the difference between the area under LAI curve for the field of interest and the one for the local average

The fourth and last approach aims at detecting the emergence date of maize in the Demonstration site South Africa. The approach is based on the detection of the first phenological stages (crop emergence, first leaf development) from satellite remote sensing (i.e. Sentinel-2) time-series. The phenological stages are commonly defined according various classification systems such as the Biologische Bundesanstalt and Bundessortenamt und CHemische Industrie (BBCH) scale. The standard stages are selected to provide a continuous scale ranging from 0 to 100 which is relevant to any crop and location. Also, the vegetation indices (VIs) and hue time series are qualified candidate data source as VIs and hue works as a proxy of the Fraction of Absorbed Photosynthetically Active Radiation (fAPAR). In addition, candidate methods for phenology studies are used such as the threshold, moving window, function fitting and model fitting methods.

For the emergence date detection, different VIs and detection methods to provide an accurate estimation of the emergence date at the field level have been compared. The VIs and hue index show similar growth dynamics with the preference to VIs due to the lower associated error. Surprisingly, the absolute and relative thresholds do not present significantly different results, although the variations in sowing densities appear to affect the index values. The relative threshold method is expected to be more flexible and match more diverse situations at a larger scale. Density, cultivar, and management practices are often quite different over large areas and absolute thresholds might rapidly prove inaccurate. Therefore, the relative threshold is probably more indicated for scaling up this product over large regions. The main drawback of the relative threshold is that it will output a result regardless of the real vegetation status. A combination of an absolute threshold discriminating bare and cropped soils with a relative threshold might prove useful. Figure 37 is the final map produced for the emergence date of maize in the Free State, South Africa where a strong gradient of emergence date is detected from east to west.

In phase 2 this successful application has been first repeated similarly to a second year. The method findings and the performances are really very similar (2016-2017 and 2015-2016). The approach has been then further extended in two directions. On the one hand an alternative time scale no longer based on calendar date but rather on 'Growing Degree Days' providing a physiologically-based time. This is expected to provide a more generic retrieval algorithm, more robust and more scalable over large areas. Whatever the method to retrieve the emergence, it was found that the performances are much less sensitive to the time scale than to the methods for both performance metrics as reported in the Figure 36.

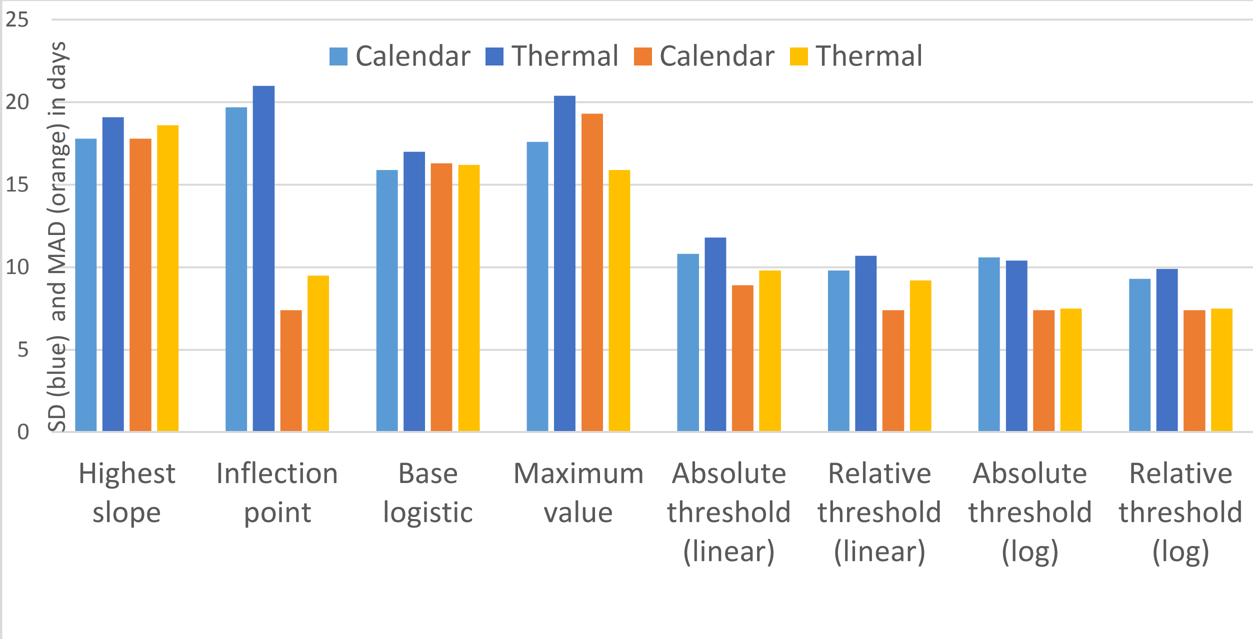


Figure 36: Methods performances for detecting the maize green onset for two time representation.

Blue corresponds to the calendar days while orange to the Growing degree days. SD stands for standard deviation and MAD for Median Absolute Deviation.

Beyond the time scale, an additional main crop, i.e. sunflower, has been tested using the method established for the maize, calibrated and validated with a more limited number (88 for calibration and 39 for validation). The same Relative Threshold method performed the best for sunflower as for the maize and the SD and MAD are very similar for both temporal scales.

Last but not least, the plant density and the crop row width vary over large regions according to local agriculture practices and meteorological conditions (dry year, drought, etc.). Their respective influence on the NDVI has been assessed carefully.

For further details, please refer to the first issue of the deliverable of WP 41 [AD17], *"D11.1_ D41.1a_PrototypeReport_Time SeriesDerivedIndicatorsandVariables_Issue1_M17.pdf"*.

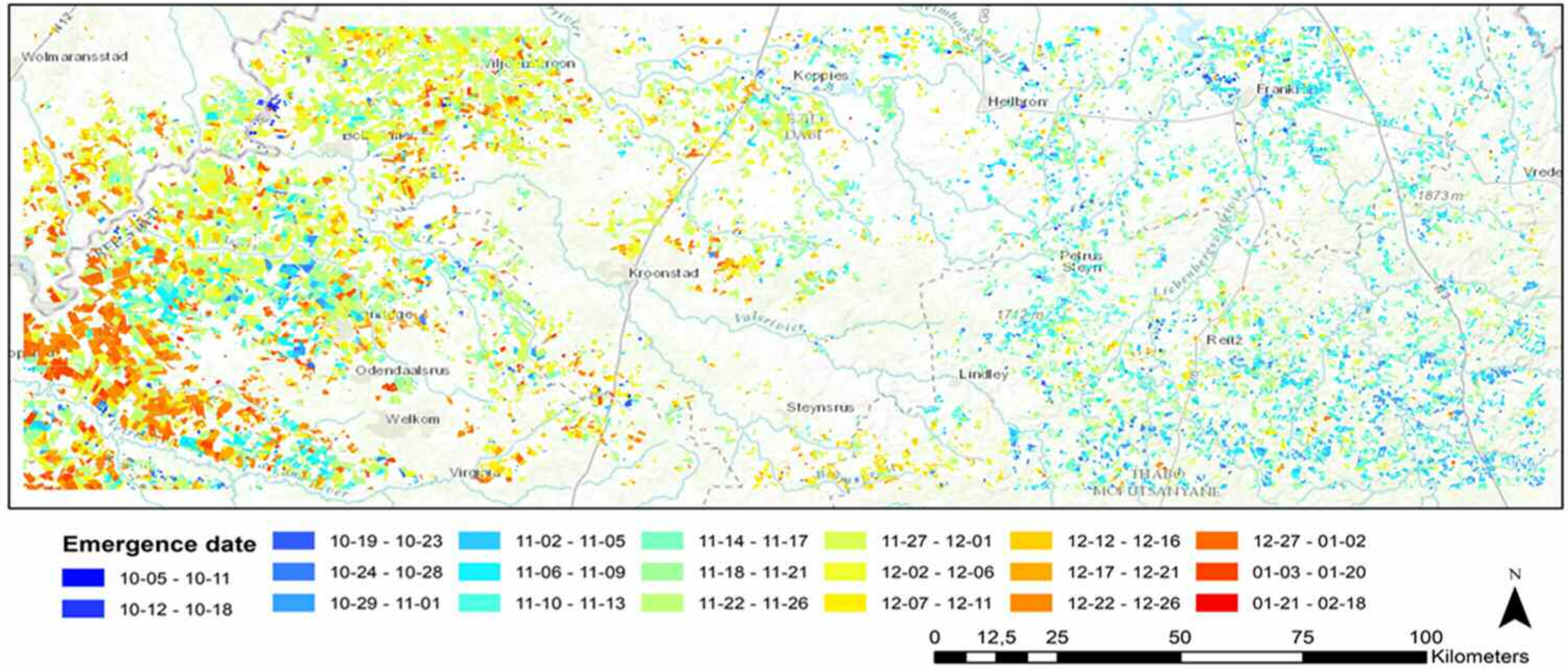


Figure 37: Emergence date map for maize in the Free State (South-Africa).

A strong gradient of emergence date is highlighted from east to west.

2.4.10 Incremental Updates of HR Layers (WP 42)

WP 42 is on "Incremental Updates of HR Layers" and builds up on the pre-processed data from WP 32 and methods for Thematic Classification from WP 33 and Change Detection from WP 34 as well as on the Time Series Consistency for HRL Product (incremental) Updates from WP 35.

Table 22: WP 42 - Incremental Updates of HR Layers

Work Package Number	12	**Lead Beneficiary**			GAF	
Work Package Title	WP 42 - Incremental Updates of HR Layers					
Short Name of Participant (Participant Number)		**GAF (1)**	SIRS (2)	JR (3)		
Person/Months per Participant		**11.50**	4.70	1.83		
Start Month	11	**End Month**		33		
Objectives To demonstrate potential of HRL incremental updates on a yearly or continuous basis using Sentinel-1/-2/-3 time series.						

The objective of WP 42 is the demonstration of the potential of HRL incremental updates on a yearly or continuous basis using Sentinel-1/-2 time series. The thematic focus within this WP lies on both Forest and Imperviousness for which prototypes are developed using the methods and workflows considered in Task 3 and the associated Deliverables. While the demonstration site North in Southern Sweden, Central in Austria/Germany and South-East in the Mediterranean region were chosen for the development of a Forest prototype, the prototype for Imperviousness was performed in the demonstration site South-West (France/Spain).

IMPERVIOUSNESS PROTOTYPE

The automated supervised classification used to derive the built-up mask follows the outcomes of the Task 3 of the project (WP 33). The supervised machine learning method based on active learning has been selected to create the updated built-up mask for 2018 at 10 meters spatial resolution over the South-West, the Central and the South-East demonstration sites. It works in both interactive and batch mode. Following the results of the WP31 (separability of the information for thematic classifications) and WP33 (Time Series Analysis for Thematic Classification), the input data selected rely on multispectral information such as biophysical variables such NDVI but also textural metrics and granulometry by mathematical morphology (Differential Attribute Profiles (DAP)) derived from Sentinel-1 and Sentinel-2 images on the full time period (atmospherically corrected, topographically normalized and cloud free). The active learning algorithm shows great classification performances whilst being very computer efficient, thus substantially reducing processing time overall and dealing with large dataset. The production of the built-up mask is achieved with an automated selection of reference (or training) data using a stratified random approach based on the HRL. This results in a built-up mask with values of 0 (non sealed areas) and 1 (impervious surfaces).

The improvement of the results of the SAR classification, based on various temporal statistics (using a more simple algorithm, the SVM classifier) is currently being tested at test site scale and the demonstration site scale – in order to determine the best combination of statistics to improve further the SAR classification, or at least to explain the difference between the optical and SAR classification results already pointed out in phase 1.

The implementation of the prototypes on the HRL Imperviousness will lead to the production of a change layer (IMC) produced at 20m (over the Central and South-East demonstration sites, between the years 2015 and 2018) and at 10m over the South-West demonstration site between 2017 status layer, produced as a prototype for phase 1, and the new prototype for 2018 as well as 3 status layer (IMD) at 10m for 2018, one for each of the 3 demonstration sites. Nevertheless, results from Sentinel-1 from phase 1 were somewhat not as good as Sentinel-2 and will need to be improved in phase 2. Therefore, further improvements and investigations will be performed as part of the second project phase:

(i) Separation of buildings toward the flat impervious surfaces are currently being tested – and the production of a built-up layers for each demonstration site will be implemented if the results from WP33 are conclusive,
(ii) Integration of Sentinel-1 times series to be implemented.

FOREST PROTOTYPE

In view of a potential future HRL Forest Incremental Update layer, the delineation of forest change/loss is based on the comparison of a pre- and post-change tree cover mask as described in the methods compendium of WP 34. The TCM 2015 in 20m spatial resolution as derived by the Copernicus HRL Forest Dominant Leaf Type layer 2015 represents the pre-change mask whereas the DLT 2017 classification represents the post-change mask with reference year 2017. The Incremental Update layer resulting thereof, hereinafter explicitly named as Tree Cover Change (TCC), compares the pre- and post-change mask (TCM 2015 and newly classified TCM 2017 resampled to 20m) to detect areas of forest loss. Due to the very short time interval of mostly < 1 year between the two masks (the HRL 2015 data are mainly from spring and summer 2016 and the ECoLaSS data from spring and summer 2017), this layer concentrates on negative changes (loss) only. The presented methodology can incorporate both, Sentinel-1 and Sentinel-2 data without significant adjustments which provides more flexibility in areas of frequent cloud cover. Whereas in phase 1, only optical Sentinel-2 data was utilised, the extension to SAR data is being applied in project phase 2.

In order to generate a comparable and future-oriented data basis for the incremental update, the same feature and sample sets have been used to derive improved TCMs in 10m spatial resolution for the reference years 2017 and 2018 using Sentinel-1 and Sentinel-2 data. Then, the same approach to derive the incremental update layer 2015-2017 (map-to-map change approach) has been applied, leading to an improved geometric and thematic accuracy of the derived changes (forest loss). Thereby, the Minimum Mapping Unit could be significantly improved in phase 2.

For further details, please refer to the first issue of the deliverable of WP 42 [AD18], *"D12.1_D42.1a-PrototypeReportConsistentHRLayerTimeSeriesIncrementalUpdates_Issue 1_M17.pdf"*.

2.4.11 Improved Permanent Grassland Identification (WP 43)

WP 43 is on “Improved Permanent Grassland Identification” and it is building on the methods and processing lines for Thematic Classification developed in WP 33 “Time Series Analyses for Thematic Classification” and an outlook on Change Detection methods from WP 34 “Time Series Analyses for Change Detection”:

Table 23: WP 43 - Improved Permanent Grassland Identification

Work Package Number	13	**Lead Beneficiary**			JR	
Work Package Title	WP 43 - Improved Permanent Grassland Identification					
Short Name of Participant (Participant Number)		GAF (1)	SIRS (2)	**JR (3)**	DLR (5)	
Person/Months per Participant		8.30	4.70	**5.36**	3.38	
Start Month	11	**End Month**		33		
Objectives To explore and set up a robust classification approach for improved identification of permanent grasslands based on Sentinel-2 and Sentinel-1 time series and in-situ data for pan-European land monitoring.						

The objective of WP43 is the deployment and validation of improved classification methods for grassland mapping developed in WP33 using time series of Sentinel-1 and Sentinel-2 data. Output of the WP should be a prototype of a next-generation European HR Grassland Layer with comparably high thematic accuracy. As WP 43 is part of Task 4: “Thematic Proof-of-Concept/Prototype on Continental/Global Scale”, it aims at exploring and setting up a robust and automated classification approach. WP 43 also addresses methodologies for the preparation of in-situ data sets which are necessary as a reference for classification and validation. Testing and validation of the methods is carried out in the defined demonstration areas.

Results are derived focusing on (i) the background of CLMS grassland monitoring needs and requirements, (ii) optimising time series analysis methods based on the results and recommendations of WP 33 “Time Series Analysis for Thematic Classification” (iii) multi-sensor data integration methods, the use of multi-temporal time series metrics, the random forest classification approach and (iv) the validation of the prototype results.

CLASSIFICATION

With the availability of dense optical and SAR time series from Sentinel-1 and Sentinel-2, grassland mapping can profit from the increased information content provided by temporal measurements of the reflectance of grassland areas over the year. Based on reinterpreted LUCAS samples a supervised classification approach using the Random Forest classifier has been successfully applied.

In phase 1, the feature selection tests automatically executed by the Random Classifier have shown that for the WEST Demosite, from optical features the best performing indices for the separation of grassland and non-grassland are the yearly median composites of Tasseled Cap Brightness and Greenness, the Enhanced Vegetation Index and the Normalized Difference Vegetation Index. Further, the spring season (March-April), late summer (July – August) and autumn (September-October) seasons were found to optimally contribute to the grassland/cropland discrimination. Concerning the SAR data generally the following annual coefficients have shown the best performance: Standard deviation in VH polarisation, the mean in VV polarisation and the coefficient of variation in VH. On the basis of the first stages results, in the Central demosite, input indices applied in phase 2 are Normalized Difference Vegetation Index, Normalized Difference Water Index, Inverted Red-Edge Chlorophyll Index and Brightness. Regarding SAR data generally the following annual coefficients have shown the best performance: VH polarisation, the VV polarisation and the NDVVVH Ratio. Time windows include the spring period (March-May), the whole period January to November, and later winter to sprint (January to June), which in the end did not bring an added value for classification. Time features calculation covers: percentiles, coverage, minimum, maximum, median, standard deviation and mean for each of the bands and indices for a distinct time period. In different biogeographical regions the short time window is can differ. To better match the local conditions, it is important to define a time window where grassland and cropland (class generating most missclassifications) are best separable (e.g., define the period when grassland is already greening but cropland is not). In Mediterranean regions, for instance, this window may be shifted more towards winter (e.g. Dec-Mar).

The Central site prototype first results are shown in Figure 38 below. On the left, the location of the detailed view within the demosite grassland mask and on the right, Bing maps aerial view. Below left, the grassland mask zoom. Areas that appear in blue are ploughed agricultural fields. In addition, on the right grassland appears in orange, forest in very dark red-brown, cropland appears reddish and bare soil appears bluish in the S2 band combination B08-B04-B11 (i.e., NIR-SWIR-Red). The detailed view shows how well the separation between grassland and cropland worked. Currently, grassland prototypes for the Central site (status layer 2017 and 2018, change layers 2015-2018 & 2017-2018, including probability layers, together with use intensity tests obtained from NDVI time series) are to be validated.

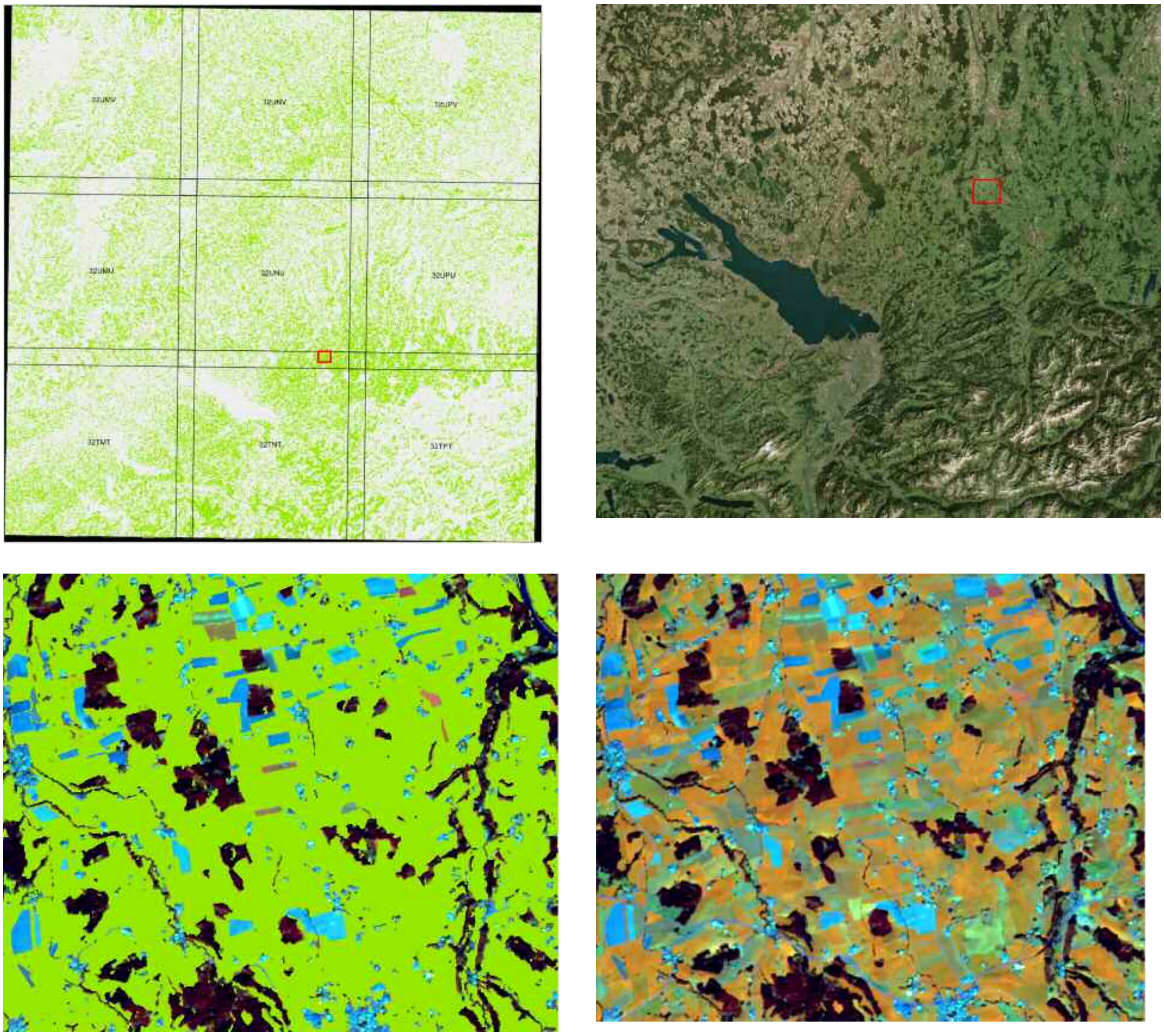


Figure 38: Grassland mask Central demosite prototype 2018.

The focus of the grasslands identification in WP33 is on analysing and applying curve fitting and outlier-detection approaches, to optimally utilize the information content of temporal trajectories. Dense Sentinel-1 SAR and Sentinel-2 optical time series data are used to derive temporal parameters with the aim to further improve the grassland identification (Requirements of WP21 [AD09]) and also to distinguish between intensively and extensively managed grasslands, the latter task being an extension of the product specification.

In Task 3 analysis are made in this direction by developing methods on regression model fitting and trend analysis of grassland areas in comparison with agricultural areas to improve the grassland and cropland discrimination. The trend analysis in Figure 39 shows the different temporal variation patterns within the growing period of grassland and cropland areas and demonstrates the potential for this separation, especially during the early stages of the phenological cycle in spring.

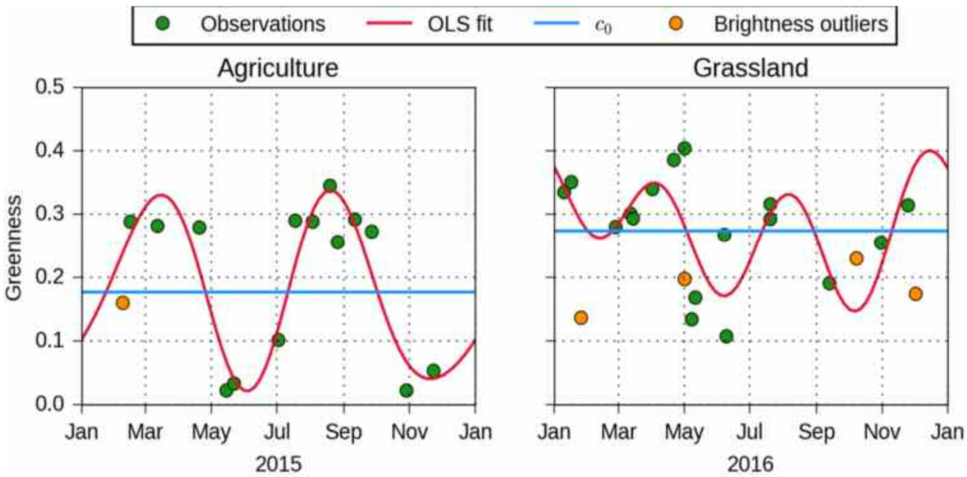


Figure 39: Comparison of an agricultural pixel to a grassland pixel.

The advantages of the curve fitting approach concerning the grassland/cropland discrimination can be appreciated in the figures. Several differences between the fitted curves can be observed, for example the value of the trend parameter C_0, the composition of the seasonal pattern with respect to the amplitudes of the different frequencies, and the minimal value and range (difference max, min) of the fitted curve (see Figure 40). Agricultural objects show lower offset values due to larger reflectance variabilities over time compared to grassland features. Therefore, agricultural objects show higher amplitudes, compared to grassland objects.

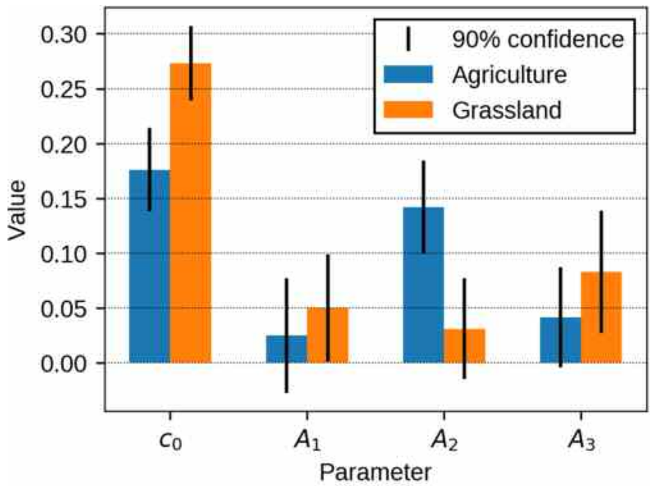


Figure 40: Tasseled Cap Greenness trend (C_0) and amplitudes (A_1,A_2,A_3) of a grassland pixel in consecutive years.

The covariance matrix of the estimates can be further used to derive the uncertainty of the amplitude values. Figure 40 contrasts the trend and amplitude parameters for distinguishing between cropland and grassland. Agricultural objects show higher amplitudes with 2 frequencies (A2) corresponding with 2 ploughing events in the seasons. Grassland objects show amplitudes with 2 frequencies but higher amplitudes with 3 frequencies (A3) corresponding with 3 mowing events in the season (see Figure 40).

Additionally, this approach is currently tested to distinguish between intensively and extensively managed grasslands. Nevertheless, to allow accurate signal trend analysis based on dense time series, the current data density of optical time series from Sentinel-2 is not fully appropriate for 2016 to 2017, as Sentinel-2B data is available from July 2017 onwards only. Therefore, the testing will be continued on dense Sentinel-2 and Sentinel-1 time series in Task 3. A new trainings data set is currently generated covering the additional classes intensively and extensively used grasslands, as in general, no ground reference information is available for grassland use intensity. A high number of sampling plots is required to train the random forest classifier. Therefore, a web based interpretation tool was developed by project partner JR to allow efficient and accurate interpretation of a high number of training plots. To allow an accurate interpretation, the web-tool allows taking into account the full time series of S-2 in addition to VHR imagery such as from Google Earth timeline, Microsoft Bing maps, ESRI Basemap.

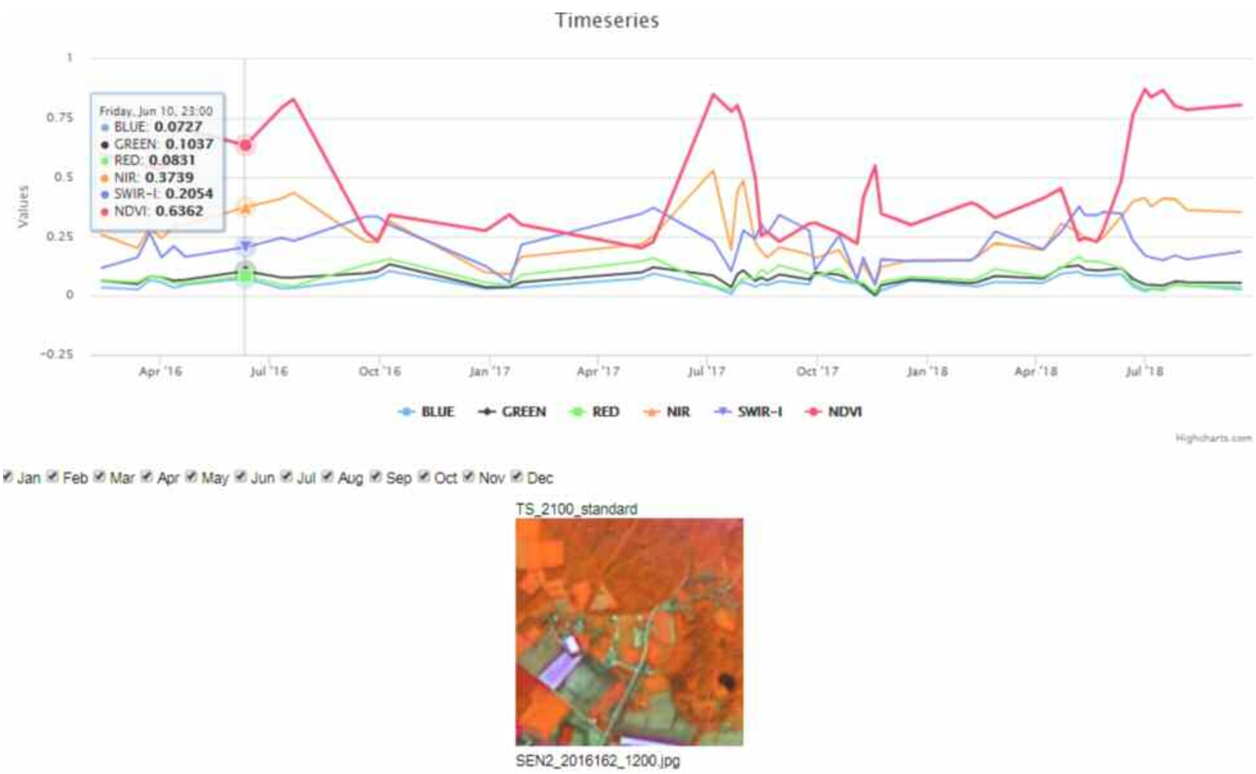


Figure 41: Sentinel-2 temporal trajectory viewer.

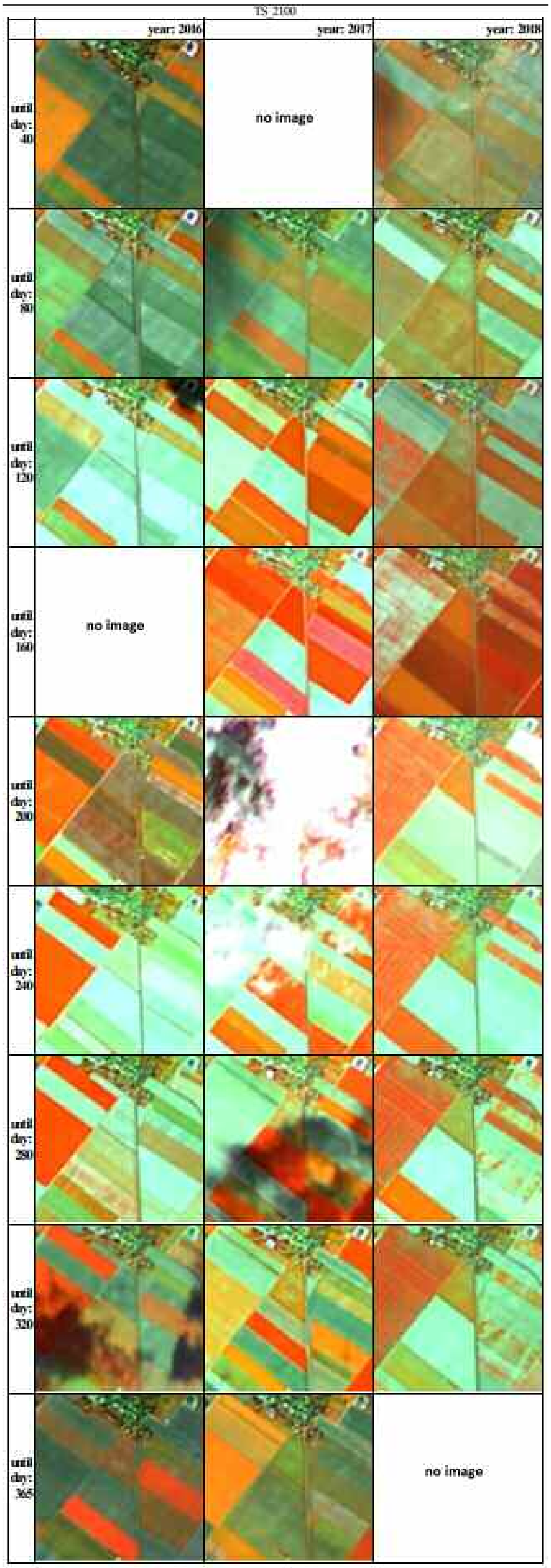


Figure 42: Sentinel-2 matrix viewer 2016-2018.

A specific functionality is provided by a temporal trajectory viewer which allows inspecting the temporal trajectory of the reflectances together with the imagery (see Figure 41). Further a matrix view provides the information on phenology as well as changes over the years (see Figure 42).

VALIDATION

The accuracy of grassland classification depends on the number of valid optical observations in the time series covering the vegetation period. In phase 1, the most promising result in the WEST demosite could be achieved by including annual statistical multi-temporal filtered SAR features in combination with annual and seasonal optical features from March-April, July-August and September-October and annual vegetation indices.

The combination of multi-temporal and multi-sensoral data improves the classification accuracy by considering phenological effects typical for grassland areas. The automated feature selection performed by the Random Forest Classifier revealed that the highest accuracy is achieved by the combined use of optical and SAR temporal features. The optical data proved to be more suitable to identify grassland areas. This is particularly true for exclusion of water bodies and sealed urban areas. On the other hand, SAR imagery proved to support the separation of grassland from cropland areas. Thus, the utilization of the complementary information of Sentinel-1 and Sentinel-2 shows great potential in terms of consistency and enhancement of the grassland mapping.

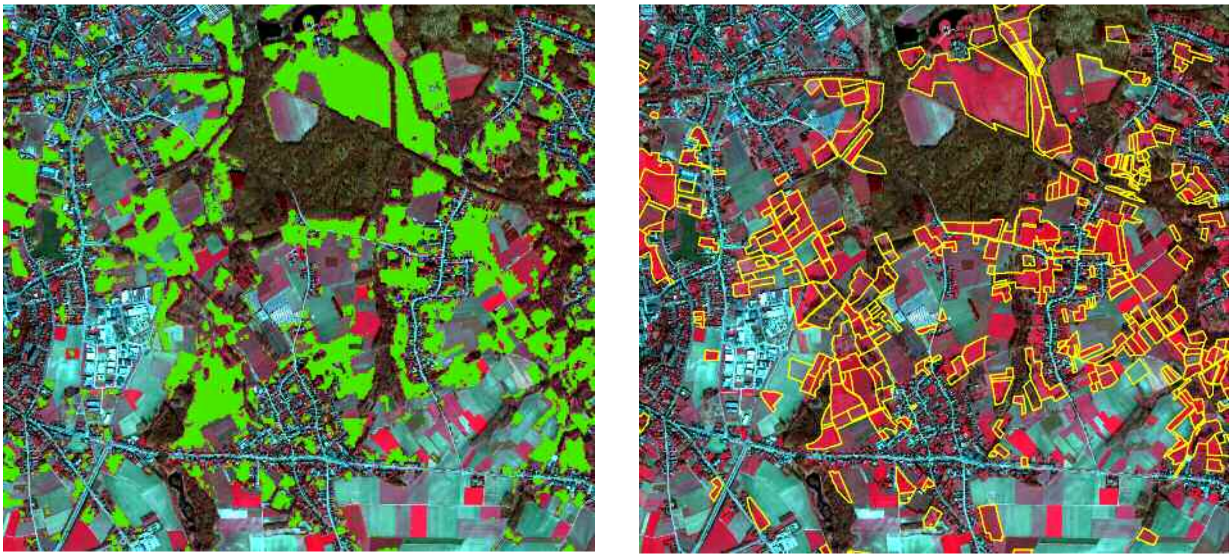


Figure 43: (Left) Classification result of SAR + OPT + VI + seasonal detailed view of 33UFS compared to (right).

WV03 image (R:IR2;G:Red;B:Green) from 14.03.2017 with LGP grassland polygons in yellow (2016), *© Departement Landbouw en Visserij*

The quality of the grassland mapping product derived by the methods developed can be demonstrated in Figure 43. The comparison of the classification result of a sub-area of the demonstration site WEST and Landbouwgebruikspercelen ALV, 2016 (LGP) polygons show a satisfactory accordance. The LGP polygons were derived by visual interpretation of aerial photos and ground truth information from individual farmers. The reference data set differentiates between several agricultural objects including grasslands, not taking into account grasslands without agricultural use.

The statistical validation (Table 24) of the ECoLaSS 2017 grassland prototype, which was performed on the basis of a stratified systematic sampling approach with area-weighted accuracy calculation, showed a high overall accuracy of 97.74% (User's Accuracy: 96.08%; Producer's Accuracy: 87.78%). Further analyses have shown that misclassifications are partly caused by gaps in optical time-series. In addition, small orchard parcels, with more than 10% tree cover, show a rather low spectral dynamic over the year compared to other classes e.g. cropland and could be therefore misclassified as grassland. On the other hand, sparse dry grassland and intensively grazed pastures, which are sparsely covered with grass, are wrongly classified as non-grassland as these areas show similar spectral characteristics as open areas.

Compared with the grassland HRL2015 the main improvements are:

- Increase of the thematic accuracy
- Seamless, wall-to-wall coverage (without "no data" gaps)
- Fully automated approach based on dense S-1 and S-2 time series
- Improved spatial resolution of 10m.

Table 24: Validation results for the SAR + OPT+ VI + seasonal product (area-weighted plausibility approach).

GRA_2017_010m_ WEST_03035_V1_0		REFERENCE				
		Non-Grassland	**Grassland**	**Total**	**User Accuracy**	**Confidence Interval**
PRODUCT	**Non-Grassland**	596.4657	12.2143	608.6800	97.99%	0.98%
	Grassland	3.5812	87.7388	91.3200	96.08%	0.49%
	Total	600.0468	99.9532	700		
	Producer Accuracy	99.40%	87.78%		97.74%	**Overall Accuracy**
	Confidence Interval	0.90%	2.28%		0.93%	**Confidence Interval**

SUMMARY

In the second reporting period the focus is on improvement of grassland identification, and on methods for change detection with special emphasis on grassland use intensity. The most promising methods are being implemented in the demonstration site WEST SOUTH-EAST and CENTRAL demonstration sites at present. Further enhancements to achieve in phase 2 will relate to the improvements of the minimum mapping unit from currently 1ha to 0.5ha or below.

For further details, please refer to the first issue of the deliverable of WP 43 [AD19], *"D13.1_D43.1a-PrototypeReportImprovedPermanentGrassland_Issue 1_M17.pdf"*.

2.4.12 Crop Area and Crop Status/Parameters Monitoring (WP 44)

WP 44 is on "Crop area and crop status parameters" and builds up on pre-processed data from WP 32 including Sentinel-1 and -2 data and methods tested in Task 3 WPs [AD12, AD13, AD14, AD15, AD16].

Table 25: WP 44 - Crop Area and Crop Status/Parameters Monitoring

Work Package Number	14	**Lead Beneficiary**		UCL	
Work Package Title	WP 44 - Crop Area and Crop Status/Parameters Monitoring				
Short Name of Participant (Participant Number)	GAF (1)	SIRS (2)	**UCL (4)**		
Person/Months per Participant	11.50	4.10	**7.00**		
Start Month	11	**End Month**		33	
Objectives To demonstrate a proof-of-concept system for delivering agriculture-related products on future pan-European scale by taking advantage of the continuous fluxes of Sentinel-1, 2 and 3 data, and demonstrating its potential in food insecure countries.					

This WP aims at extending S-2 processing chain to S-1 and to a larger number of crop types for crop type identification. Specifically, a classification processing chain considering multi-annual spectral signatures, is implemented on the backscattering and optical signature respectively acquired by S-1 and S-2 satellites for mapping agricultural practices, as well as explore the algorithm potential in food insecure countries.

Different methods are applied for crop type classification where S-2 data sets and integration of S-1 and S-2 data are used for calculating input features for the classifiers comprising NDVI, NDWI, BRI, maximum and minimum values, standard deviation, coefficient of variations and the 10^{th}, 25^{th}, 50^{th}, 75^{th}, 90^{th} percentiles. It is worth mentioning that the used data are subjected to pre and post processing steps serving the WP goals. The LPIS datasets, are used as references and the Random Forest (RF) classifier is used due to the efficiency on large data bases, the ability of using thousands of input variables without deletion, estimation of the relative importance of the variables and the relative robustness to the outliers, complemented with LUCAS datasets where appropriate. The classification workflow comprises predefined steps including computing the image statistics, class features generation, applying the RF classifier, applying the majority filter for harmonizing the results, calculating the confusion matrices and accuracy assessment.

Results of applying the RF classifier on S-2 data only acquired over Europe are promising (example is shown in Figure 44), especially for the tile 31UFR, where the overall accuracy is near 85%. However, the tile 31UEQ overall accuracy remains below the 70% threshold, despise various attempts to improve the classification results. Indeed, some classes are well identified, such as beets, while others, in particular potatoes and linen, still exhibit strong confusion with other classes. The rest of the classes are identified at an acceptable producer accuracy (between 63% and 77%) and a user accuracy between 60% and 78%. The final classification statistics (Table 26) show that the overall accuracy is of 77%, the producer accuracy between 46% and 96% while the user accuracy between 49% and 96% with Kappa around 0.70 and F-Score between 0.27 and 0.47.

Table 26: Accuracy assessment of crop type classification (Random Forest Classifier on S-2 datasets)

	31UEQ	**31UER**	**31UFQ**	**31UFR**	**Cropland Type**	**Cropland Mask**	**Remarks**
OA	69.03%	78.30%	78.26%	84.30%	77.08%	98.89%	Could be improved with: - a modification of the classes, - better samples - use of textural indices - use of S-1 data - reclassification of the cropland types on the cropland mask only

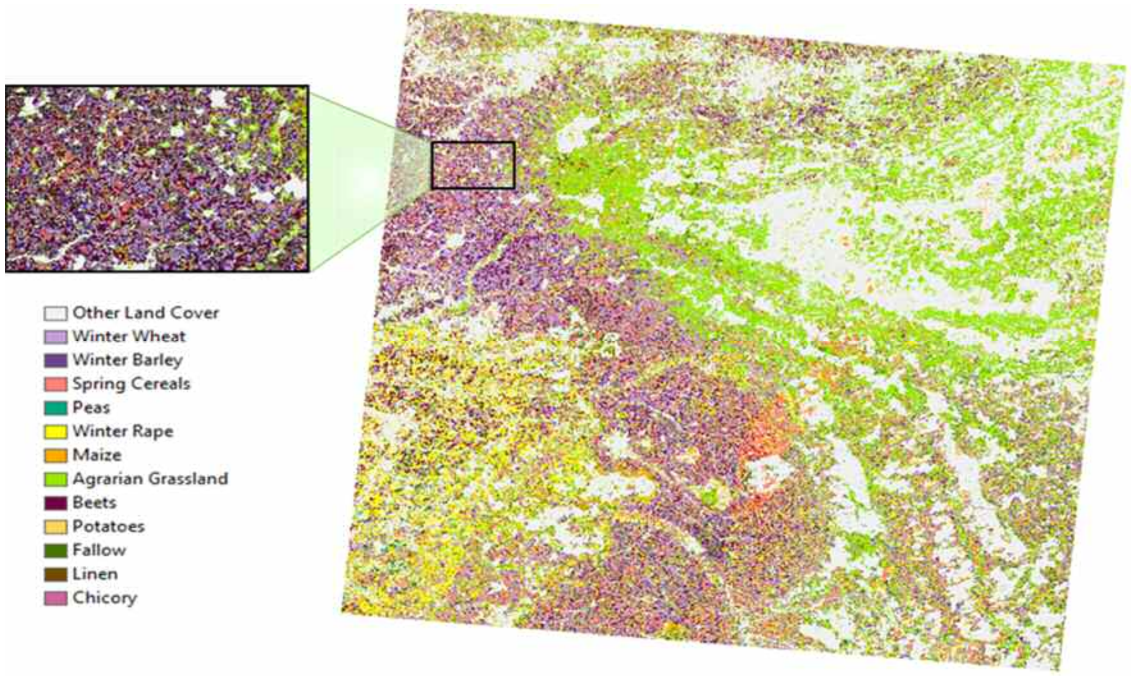


Figure 44: Classification results of crop types of one of the tiles in the demonstration site West

However, applying the RF algorithm on data sets acquired by S-1 and S-2 satellites over Europe results in relatively higher accuracy in crop type identification. Table 27 summarizes the overall accuracies obtained from applying the classifier without and with grouping similar classes in addition to the overall accuracy when applied with majority filtering within the demonstration site West. For the demonstration site Central, experiments with S-1 only, S-2 only and a combined approach using S-1 and S-2 have been tested in WP33 and will be applied next to the demo.

In phase 1, both S-1 and S-2 data were used for the classification, the OA is at approximately 89% with a Producer's Accuracy (PA) of 46-98% and a User's Accuracy (UA) of 28-95%. Regarding the crop mask classification, which was performed using the same methods as in the crop type classification the accuracies are even higher with an OA of approximately 97% (F1-Score 0.97) and a PA of 86-99% and a UA of 94-97%.

Table 27: Overall Accuracy (OA) of classification results based on specific model per tile.

OA is presented before and after grouping crop classes and applying majority filter on for the 31UFR, 31UFS and 31UES tiles

Tile	OA before grouping classes (up to 159 different classes)	OA for classes grouped (24 classes)	OA after majority filtering (24 classes)
31UFR	88.81 %	92.35 %	93.92 %
31UFS	84.13 %	88.55 %	90.76 %
31UES	82.99 %	91.13 %	93.55 %

It is worth mentioning that extending the proposed approaches to African sites (Mali) results in high classification accuracies where the overall accuracies of all applied methods are higher than 90 %. Also, high classification accuracies are obtained from integrating the high resolution layers to the crop map classification. Figure 45 provides examples of the classification results of the crop map classification in combination with the HRL Grassland 2015 in central and southern Baden-Wurttemberg.

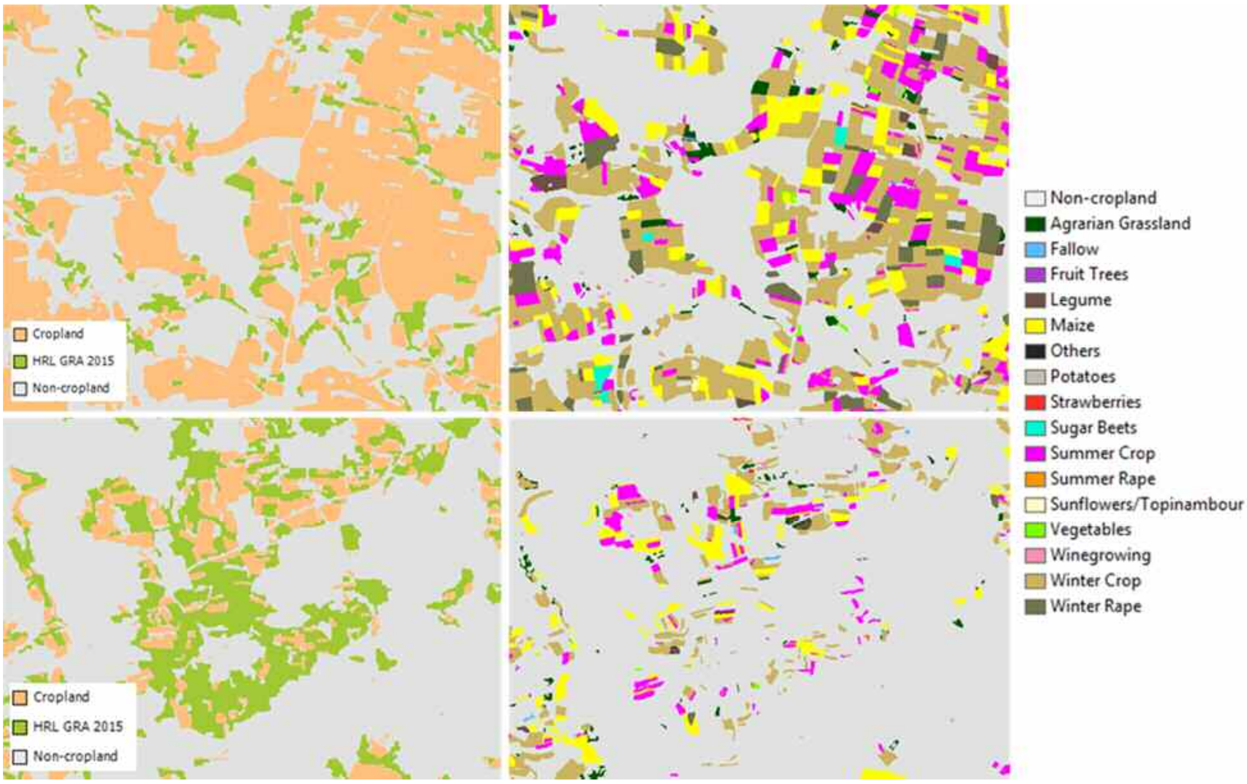


Figure 45: Results of crop map classification in combination with the HRL Grassland 2015. Central (upper Figures) and Southern Baden-Wurttemberg (below).

The results from the classification based on the combination of S-1 and S-2 are promising so far. However, in case of the prototype for the Central demonstration site further research is needed to optimize the validation methods both for the crop mask and the crop types, due to inconsistencies between the different ancillary data such as LPIS data of Baden Württemberg and those of Austria, in terms of naming and general class structure. Furthermore, those crop types, which couldn't be classified as successful as others in the test are being further analysed to be better distinguished. Such remaining issues are being addressed during phase 2 of the project. One possible approach is the stratification basing on biogeographic criteria, and other actions are related to extending the sample base. The provision of the LPIS data of Bavaria might support this in the Central demosite. However, the differentiation between the various grassland types, between managed grassland and agrarian grass types remains an issue and should be subject of further research and investigation, in coordination with some outcomes from the implementation of WP43 "Improved Permanent Grassland Identification" if suitable.

Furthermore, the development of the Crop Mask (CRM) and Crop Type Map (CRT) products will further continue over the three Demonstration sites (West, Central and Mali) and further extend to two other Demonstration sites South France and South Africa. Specifically, the emphasis will be put on the development of a pan-European crop type mapping strategy. The first step consisting in the definition of single fully compatible crop typology appropriate for the European level has been completed and used for the processing of the respective demonstration sites. The demonstration performances associated with this crop typology might provide new insights for its refinement. For the Mali site, VHR imagery has been acquired to quality control the available in situ data for the year 2018. The Sentinel-2 preprocessing for both Western Cape and Mali is still going on because of the size of these demonstration sites.

For further details, please refer to the first issue of the deliverable of WP 44 [AD20], *"D14.1_D44.1a-PrototypeReportCropAreaandCropStatusParameters_Issue 1_M17.pdf"*.

2.4.13 New LC/LU Products (WP 45)

WP45 is on "New LC/LU Products" and is mainly dependent on WP33 "Time Series Analyses for Thematic Classification" outputs, and the overall results of Task 3, as well as the outputs from WP44 "Crop Area and Crop Status/Parameters Monitoring", and from Task 4 in general.

Table 28: WP 45 - New LC/LU Products

Work Package Number	15	**Lead Beneficiary**			SIRS	
Work Package Title	WP 45 - New LC/LU Products					
Short Name of Participant (Participant Number)		GAF (1)	**SIRS (2)**	JR (3)	UCL (4)	
Person/Months per Participant		8.00	**5.90**	2.83	4.00	
Start Month	11	**End Month**		33		
Objectives To design and implement new LC/LU products from existing input products in order to fit as far as possible the current and future Copernicus Land services user needs.						

Inputs from WP 33 and WP 44 represent the foundations to design new Land Cover/Land Use products, not only built on existing datasets, but also designed to meet the future CLMS user needs. Those new LC/LU products will therefore be based on Sentinel data, optical and SAR, and will present an increased spatial resolution compared to existing pan-European land cover products such as CLC to fit all actual and future CLMS production requirements.

To do so, the state of play for the availability of the required data is sketched, depending on the production need for new LC/LU products. Combined with the refinement of the definition of thematic classes, possibly following the EIONET Action Group on Land monitoring in Europe (EAGLE) recommendations, this should enable the implementation of a new HR LC layer, that will then be validated at pan-European level.

Few previous attempts at global land cover mapping can be found, among which the CORINE Land Cover and the different declinations of the Global Land Cover (GLC), presenting a medium spatial (100m at best) and low temporal resolutions dataset (every 5 years at best, before a new update in the case of CLC). Moreover, there is uneven representation of landscape characteristics depending on the bio-geographical situation.

The creation of a pan-European HR LC layer could be obtained by merging together all the currently available layers, in addition to the new agricultural prototypes as developed in WP 44. This merge constitutes an opportunity to enforce a logical consistency between the current and upcoming thematic products, which are being produced independently, without requiring post-processing to ensure the spatial and temporal coherence.

The new production of 3 New Land Cover Prototypes will be performed in the South-West, Central and West demonstration sites. The South-West site covers the south of France, small parts of Spain and the Principality of Andorra in the shape of 6 Sentinel-2 tiles, while the Central site covers 9 S-2 tiles over the South of Germany, part of Austria and a few areas from France, Switzerland, Italy and Liechtenstein. The West demonstration site covers Belgium, part of the North of France and the Luxemburg. To produce the New Land Cover Prototypes, two different methodologies will be adopted. The first workflow is a newer version of the one adopted for the first phase still ensuring a level of automation that could be applied at European scale, that is inspired by the CLC+ work documents:

1. The image processing uses raw S-2 data as input. Interpolated version of the time series to fill in the gap left by the clouds is produced for each band, and features such as spectral indices (NDVI, NDWI and BRI) are computed based on those interpolated images.
2. The generation of the hardbone – a fixed skeleton which represent persistent object borders in the landscape – is based on different ancillary data;
3. Several different segmentation algorithms are currently tested, in order to take into account the multi-scale variability of each landscape. The Large-Scale Mean Shift Segmentation (LSMSS) that

created the softbone over the South-West in the first phase, which is an aggregation of persistent landscape objects, represented by polygons over the whole AOI, will be improved in this phase;

4. The skeleton and those segmentation test will be merged with a Minimum Mapping Unit (MMU) of 0.5ha;
5. The pixel based classification, a Random Forest (RF) algorithm, uses reference databases (50% of the samples for calibration and 50% of the samples for validation) to generate a first map, that is harmonized with a majority filter, before aggregating the results with the softbone and the hardbone and cleaning the output by eliminating isolated pixels.

The hardbone and the softbone are generated separately from the image processing. Several reference datasets are required for the creation of the hardbone, and following geometric rules, selected information of those databases is merged according to a fixed priority order. The Open Street Map (OSM) dataset sets the lines of roads and railways, the EU-Hydro beta release combined with the WAW HRL 2015 the canal and river networks and other permanent water bodies, the Forest and IMD HRL 2015 a delineation of tree-covered and urban areas, and finally, the CLC 2012 provides a schematic cropland area, based on a selection of various crop types that are extensively cultivated in the region. The result over the Central test site for the hardbone process can be seen in Figure 46.

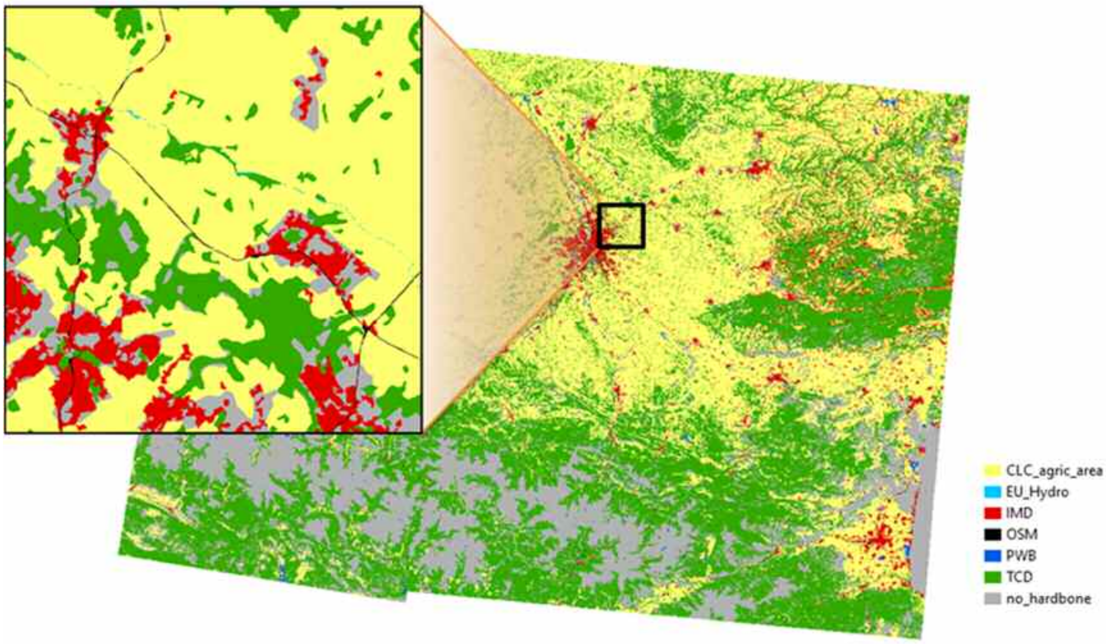


Figure 46: NLC Hardbone over the South-West demonstration site

For the softbone step, a selection of most cloudless images is stacked and fed to a Large-Scale Mean Shift Segmentation (LSMSS). The generated shapefiles (see Figure 47) contain mean and variance information for polygons regarding the possible membership to each layer. The determining parameter, the Minimum Segment Size (MSS) in pixels has to be adjusted by trials and errors, and may be depending on the considered region.

In order to harness the discrimination potential of elements of various size, the 3 layers (with a MMS of 15 pixels, 200 pixels and 500 pixels) generated by the segmentation algorithm will be merged into a single layer in order to emulate the creation of a multi-scale segmentation. This work is still in progress at the writing of this preliminary report and is expecting to be quite challenging.

Therefore, no fusion of the improved softbone (compared to phase 1, where the softbone at 15 pixels was selected) and the hardbone has been done yet. However, pixel-based optical classifications are being run in parallel, with different hyperparameters and sampling strategies.

Figure 47: NLC Softbone: result of the segmentation for a MSS of 15 pixels.

The softbone is able to discriminate fine details such as isolated patches of urban area.

Other MSS have been tested (at 200, 500 pixels) but did not lead to conclusive results

Other segmentation algorithms, such as the k-means, are being investigated in order to bypass this minimum segment size parameters. Results from the WP41 on the Maximal Activity Phenology Layer showed in the first phase that this particular algorithm would lead to satisfying and coherent results at field scale.

The RF classification is based on relevant in-situ data sources such as the historical HRL 2015 IMD, Forest, Grassland and the water class from the HRL Water and Wetness – but also on CLC2018 as well as LUCAS dataset. The 12 classes for the last version of the CLC+ nomenclature can be listed as:

- Sealed areas (1);
- Woody needle leaved trees (2);
- Woody Broadleaved Deciduous (3);
- Woody Broadleaved evergreen (4);
- Woody Shrub (5);
- Permanent Herbaceous – grasslands (6);
- Periodically Herbaceous – arable lands (7);
- Lichens and Mosses (8);
- Sparsely Vegetated (9);
- Non-vegetated – bare rocks, scree, sand, lichen, permanent bare soils (10);
- Water (11);
- Snow and Ice (12).

The repartition of the LUCAS points available, and used in the manual selection of sampling data, over the test site for South-West (S-2 tiles **31TCJ and 30TYP)** can be found in the Table 29.

Table 29: Available points in the LUCAS dataset from 2018 (31TCJ and 30TYP S-2 tiles).

Last version available of the nomenclature	Matching points over the test site in LUCAS	Matching polygons in CLC 2018
1. Sealed (Buildings and flat sealed surfaces)	110	1131
2. Woody needle leaved trees	39	375
3. Woody Broadleaved Deciduous	335	2440
4. Woody Broadleaved evergreen	0	0
5. Woody shrub	19	422
6. Permanent herbaceous (grassland)	370	1013
7. Periodically herbaceous (arable land)	633	1085
8. Lichens and mosses	0	-
9. Sparsely vegetated	-	0
10. Non vegetated (Bare rocks, scree, sand, lichen, permanent bare soils)	29	2
11. Water	9	154
12. Snow and Ice	0	0

The best results are reached when at least 50 points are used per class and can be seen over the Toulouse region in the Figure 48. The use of random forest requires an equal number of points or polygons per class.

As seen in Table 29, woody shrub samples could be automatically selected from polygons in the 324 CLC class. However, since this class characterizes transitional land covers, at a minimal mapping unit of 25ha, the automated addition could potentially degrade the classification results if many evolutions have taken place in the landscape. It is also expected that the large spatial resolution may lead to the aggregation of mixed pixels, such as woodlands and bare soils, due to clear cuts, with potential shrub and forest regrowth resulting from older cuts, which would also lead to expected confusion in the classification results, due to the variability in the spectral and temporal signature. This work to refine the sampling selection step is still in progress.

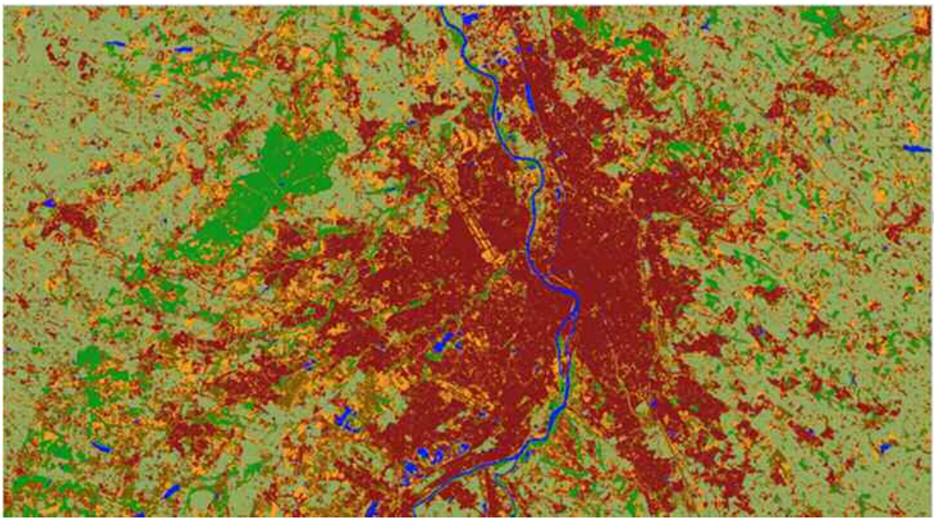


Figure 48: NLC CLC+ classification test.

Sealed areas (red), forest (grey), water (blue), grasslands (orange), annual crops (green) and permanent crops (brown).

The water class can be completed at the moment with pan-European layers such as the WaW HRLs 2015 status layer. However, the other classes are quite rare over the chosen test site. Despite their presence in the CLC nomenclature, the minimal mapping unit of 25ha also leads to an extremely reduced number of polygons. The confusion matrix of the classification over the South-West tests site can be found in the Table 30.

Table 30: Confusion matrix for the 2 tiles over the South-West site, with the classes only tested at the moment.

	sealed areas	annual crops	permanent crops	grasslands	forest	water
sealed areas	13024.00	20.00	2153.00	1169.00	32.00	181.00
annual crops	1869.00	93437.00	4266.00	2380.00	31.00	0.00
permanent crops	6401.00	7945.00	68375.00	6056.00	938.00	1449.00
grasslands	144.00	1240.00	3366.00	8717.00	273.00	0.00
forest	5.00	0.00	342.00	49.00	31122.00	69.00
water	66.00	190.00	106.00	78.00	7.00	12493.00

The kappa score is at 0.791, while the overall accuracy of the classification is at 0.85.

Since multi-scale segmentation can be quite time- and resource-consuming to run at such scales (temporally for the time series, geographically for the surface covered as well as spectrally for all the bands used) and the methodology proposed here is a compromised that will be evaluated over the South-West test site before being tested over the Central tiles. The mock-up of a multi-scale segmentation will still need to be demonstrated to be operationally working over large areas.

Several classes (woody shrub, lichens and mosses, sparsely vegetated and non-vegetated) will be quite tricky to sample for the training of the classifier. The obtainment of spectrally pure samples will be challenging for those classes, in part because of the various land covers that can be categorized in them, and also because samples at pan-European level will mostly be provided by CLC2018, with a spatial resolution of 25ha.

Besides the CLC related New LC layer described above, a pan-European HR LC layer was tested in three of the European demonstration sites (South West, West, Central) by merging together all the currently available HRLs of the year 2015 (Imperviousness, Forest, Grassland, Water and Wetness). In addition to that for the Central and West site the new agricultural prototypes, namely the crop mask (CRM) as developed in WP 44 (where possible) were used for the combined layer. The merge of all HRLs plus the crop mask partly leads to overlaps between different layers which need to be checked for plausibility. This analysis is currently ongoing and will be carefully described in the upcoming second issue of the *"D15.1_D44.1a-Prototype Report New LCLU Products"*. Generally speaking, this merge constitutes an opportunity to enforce a logical consistency between the current and upcoming thematic products, which are being produced independently, without requiring post-processing to ensure the spatial and temporal coherence.

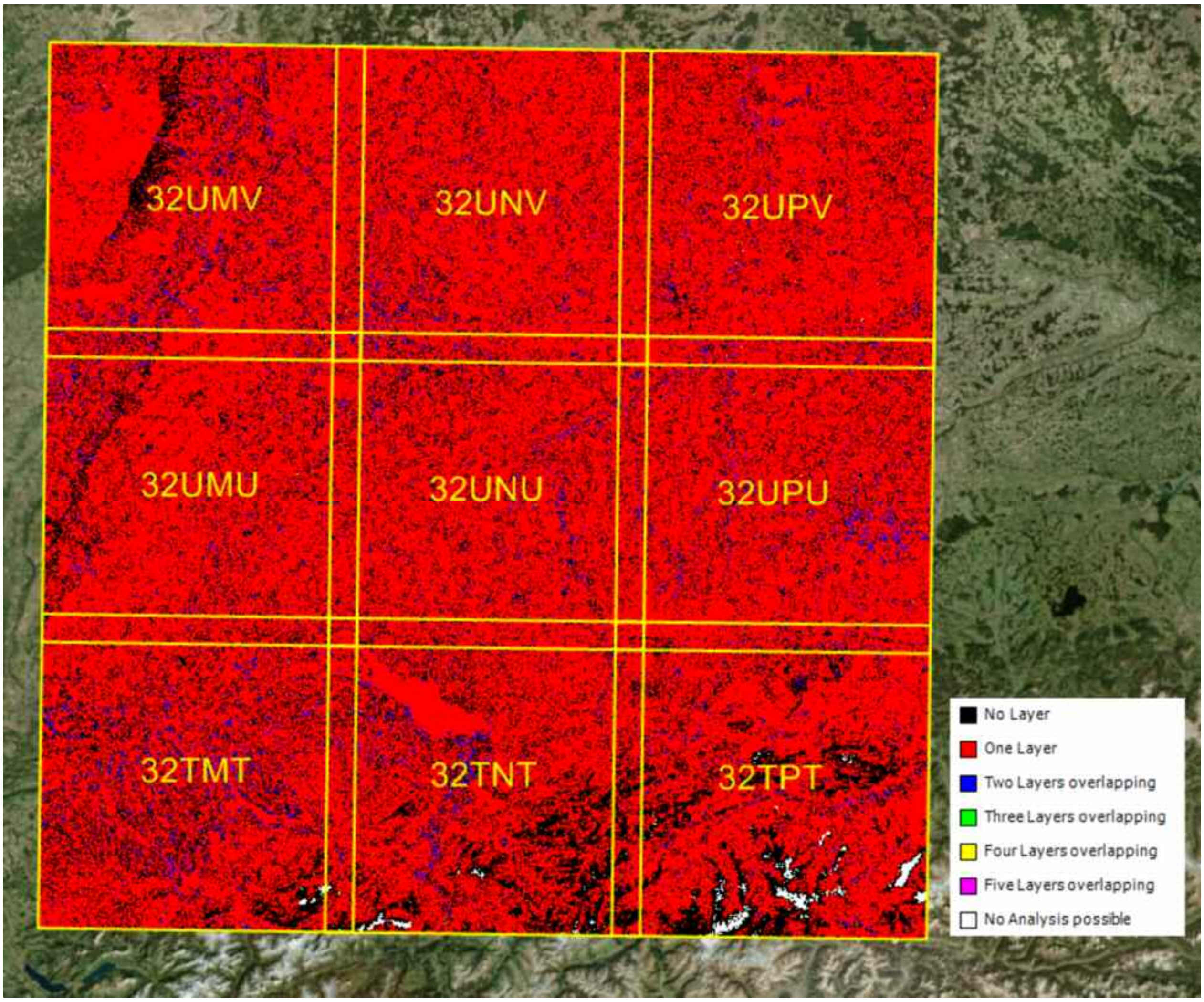


Figure 49: Merge between all 2015 HRLs (IMP, FOR, GRA, WAW)

Figure 49 shows the HRLs consistency in the sense that most pixels do not present overlap (red) being assigned to a single HRL product. If any, overlap occurs mainly between two HRLs (blue). As expected, it is along linear elements where inconsistencies are more recurrent. Spatial resolution limitations and the pixels containing the exact border between categories explain this fact, commonplace in classification products.

For further details, please refer to the first issue of the deliverable of WP 45 [AD21], *"D15.1_D44.1a-PrototypeReportNewLCLUProducts_Issue 1_M17.pdf"*.

2.4.14 Stakeholder Consultation (WP 51)

WP 51 is on "Stakeholder Consultation" and is in closely coordinating with WP 21 "Assessment of Service Evolution Requirements" and WP 61 "Communication, Dissemination and Exploitation". The outcomes of WP 51 have a high influence on the prototype developments in Task 4, and serve as input to the WPs 52 "Candidates for Operational Roll-out" and 53 "Integration Plan into Copernicus Service Architecture" as part of the Operationalisation Framework.

Table 31: WP 51 – Stakeholder Consultation

Work Package Number	16	**Lead Beneficiary**		GAF		
Work Package Title	WP 51 – Stakeholder Consultation					
Short Name of Participant (Participant Number)		**GAF (1)**	UCL (4)			
Person/Months per Participant		**2.90**	3.00			
Phase 1	**Start Month**	7	**End Month**	18		
Phase 2	**Start Month**	22	**End Month**	34		
Objectives: To conduct a stakeholder consultation process with EC, EEA, JRC and others in order to gather their feedback on the project's technical developments and adaptation needs, to assess current and evolving priorities and to allow an informed discussion on their side.						

WP 51 Stakeholder Consultation is the first part of Task 5 "Operationalisation Framework", in which the future conditions, under which new/improved Copernicus Land products will (or will not) qualify as operational Copernicus Land service candidates, will be assessed. It specifically has to ensure the proper involvement of main stakeholders and decision-makers in this assessment process, through regular consultations with the main stakeholders such as EEA, JRC, EC DGs and key national stakeholders. In these consultations, the developed proofs-of-concepts/prototypes of Task 4 are discussed and assessed, particularly in phase two of the project, in order to determine priorities/adjustments for the continuation of work and seek the stakeholders' view/approval of suggested operational candidates.

The most recent Deliverable *D16.3: "D51.1c - Stakeholder Consultation Report"* [AD22] is the third report of WP 51 and has been delivered at M27 (March 2019). Because of the paramount importance of the stakeholder process for ECoLaSS, it has been agreed that four Issues of this Deliverable shall be provided in the course of the project, each providing the latest status update on stakeholder involvement and related achievements of the project. The current 27-month phase has focussed on establishing a close relation and information exchange between the ECoLaSS project and the relevant stakeholders as well as to collect their key user requirements in two assessments.

The Deliverable D51.1 has a close link to WP 21 "Assessment of Service Evolution Requirements" with its main Deliverable *"D21.1a – Service Evolution Requirements Report"* [AD09], in which the results of user and stakeholder interviews are documented and the functional and technical evolution requirements of existing and upcoming services of the Continental and Global CLMS Components are collected and consolidated. In practise, gathering the stakeholder requirements in the frame of WP 21 and consulting with stakeholders on the planned service developments in WP 51 often went hand in hand throughout the first 27 months of the project. Whereas the first, second and third Issues of the WP 51 Stakeholder Consultation Report comprehensively document the entire stakeholder consultation process as such, the related thematic recognitions in terms of CLMS evolution are currently mostly documented in the Deliverable "*D21.1a – Service Evolution Requirements Report"*, and are therefore not repeated in the WP 51 reports.

In view of the collected information, the project team gained many valuable insights into future CLMS product needs and about the perception, use and further needs with respect to the CLMS products by the various stakeholders.

For a Horizon2020 project like ECoLaSS, with clearly defined tasks and resources, it would be generally not possible to individually interact with the entirety of potential stakeholders on a single basis. Therefore, the ECoLaSS team has taken on the approach of consulting in as many cases as possible with federating entities of relevant stakeholder segments, or proxies of relevant bigger groups of stakeholders. These allow to comprehensively address, or interact with, a large group of stakeholders in an efficient manner.

Summarising the project's achievements in stakeholder consultation from M1-M27, substantial and fruitful interactions have been taking place with all major relevant European (EEA, JRC, DGs GROW, ENV, CLIMA, AGRI, REGIO, DEVCO) and many national stakeholders in key Member States (e.g. DLR, BKG, UBA, EAA, IGN, CGDD, NRCs etc.), as well as with a multitude of further stakeholder groups (EARSC, parallel H2020 projects, ESA projects, operational CLMS services). German and French National Copernicus Meetings/Fora were attended by GAF and SIRS, respectively, and ECoLaSS was presented there. Further Copernicus Meetings and Copernicus conferences/fora organised by the EC or EEA, e.g. upon invitation or suggestion of the EC (e.g. the Copernicus Data Access and Contributing Missions Workshop, CCI+ Information Day, the EEA Land Monitoring & CLC+ Workshop, the Copernicus for Agriculture - Industry Workshop, the Copernicus Event "20 years Baveno Manifesto", IACS Workshop, etc.), have been attended in until M27. Several further opportunities for consultation of relevant stakeholders have been used in the frame of international scientific, Earth Observation and Copernicus conferences and workshops (such as WorldCover, ISRSE, MultiTemp, IUFRO, MARS Conference, Big Data from Space Conference, PROBA-V Symposium, EARSeL/NASA LCLU Workshop, IGARSS Conference, INSPIRE Conference, etc.). This was facilitated by the consortium partner's collective unique positioning in the Copernicus and land monitoring community, as well as by a sophisticated stakeholder consultation concept, building on a dual strategy of targeted stakeholder meetings and using basically every opportunity for back-to-back meetings. Therefore, the consortium considers the WP 51 to be fully on track as planned.

Some improvement potential had been recognised already in the first half of the first Reporting Period in view of the intensity of the exchange with the JRC unit responsible for the global CLMS component (i.e. the team of Michael Cherlet). Although a dedicated focus had been put on this throughout the first 27 months of the project and every opportunity was used to meet with the respective JRC colleagues alongside Copernicus-related workshops and events, it has to be conceded that the desired aim of establishing a dedicated JRC-(EEA)-ECoLaSS meeting could not be achieved yet. However, in late 2018 a dedicated exchange meeting with the H2020 sister projects and representatives of EEA, JRC, EC DGs and the EC was held in Brussels, Belgium. Since this meeting was very much appreciated by everybody involved a follow-up meeting was scheduled for early April 2019 organised by the SENSAGRI project team.

Another aspect for improvement that was recognised during the project (M1-18) was the fact, that there was still room for more interaction with national stakeholders. This was successfully addressed by designing and executing a webinar dedicated to the EIONET NRCs Land Cover, which was held on October 18th 2018. In the same context the addressed NRCs were encouraged to provide their specific needs regarding the already available and potential future CLMS products.

The close and fruitful contacts with EEA will be continued. Some further potentially relevant entities may be addressed as the opportunities arise. In view of the collected information, the project team gained many valuable insights with respect to future CLMS product developments and the perception, use and further needs of the various stakeholders with respect to the CLMS products.

The outcomes of WP 51 are documented in detail in the related Deliverable *"D51.1c Stakeholder Consultation Report (Issue 3)"* [AD22].

2.4.15 Candidates for Operational Roll-out (WP 52)

The main scope of WP 52 is on benchmarking and identifying those candidate new/improved Copernicus Land products which will finally prove fit for operational service roll-out. WP 52 is directly dependent on the processing methods benchmarked and analysed in Task 3, as well as on the thematic prototypes developed in Task 4, which act as the core input information.

Table 32: WP 52 - Candidates for Operational Roll-out

<table>
<tr><td>Work Package Number</td><td>17</td><td colspan="3">Lead Beneficiary</td><td colspan="2">GAF</td></tr>
<tr><td>Work Package Title</td><td colspan="6">WP 52 - Candidates for Operational Roll-out</td></tr>
<tr><td colspan="2">Short Name of Participant (Participant Number)</td><td>GAF (1)</td><td>SIRS (2)</td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Person/Months per Participant</td><td>4.30</td><td>2.30</td><td></td><td></td><td></td></tr>
<tr><td>Start Month</td><td>13</td><td colspan="2">End Month</td><td colspan="3">35</td></tr>
<tr><td colspan="7">Objectives
To benchmark the Copernicus Land prototype products against a set of performance/maturity criteria (which will be elaborated during the project), in order to assess their overall readiness for future operational implementation and identify those prototypes which qualify as candidates for operational roll-out.</td></tr>
</table>

The main focus of the benchmarking procedure is on assessing the service candidates' overall readiness for future operational implementation in order to provide direct benefit to the operational CLMS from 2020 onwards. The results of the first benchmarking process are fully documented in the Deliverable *"D52.1a - Report of Candidates of Operational Roll-out"* [AD23].

The following benchmark criteria appear imperative and have finally been chosen for the benchmarking process:

- representing a **long-term service evolution challenge,** rather than becoming likely part of "regular" service maintenance and enhancement efforts covered already by the current tasks delegated to the EEEs through the Copernicus work programme and funding until 2020 (e.g. in the latest Copernicus 2015 projects and upcoming Copernicus calls 2018);
- maintaining a sufficient level of **complementarity with respect to the Copernicus portfolio,** and alignment to the **current and upcoming Copernicus Land service environment's overall logic and setup**;
- answering to identified **high-priority evolution needs** (as e.g. listed in the *Guidance Document*) in response to known shortcomings;
- having **political support** (e.g. from EEEs side);
- respecting the border between **Copernicus core services** and **downstream (DS) services**;
- being based on the **latest scientific state of the art**;
- providing **appropriate timing**, which will allow that R&D results will become available in a sufficiently timely manner in order to support an informed stakeholder discussion, thus enabling smooth integration into the calendar of future operational Copernicus Land Monitoring service procurements;
- providing overall **technical maturity**;
- **operational feasibility** in terms of adequate (future) availability of:
  - (i) required EO/in-situ input data,
  - (ii) data processing and handling capacities, as well as
  - (iii) related hardware/software solutions and processing infrastructure;
- reaching a **high level of automation**, thus avoiding undue efforts and costs for manual interaction;
- providing convincing evidence of **service roll-out potential to pan-European level**;
- showing a good trade-off between expected costs and information gain by means of a **positive cost/benefit analysis**;
- availability of a **proper documentation** of methods and product/service specifications;

- **non-limiting conditions** for making the results (including IPR) available to the EEEs, their contractors and service providers, for use and exploitation. It is assumed that this wil be non-limiting in any case, therefore it is not included in the evaluation.

The results of the benchmarking analysis are compiled in Table 33. A qualitative evaluation has been applied, ranking from:

- very satisfactory/relevant/applicable (++)
- satisfactory/relevant/applicable (+)
- neutral (o)
- not satisfactory/relevant/applicable (-)
- not at all satisfactory/relevant/applicable (- -)

Moreover, an overall score for each prototype has been calculated by applying between five (for the rating ++) and one (for the rating - -) points to each of the benchmarking criteria (see Table 33).

The highest overall scores could be retrieved for the prototypes “Incremental IMD Change”, “Improved Grassland Status Layer at 10m”, and “Incremental Forest Change” which can therefore be concluded to be the overall most promising candidates for future roll-out as operational CLMS products 2020+.

These most promising prototypes were closely followed by “Improved IMD Status Layer at 10m”, “Improved DLT Status Layer at 10m”, and “New Crop Mask Status Layer at 10m”. A little further behind are the “New Crop Type Status Layer at 10m” and “Crop Growth Condition”. These five prototypes show potential for implementation as future CLMS products 2020+.

The least points were retrieved for the prototypes “CLC Evolution”, “Crop Emergence Date Map”, “Generic Land Cover Metrics” and “Multi-Annual Trends and Potential Change”, which are interpreted not yet to be mature enough for a roll-out as future operational CLMS products 2020+. Phase 2 of the ECoLaSS project is currently addressing and improving all of the abovementioned prototypes in a second round, which will conclude to a final evaluation of the roll-out potential of the prototypes as future operational Copernicus Land product 2020+.

Table 33: Benchmarking evaluation of candidates for operational roll-out in project phase 1

	Service/product candidate	long-term evolution	portfolio comple-mentarity	answering identified needs	political support	respecting core vs. DS	State of the art/Innovation	Maturity/ Timing	adequate EO availability	adequate in-situ availability	processing capacity (platform, SW)	Automation level	pratically proven Roll-out potential	Cost/ benefit (forecast)	Documen-tation	Overall score
WP 42 Imperviousness incremental update	improved IMD status layer at 10m	-	o	+	++	++	+	++	++	+	++	++	+	+	+/++	59,50
	incremental IMD change	++	+	++	++	++	++	+	+	o	++	+	+	+	+/++	61,50
WP 42 Forest incremental update	improved DLT status layer at 10m	-	o	+	++	++	+	++	++	+	++	+	+	+	+/++	58,50
	incremental forest cover change	++	+	++	++	++	o/+	+	+	o	++	+	+	+	+/++	60,00
WP 43 Improved Grassland	Improved Grassland status layer at 10m	o	o	++	++	++	+	++	++	+	++	+	+	+	+/++	60,50
WP 44 New Agriculture product	New crop mask status layer at 10m	++	++	++	-	++	++	o	++	-	++	+	+	+	+/++	58,50
	New crop type status layer at 10m	++	++	++	-	++	++	o	++	--	++	+	o	+	+/++	56,50
WP 45 New Products	CLC evolution	+	+	++	+	++	++	o	++	o	o	o	-	+	+	54,00
WP 41 Time series indicators	Crop growth condition	++	+	+	o	o	++	+	++	--	++	++	+	+	+	56,00
	Crop Emergence Date Map	++	+	o	o	o	++	o	+	--	++	+	+	+	+/++	52,50
	Generic Land Cover Metrics	++	+	+	+	+/++	+	-	+	o	++	o	-	+	o	51,50
	Multi-annual trends & potential change	++	+	o	o	+/++	+	-	++	o	++	o/+	-/o	+	o	51,50

++	very satisfactory/relevant/applicable
+	satisfactory/relevant/applicable
o	neutral
-	not satisfactory/relevant/applicable
--	not at all satisfactory/relevant/applicable

2.4.16 Integration Plan into Copernicus Service Architecture (WP 53)

WP 53 is on the “Integration Plan into Copernicus Service Architecture” within Task 5 “Operationalisation Framework”. The main inputs are results of the other Task 5 WPs, i.e. WP 51 “Stakeholder Consultation” and WP 52 “Candidates for Operational Roll-out”.

Table 34: WP 53 - Integration Plan into Copernicus Service Architecture

Work Package Number	18	**Lead Beneficiary**			SIRS	
Work Package Title	WP 53 - Integration Plan into Copernicus Service Architecture					
Short Name of Participant (Participant Number)		GAF (1)	**SIRS (2)**			
Person/Months per Participant		2.80	**2.30**			
Start Month	13	**End Month**		36		
Objectives To develop an appropriate integration plan for new and improved product into the Copernicus service architecture.						

The setting-up of an integration plan in WP 53, which will represent one of the main outcomes of ECoLaSS at the end of project phase two, will facilitate the formal process of integration of the candidate new/improved products specified in WP 52 into the Copernicus Land Monitoring programme and service architecture.

By the time of writing the first Periodic Report, the work in WP 53 was slightly delayed, due to the knock-on effect of the delayed WP 52 results. Nevertheless, the first-phase main activities were concluded, and the respective WP 53 results presented in Deliverable “D53.1 Integration Plan into Copernicus Service Architecture”, fully documenting the task outcomes.

The integration into the Copernicus service architecture is expected to distinguish two main mechanisms for integrating operational candidate products:

- Products which constitute improvements of existing Copernicus Land products will be easier to integrate, and the related integration plan 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 (such as e.g. the HRLs 2021).
- For newly developed products, a careful assessment will need to be undertaken to examine how and when they could be integrated into the then existing Copernicus Land service architecture in terms of availability of respective funds/budget lines, policy relevance and complementarity with other products.

In either case, the considered new products and/or product improvements have been deemed to have reached a Technical Readiness Level (TRL) of at least 6-7, 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 and the related Copernicus Reference Data Access (CORDA) will also be carefully monitored to ensure relevant data sources are available in time for the integration of these product into the Copernicus Land service architecture. The following products have been reviewed:

- The improved Imperviousness layers;
- The improved Forest layers;
- The improved Grassland layers;
- The new Crop mask.

In phase 1, the feasibility of an increase in spatial resolution, from 20m to 10m, for the status layer has been successfully tested for the IMP, FOR and GRA products. Change layers have been generated at a 20m resolution, in order to ensure a smooth transition. The phase 2 will assess the feasibility of a yearly update at 10m, as well as the possibility to use DIASes to produce the layers.

The imperviousness layers, composed of the new status layer for 2017 and the change layer at 20m between 2015 and 2017, take full advantage of the optical data of S-2 but further exploration is planned in phase 2 to integrate the S-1 data. Both layers have been deemed operational and have been included in the ITT 2018. Two new products will be also tested, the building footprint mask as well as continuous scale change layer for the degree of imperviousness.

The forest layers, composed of the new status layer for 2017 and the change layer at 20m between 2015 and 2017, take full advantage of the optical data of S-2 but further exploration is planned in phase 2 to integrate the S-1 data, as it has become a strict requirement in the 2018 ITT, just like both layers which have been deemed operational. Two new products will be also tested, an improved continuous tree cover density layer and a new tree cover density change layer.

The grassland status layer has undergone significant modifications in its specifications, based on a multi-temporal approach, integrating optical/SAR-based processing chain using the entire S-1 and S-2 archives. Change detection and approaches to discriminate between intensively and extensively used grassland will be addressed in phase 2.

The Crop Mask is the only completely newly designed prototype that shows all signs of being mature enough at the moment for operationalization in the near future. The prototype has been produced for three different sites; two sites in Europe i.e. Central and West and for the African demo site in Mali. However, the crop mask prototype for the Mali site is 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. The crop mask is a binary and completely new product, which is based on both optical and radar input data.

Most of the activities during phase 1 of ECoLaSS have focused on the improvement of existing products and on the development of new products. However, although exhibiting the right potential, the new products, in particular the new Phenology products as well as the new generation of land cover products, seem to be at a too early stage, and further work during phase 2 is required before the new candidate products can be considered ready for full operational roll-out and integration into the Copernicus Land portfolio. The availability of input EO data will also be reassessed at the end of Task 5, in the continuity of the Task 2, with an emphasis on the WP22.

The outcome of WP 53 is captured in the Deliverables "*D53.1 - Integration Plan into Copernicus Service Architecture"* [AD24], primarily aimed at giving recommendations to the EEEs, and in "*D53.2 White Paper on Copernicus Land Evolution*" [AD29], directed mainly towards decision makers in the EC. The D53.1 Integration Plan will focus on outlining a roadmap towards the integration of improved and new products into the Copernicus service architecture. On the other hand, the Deliverable D53.2 is basically focus on summarising the outcome of the whole Task 5 and providing the rationale behind each suggested operational candidate product, together with a related clear justification as to why it should become part of the Copernicus service evolution, specifically in view of policy requirements and stakeholder needs. This White Paper, drafted at the end of phase 1 and fully completed at the end of phase 2, will be most relevant and meaningful towards the end of the project when the respective investigations will have been concluded.

At present, the outcome of WP 53 is captured in the Deliverables "*D53.1 - Integration Plan into Copernicus Service Architecture"*, primarily aimed at giving recommendations to the EEEs, and in the preliminary D53.2 White Paper on Copernicus Land Evolution, directed mainly towards decision makers in the EC. The D53.1 Integration Plan focuses on outlining a roadmap towards the integration of improved and new products into the Copernicus service architecture. On the other hand, Deliverable D53.2 basically focuses on summarising the outcome of the whole Task 5 and providing the rationale behind each suggested operational candidate product, together with a related clear justification as to why it should become part of the Copernicus service evolution, specifically in view of policy requirements and stakeholder needs. The final version of the White Paper will be most relevant and meaningful towards the end of the project when the respective investigations will have been concluded. The first draft issue can only be a first outline of that [AD29].

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

2.4.17 Communication, Dissemination & Exploitation (WP 61)

This sections describes the activities carried out for the WP 61, which is dedicated to "Communication, Dissemination & Exploitation" and is as such, connected to all activities and developments carried out in the project throughout the full project runtime and beyond.

Table 35: WP 61 – Communication, Dissemination & Exploitation

Work Package Number	19	**Lead Beneficiary**	DLR		
Work Package Title	WP 61 – Communication, Dissemination & Exploitation				
Short Name of Participant (Participant Number)		GAF (1)	SIRS (2)	JR (3)	UCL (4)	**DLR (5)**
Person/Months per Participant		1.70	1.90	1.06	1.50	**1.15**
Phase 1	**Start Month**	4	**End Month**	18	
Phase 2	**Start Month**	19	**End Month**	36	
Objectives: To define and perform communication, dissemination and exploitation activities during the project in order to promote the new/enhanced Copernicus Land information product developments and findings of the project.					

Objective of WP 61 "Communication, Dissemination and Exploitation" is to define and perform communication, dissemination and exploitation activities during the project, in order to promote the new/enhanced Copernicus Land products developments and findings of the project. This is being done through i) communicating within the project team and with stakeholders (e.g., EEA, EIONET group, JRC) by means of technical meetings, workshops etc.; ii) defining specific dissemination actions tailored for the different defined target groups; iii) preparing communication and dissemination media for providing information on the project status and ongoing activities, e.g., through the website, social media, project flyer, etc.; and iv) coordinating dissemination activities on dedicated conferences and workshops as well as in scientific publications.

Several activities are actively being pursued for dissemination and exploitation of the project results via different channels which aim at providing the project results to the stakeholders and users as soon as possible and at different levels of detail, throughout the project's lifetime as well as in the follow-up of the project. All these activities are detailed in the deliverable "*D19.2_D61.2a_Communication, Dissemination and Exploitation Plan_Issue 1_M9"* (PEDR) of the ECoLaSS project, and have been updated in the second issue "*D19.3_D61.2b_Communication, Dissemination and Exploitation Plan_Issue 2_M27"* [AD26] (PEDR). The PEDR comprises a roadmap for implementing various dissemination and promotional activities in the project, tailored towards diverse target audiences and is used by the consortium to measure the dissemination progress over time. Communication activities of the project team with the relevant stakeholders (e.g. EEA, EIONET group, JRC) by means of technical meetings, workshops etc. are highlighted. Dissemination and exploitation measures such as project flyers, publications in scientific journals and conference proceedings, presentations and posters as well as on the project website are described in detail. In addition, Deliverable *"D19.4_D61.3_Collection Of Communication And Dissemination Material_Issue 1_M18"* [AD26] documents all papers, abstracts, presentations, posters, videos, press releases etc., as a Collection of Communication and Dissemination Material up to M18, end of phase 1. The second and final issue of this report will be delivered at M36, compiling the materials by the end of phase 2 (i.e., end of the project).

One of the dissemination measures described in the PEDR is the project website. It has been set up at www.ecolass.eu and is maintained and regularly updated throughout the project's lifetime. It was delivered by M6 with the corresponding deliverable: "*D19.1_D61.1 ProjectWebsite_Issue 1_M6"* [AD25]. The website instrument aims at providing information about the ECoLaSS project including background, the members of the consortium, the test and prototype sites of the project, as well as up-to-date information about ongoing activities, e.g., the participation in relevant events. Furthermore, it provides contact details and links to other outreach instruments, such as social media channels or the blog. Once accepted, all (public) deliverables are being published online to achieve maximal transparency and outreach.

Since the webpage serves content to a diverse audience, it has been recently restructured in a way to provide multiple levels of depth of content. A high-level overview for users not yet familiar with the project or users without in-depth understanding of remote sensing or Copernicus Services is served under "Home" and "About". Next, a more detailed breakdown of the ECoLaSS findings, methods and products for audiences familiar with the technical specifics is provided under "Developments & Findings". Lastly, the in-depth technical documents on prototype developments, methods compendia and other project deliverables are provided as embedded documents for expert users, as are all publications originating from the project which are allowed to be distributed as open-access.

Figure 50: ECoLaSS website: Main Page

Other outreach instruments abovementioned are social media channels and the blog. The blog https://www.ecolass.eu/news-events informs users more in detail about new developments or important events of the ECoLaSS project. It includes articles with additional detail compared to social media which are mainly supplemented with graphics or videos and shorter statements.

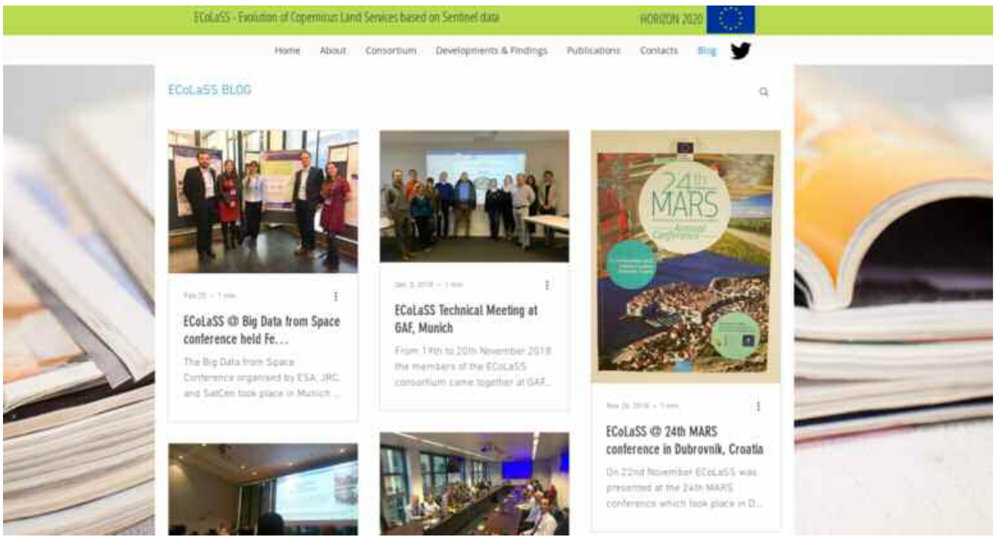


Figure 51: Website - Blog.

In turn, the social media channel Twitter @ECoLaSS2020 (https://twitter.com/ecolass2020 was created 6 months after project start and is being maintained and regularly updated throughout the project lifetime. The account currently follows 13 other accounts, has 130 followers and 41 tweets.

Figure 52: ECoLaSS Twitter account

Additionally, a project specific site has been created on ResearchGate, which lists the scientific work and publications of the project and links to the website as well as twitter (Figure 52). The target is to reach specifically the scientific community.

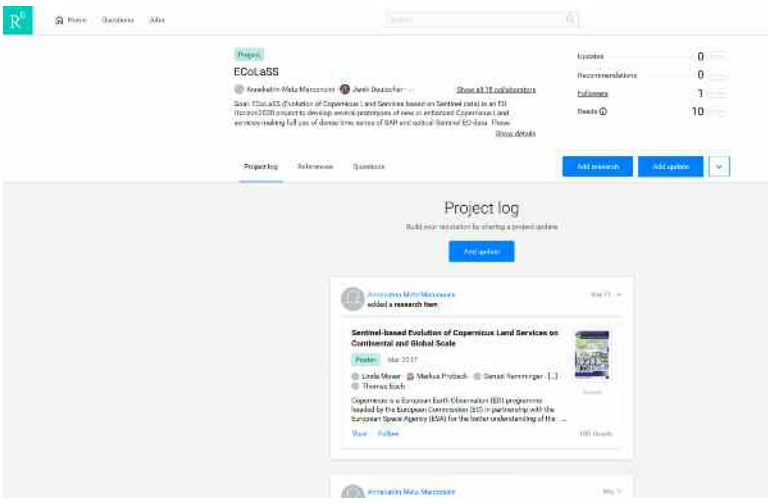


Figure 53: Screenshot of project description on ResearchGate

In phase 2 of the project, significant efforts have been undertaken to improve the presentation of the project results so far as requested by the last review comments. This includes:

- Summaries of service, data and infrastructure requirements identified in Task 2
  https://www.ecolass.eu/requirements
- Summaries of processing approaches
  https://www.ecolass.eu/processing-lines
- Updated test and demonstration sites
  https://www.ecolass.eu/test-prototype-sites
- Interactive viewers for the ECoLaSS high resolution layer prototypes (Figure 54) and comparisons between existing HRL layers and the ECoLaSS Prototype products, lining out the differences and improvements achieved

  https://www.ecolass.eu/hrlprototypes
- Prototype descriptions including embedded in-depth metadata
  https://www.ecolass.eu/hrl-landcover
  https://www.ecolass.eu/hrl-agriculture
  https://www.ecolass.eu/hrl-imperviousness
  https://www.ecolass.eu/hrl-time-series-indicators
  https://www.ecolass.eu/hrl-grassland
  https://www.ecolass.eu/hrl-forest
- Summaries of operationalization prospects as identified in Task 5
  https://www.ecolass.eu/operationalization

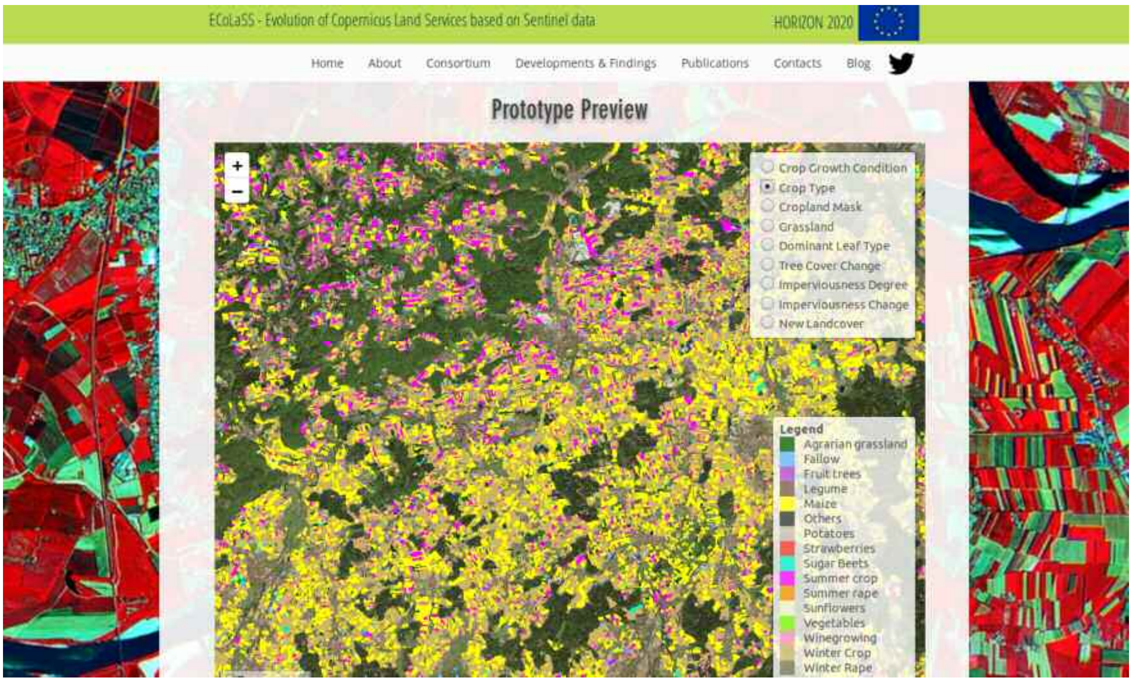


Figure 54: Interactive maps of ECoLaSS high resolution prototypes

A WMS tile-server for hosting the content of the interactive maps has been set up on the DLR Geoservice (https://geoservice.dlr.de/web/) which also displays the data in its own interactive viewing platform. This has the side-benefit of increasing the outreach of the ECoLaSS products to new expert users, which explore the continuously growing suite of high-quality products on the DLR Geoservice platform (e.g. Global Urban Footprint, TanDEM-X DEM, etc.).

Moreover, the ECoLaSS Prototype can now be imported in local GIS software by connecting to the WMS service as a remote data source. See, for example, Figure 55 which demonstrates the ECoLaSS new landcover prototype being displayed in a local QGIS instance.

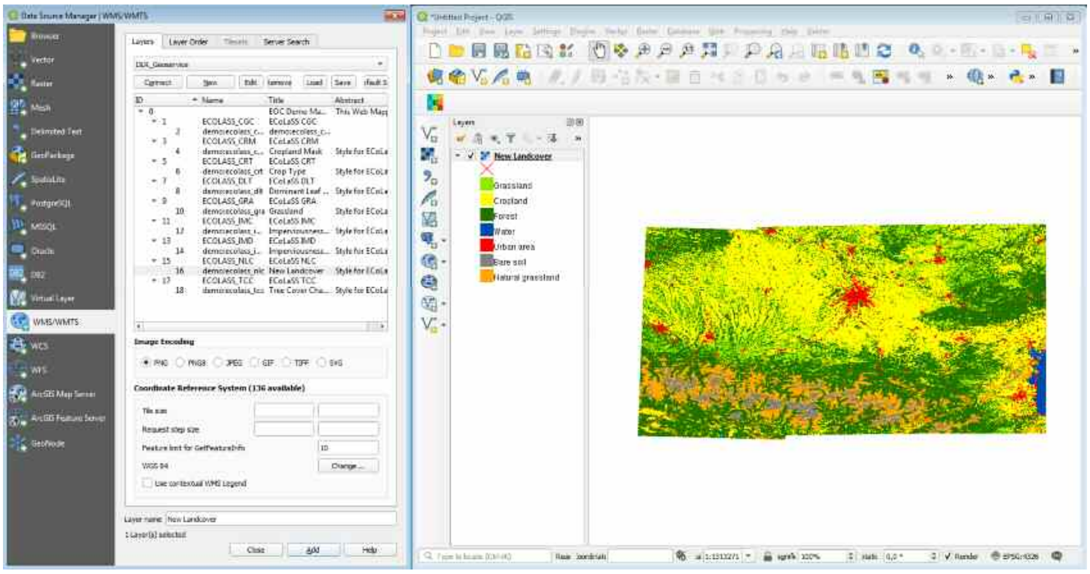


Figure 55: ECoLaSS New Landcover prototype hosted on DLR Geoservice and displayed locally in QGIS.

Finally, the contribution of the consortiums partners to scientific conferences, project relevant events and workshops has been planned and is frequently updated according to the availability of new dates and information on additional events. An updated version of the table of meetings and events can be found in chapter 4.

2.4.18 Market Opportunities & IPR Strategy (WP 62)

WP 62 is addressing the "Market Opportunities & IPR Strategy" and is part of Task 6 "Communication, Dissemination and Exploitation".

Table 36: WP 62 - Market Opportunities & IPR Strategy

Work Package Number	20	**Lead Beneficiary**		GAF		
Work Package Title	WP 62 - Market Opportunities & IPR Strategy					
Short Name of Participant (Participant Number)		**GAF (1)**	SIRS (2)	JR (3)	UCL (4)	DLR (5)
Person/Months per Participant		**2.70**	1.20	1.00	1.00	0.85
Start Month	10	**End Month**		34		
Objectives To assess long-term market opportunities for European EO service provision industry and manage all issues with relation to IPR, access rights and knowledge management.						

This WP tackles, on the one hand, (i) market opportunities that may arise during the project runtime and, on the other hand, (ii) the consortium's IPR strategy.

MARKET OPPORTUNITIES

Regarding market opportunities, the main expected impacts from the H2020 Work Programme 5. Leadership in Enabling and Industrial technologies iii. Space, and the specific Topic EO-3-2016: Evolution of Copernicus Services, include the need to:

- "enhance the European industry's potential to take advantage of emerging market opportunities and capacity to establish leadership in the field";
- "boost competitiveness of the industrial actors in EU and national procurements"; and
- "establish a proof-of-concept or a prototype, which can act as reference for the independent assessment of Copernicus service evolution, in light of product extensions and service improvements."

Although no direct commercial market opportunity is targeted by ECoLaSS, it is envisaged that the technical achievements of the ECoLaSS project may provide the consortium partners a certain increase of know-how which will support accessing new market opportunities in the Land domain. The highly automated EO data pre-processing chains which are being developed, as well as the related time series analysis methods and semi-automated thematic post-processing workflows (e.g. for HRL incremental updates, grassland mapping, crop area and status mapping as well as specific new land cover products) are relevant both, for further commercial and scientific long-term market development in a variety of markets in the frame of the Copernicus Land Monitoring Services and beyond. The current major thematic and scientific gaps in high spatial and high temporal resolution mapping and monitoring using Sentinel- (and other EO data) time series are addressed within ECoLaSS, but will be equally important for other EO based projects, products and scientific developments.

Another example is the need for geo-spatial data/information on land cover and land cover change for several United Nations (UN) Conventions such as the UN Framework Convention on Climate Change (UNFCCC) and the UN Convention on Biodiversity (UNCBD). Several financiers provide funding for implementation of these Conventions and a major component of the funds is allocated to land cover and biodiversity monitoring, both in Europe and globally. This is one of many funding sources for the consortium to potentially access with the improved methodological processes planned in ECoLaSS. Other funding and market opportunities for European industry are the European Space Agency (ESA) or Joint Research Centre (JRC), and for global sources of funds related also to improved agricultural monitoring e.g. international financing institutions with e.g. the World Bank or the Asian Development Bank.

Moreover, there are several opportunities centred around Sentinel data time series processing for LC/LU-related applications by a range of other potential customers, which are not located directly within the Copernicus service perimeter, but attached to it or even outside (e.g. national procurements, not only in the field of Copernicus but also other related fields). Overall, the emerging next-generation services will allow the European industry to strengthen its know-how and leading market position in the international competition, and will thus also support creating company and job growth as well as new export opportunities. The project aims altogether to provide more added value to existing Copernicus Land services and help to extend as far as possible the pan-European experiences to other regions/continents.

Through the development of dedicated Sentinel-based processing methods (Task 3) and thematic prototypes (Task 4) of future Copernicus Land Monitoring services and products, ECoLaSS is contributing to the CLMS evolution, helping to close gaps in the current portfolio in terms of technical, methodological as well as operational capabilities. The presentation of first prototype results to the key stakeholders provided the project with the opportunity to get valuable feedback regarding the prototype performance, further practical needs and potential use cases, based on the published prototype products. The results from this feedback cycle is being ingested into the second iteration of the prototypes, in which related recommendations are being implemented as far as feasible.

Various stakeholder groups are being addressed, such as public sector entities, the private sector and the scientific community. The various dissemination activities and media are each focused on one or several of these groups, allowing either one-way or two-way interaction with ECoLaSS, the intention being to always allow and encourage ways of feedback to the project.

Main (physical) dissemination activities comprise dedicated meetings with stakeholders as well as presentations at symposia, conferences and workshops. Main distribution media are project flyers and posters, publications in scientific journals, conference proceedings and other suitable printed or online sources, as well as information dissemination via social media and the project's webpage.

It is the consortium's understanding that the primary aim of this Horizon 2020 Research and Innovation Action (RIA) is to develop and convincingly demonstrate innovative services and products which qualify as candidates for next-generation operational Copernicus services to be procured. In that sense, the ECoLaSS project is primarily aiming to provide such convincing results for the future Copernicus Land Monitoring Service to the EC and the delegated Copernicus EEEs. Thus, instead of a business plan to address market opportunities, the project has, after thorough assessment of all project findings, provided an Integration Plan into the Copernicus Service Architecture [AD24]. Notwithstanding, the specific nature of the H2020 call and topic addresses industry related impact [AD01] by enhancing the European industry s potential to take advantage of emerging market opportunities and capacity to establish leadership in the field and boosting competitiveness.

Further considerations on market opportunities and impacts of ECoLaSS are given below.

IPR STRATEGY

With the primary aims of ECoLaSS being the testing, prototypic demonstration and suggesting of next-generation operational Copernicus land monitoring services, it is clear that the project does not pursue a dedicated commercial business model and does also not aim to create commercially relevant new IPR which would need to be specifically protected. In that sense, and with only a few exceptions (where either internal consortium issues are affected or detailed stakeholder information has to be protected), all Deliverables are and will be publically available. In order to manage these various types of information and the different levels of confidentiality, an effort to categorise the proprietary nature of the information has been adopted based on the current H2020 system of defining levels of dissemination. Thus the categories are as follows:

- PU = Public
- CO = Confidential, only for members of the consortium (including the Commission Services)

Beyond that, the ECoLaSS consortium has recognised the need to protect IPR generated before and/or independent from the project. Following the H2020 Annotated Model Grant Agreement, which provides clear guidelines on the IPR requirements, ECoLaSS is taking into consideration Article 23a (Management of Intellectual Property, Item 1), Article 24 (Agreement on Background), Article 25 (Access Rights to Background), Article 26 (Ownership of Results), Article 27 (Protection of Results - Visibility of EU Funding), and Article 31 (Access Rights to Results). Beyond all these legal details, the ECoLaSS CA provides internal management guidelines and further elaborates the IPR issues which the consortium partners develop jointly. It contains as an annex an agreement on background (either as positive list or negative list) and provisions on joint ownership.

Based on experiences in previous H2020, FP7, EEA & ESA supported projects, the consortium has recognised that there are different types of information that need to be considered as being 'proprietary information' and which have different levels of confidentiality restriction in terms of dissemination and utility. These include:

- Technical Information: (i) techniques, methodologies, formulas, processes; (ii) research, experimental and developmental work, design details and specifications; (iii) institute software, including source and executable or object code, algorithms, computer processing systems, techniques, methodologies, formulas, processes, compilations or information, unique software and hardware configurations, design concepts and similar related materials.
- Management Information: (i) management procedures for the consortium; (ii) management procedures for project implementation; (iii) management documents/reports; (iv) quality assurance systems.

In the above sense, pre-existing knowledge in the form of customised proprietary software solutions available to all ECoLaSS partners as well as respective source codes will not be made publically available, as they are considered Background IPR. However, all investigated methods, algorithms and principles are being described in detail in the respective Deliverables to ensure maximum transparency and traceability.

All outcomes of WP 62 are documented in the related Deliverable "*D62.1 Market Opportunities and IPR Strategy*" [AD30].

3. Impact

The main expected impacts from the Work Programme 5. Leadership in Enabling and Industrial technologies iii. Space, and the specific Topic EO-3-2016: Evolution of Copernicus Services include the need to:

- "enhance the European industry's potential to take advantage of **emerging market opportunities** and capacity to establish leadership in the field";
- "boost **competitiveness** of the industrial actors in EU and national procurements"; and
- "**establish a proof-of-concept or a prototype**, which can act as reference for the independent assessment of Copernicus service evolution, in light of product extensions and service improvements".

In that sense, the impact on SMEs was also discussed in the Recommendations exchange (see section 5 below) and several activities are being carried out aiming to fulfil the abovementioned goals:

EMERGING MARKET OPPORTUNITIES:

The ECoLaSS project is primarily aiming to suggest and demonstrate innovative services and products, extending or improving the future Copernicus Land Monitoring Service. In that sense, it is a project not oriented to building up specific service provider know-how that could be commercialised independently from the CLMS, but to evolve the CLMS's portfolio and thus its potential impact and outreach. Such evolution of the portfolio will not only open opportunities to potential new value-added/downstream service activities, but also to new users' groups.

However, the targeted highly automated EO data pre-processing chains that are being developed, as well as related analysis methods and semi-automated thematic post-processing workflows, are relevant for further commercial and scientific long-term market development, in a variety of other markets beyond the Copernicus Land Monitoring Service.

Taking all this into account, instead of a business plan to address market opportunities, the project, after thorough assessment of all project findings, provides an "Integration Plan into the Copernicus Service Architecture (Deliverable D53.1 in WP 53)" [AD24]. The first version of this deliverable was submitted by the end of Reporting Period 1, with some first conclusions. A final version with more specific and consolidated conclusions and recommendations will be delivered towards the end of the project.

At the same time, through open access scientific publications, the competitiveness of the service provider community as well as the various user communities outside the consortium are strengthened, improving the scientific state of the art. Additionally, the ECoLaSS Deliverables are provided as publically accessible documents, with the goal of increasing their outreach and impact.

IMPROVING COMPETITIVENESS OF THE EO SERVICE INDUSTRY AND RESEARCH PARTNERS

Through a successful development and (prototypic) implementation of new/enhanced Copernicus Land services, which utilise Big Data processing and analysis techniques for various Land applications, the competitiveness and leading market position of the European EO value-adding industry as a whole is strengthened. This is actually supporting creating company and job growth and new export opportunities. The ECoLaSS research partners will further undertake to pursue own exploitation opportunities, targeting a return of their investments via an enhancement of their capabilities to act as technology transfer hubs.

ESTABLISHING PROTOTYPES FOR COPERNICUS LAND SERVICE EVOLUTION

Through the development of dedicated Sentinel-based processing methods (Task 3) and thematic prototypes (Task 4) of future Copernicus Land Monitoring services and products, ECoLaSS contributes to the CLMS evolution, closing gaps in the current portfolio in terms of technical, methodological as well as operational capabilities.

The prototypes are structured in two phases or iterations (conforming with the two Reporting Periods of ECoLaSS), allowing several improvements before resulting in a final prototype. The first cycle of the prototypes (mainly addressed by WPs 41-45) started at M10 under the activities of Task 4 and concluded with the end of Reporting Period 1. The second cycle is taking place during Reporting Period 2. Recommendations are implemented as far as feasible. The project is in contact with the stakeholders to possibly obtain also intermediate feedback on interim results before the end of the prototyping phase, in order to ensure as far as possible that results will be aligned with the expectations. Indeed, the feedback provides the project with the opportunity to assess not only the performance but also the real needs and potential uses, based on the concrete prototype cases.

One important aspect which has to be highlighted here is that the ECoLaSS project aims to ensure that there is a clear discrimination between the longer-term "evolution" of next-generation CLMS products (2020+), for which developments are addressed by ECoLaSS, and the shorter-term "maintenance" of the CLMS portfolio with respective smaller improvement steps. In that sense, the HRL 2018 ITT published on 17 July 2018, provided remarkable proof that this ambition largely works.

Thanks to the continued close coordination between the ECoLaSS team and the EEA, the EEA had been well aware of the ongoing ECoLaSS developments, and the level of operational maturity (or not) of the respective developments. In that sense, it is not surprising that the more complex next developments such as an agricultural service, incremental HRL updates and a further grassland characterisation are not part of the (mandatory) HRL 2018 tender specifications, whereas other more "regular" developments such as full time series processing, combined use of optical/SAR, use of cloud infrastructure etc., which are being investigated in ECoLaSS from the beginning, are part of that ITT.

In addition, it should be mentioned here that several of these upcoming new products and services have meanwhile found their way into the next Copernicus and EEA Work Plans, such as:

- HR Vegetation Phenology and Productivity (HR VPP) parameters in near real time, expected to start in summer 2019;
- CLC+ expected to be upcoming in the second quarter 2019;
- HRL Grassland enrichment with management practices (mentioned in the draft Copernicus Work Program 2020);
- HRL Crops (mentioned in the draft Copernicus Work Program 2020, with envisaged kick-off for the production expected in 2020, including major groups of crop types) .

Dissemination of Project results

An important mechanism to ensure a wide impact of the project is a broad dissemination of its results. Therefore, ECoLaSS has defined a range of suitable dissemination paths, increasing the possibility to reach more users, to get closer to the currently existing ones and to keep both updated on the project progress.

Since not all users and stakeholders have the same degree of knowledge and/or impact, the project has established various targeted means and levels of dissemination, aiming at spreading and nurturing the knowledge about the project.

Various stakeholder groups are addressed, such as public sector entities, the private sector, the scientific community, the public etc. The different dissemination activities and media are focused on one or several of these groups, allowing either one-way or two-way interaction with ECoLaSS, the intention being to always allow and encourage ways of feedback to the project.

Main dissemination activities comprise meetings with stakeholders, conferences and workshops. Main distribution media are project flyers and posters, oral presentations, publications in scientific journals, conference proceedings and other suitable printed or online sources, as well as information dissemination via social media and the project's webpage.

All these activities are currently ongoing. Further detailed information and a discussion of the impact is provided in the *"D61.2 – Communication, Dissemination and Exploitation Plan"* [AD26], which has already been delivered as the second issue, as aforementioned and is explained in chapter 4.

4. Update of the plan for exploitation and dissemination of the results

This chapter presents an update of the Communication, Dissemination and Exploitation Plan (PEDR), with respect to the second version published at M27 (“*D61.2 - Communication Dissemination and Exploitation Plan_Issue 2_M27”*) [AD26].

Regarding the year 2017, a further extension of the addressed events as compared to the envisaged list stated in the PEDR are the insertion of the EuroGeographic Land Meeting that was of high topical relevance for ECoLaSS, but was made public at a later stage, the MULTIPLY – SENSAGRI – ECoLaSS Meeting that was set up by the ECoLaSS Project Officer Massimo Ciscato, the Big Data from Space Conference which was of ultimate relevance for high volume data processing being a part of ECoLaSS, and two stakeholder meetings in the framework on WP 51: dedicated ECoLaSS meetings with both DG CLIMA and EEA.

With respect to the plan for 2018 as stated in the PEDR, the planned EC/EARSC Global Land Workshop did finally not take place, therefore there was no participation from ECoLaSS. For the EIONET NRC Land Cover Annual Meeting 2018 the consortium could finally not achieve to get invited. Moreover, there was no participation of ECoLaSS at the EGU 2018 in Vienna, and the ForestSAT 2018 was not visited. To compensate, several events have been added to the PEDR in 2018: Dedicated ECoLaSS Meetings as part of WP51 took place with four EC DGs: DG AGRI, DG ENV, DG REGIO and a short interaction with DG DEVCO. Two participants from the consortium joined the H2020 MULTIPLY Workshop initiated by the H2020 “sister” project MULTIPLY. Moreover, in terms of dissemination, ECoLaSS was presented at the following events that were added to the PEDR: Copernicus for Agriculture - Industry Workshop, the PROBA-V Symposium 2018, and the EARSeL/NASA LCLU Workshop, and was presented additionally at the INSPIRE Conference in September 2018.

In 2019, the focus will be on technical and scientific publications, as the results are close to being final and prototypes currently under development are being refined towards their final versions in some cases already, whilst the rest is expected to be ready by late summer-autumn. At present, a publication related to WP31 outcomes, summarizing the experiences in Sentinel-1 and Sentinel-2 time series application in the development of the ECoLaSS prototypes, and two more addressing the specific topics of the permanent grasslands identification improvement and the new agriculture service prototype (crop mask/crop types) are envisaged. In addition, partners have participated in several outstanding events, like the Big Data from Space Conference in Munich (Germany), Living Planet Symposium in Milan (Italy), Copernicus Workshop on Data Access and Contributing Missions in Brussels (Belgium), IACS Workshop in Valladolid (Spain) or the AMIS-GEOGLAM Panel on the value of satellite information for enhanced in season agricultural information and decisions in Geneva (Switzerland).

Details for the years 2017 and 2018, as well as an outlook to 2019 and beyond, are provided in the table below (Table 37).

Table 37: Overview of past and future conferences and meetings with consortium participation

Type: S = Stakeholder interaction; D = Dissemination, C = Conference, W = Workshop, F = Fair.

Event	Date	Location	Status	Type	Relevant Topics	Consortium Participant
2017						
WorldCover 2017	14-16 March 2017	ESA, Frascati, Italy	Poster	D, C	LC/LU, Global CLMS Products	GAF (L. Moser)
German National Copernicus User Forum	14-16 March 2017	Berlin, Germany	Oral presentation	S	Copernicus (national)	GAF (M. Probeck)
CNES COSPACE Workshop on Vegetation	28 March 2017	Paris, France	Participation	D, W	Copernicus (national)	SIRS (C. Sannier)
French national event with different stakeholders (CNIG, IGN, AFIGEO)	30 March 2017	Marne la Vallée, France	Participation	S	Copernicus (national)	SIRS (C. Sannier)
French Ministry of Solidary Ecological Transition	13 April 2017	France	Participation	S	Copernicus (national)	SIRS (C. Sannier)
37th International Symposium on Remote Sensing of Environment (ISRSE)	8-12 May 2017	Tshwane, South Africa	Participation	D, C	LC/LU, including Global Land Service special session	SIRS (C. Sannier)
French National Copernicus User Forum: workshop on the evolution of Copernicus Services	14 June 2017	Paris, France	Participation	S	Copernicus (national)	SIRS (C. Sannier)
MultiTemp 2017	27-29 June 2017	Bruges, Belgium	Participation	D, C	LC/LU, time series methods and monitoring applications	GAF (C. Sommer), SIRS (S. Villerot, B. Desclée), UCL (X. Blaes, P. Defourny)
Presentation at the University of Applied Sciences Munich	30 June 2017	Munich, Germany	Oral presentation	D, W	ECoLaSS presentation	GAF (L. Moser)

Event	Date	Location	Status	Type	Relevant Topics	Consortium Participant
Annual General Meeting of the European Association of Remote Sensing Companies (EARSC)	04-05 July 2017	Brussels, Belgium	Participation	S	GEO and global Land products and evolution potential, ESA plans for Land services evolution	GAF (M. Probeck)
CCI+ Information Day	6 July 2017	ESA, Frascati, Italy	Participation	S	R&D plans for further evolution of land services, amongst others on bridging the gap between global and continental CLMS component	UCL (P. Defourny), GAF (M. Probeck)
IUFRO 125th Anniversary Congress	19-22 September	Freiburg, Germany	Oral presentation	D, C	Monitoring based on time series	JR (H. Gallaun)
Intergeo: Tradefair for geoinformation professionals	26-28 September 2017	Berlin, Germany	Oral presentation + Booth	D, F	Status and Evolution of Copernicus Land Services, addressing the geo-spatial industry	GAF (M. Probeck)
EuroGeographic Land Meeting	15 November 2017	Brussels, Belgium	Participation	S	Land Use/Land Cover Products: Challenges and Opportunities	GAF (M. Probeck)
EEA Land Monitoring & CLC+ Workshop (tbd.)	16 November 2017	Brussels, Belgium	Participation	S	Future Copernicus Land Services, CLC 2018 and CLC+	GAF (M. Probeck)
Multiply – Sensagri – ECoLaSS Meeting	17 November 2017	Brussels, Belgium	Meeting	S	Meeting between three H2020 Land Projects: MULTIscale SENTINEL land surface information retrieval Platform (MULTIPLY), Sentinels Synergy for Agriculture (SENSAGRI), Evolution of Copernicus Land Services based on Sentinel data (ECoLaSS)	GAF (M. Probeck), SIRS (B. Desclée)
MARS Conference	28-29 November 2017	Dublin, Ireland	Oral presentation	D, C	Integrated Administration and Control System (IACS), Future Agricultural Services	GAF (L. Moser), SIRS (C. Sannier)
Big Data from Space Conference	28-29 November 2017	Toulouse, France	Participation	D, C	Conference on Big Data from Space	GAF (H. Ott), SIRS (C. Sannier)
Meeting with DG CLIMA	7 December 2017	Brussels, Belgium	Meeting	S	Meeting with Rene Colditz from the EC Directorate-General for Climate Action	GAF (M. Probeck)
Meeting with EEA	14 December 2017	Copenhagen, Denmark	Meeting	S	Meeting with Hand Dufourmont, Tobias Langanke and Matteo Matteuzzi from the European Environment Agency	GAF (M. Probeck, L. Moser), SIRS (C. Sannier)

2018						
Meeting with DG AGRI	01 February 2018	Brussels, Belgium	Meeting	S	Meeting with EC Directorate-General for Agriculture and Rural Development	GAF (L. Moser, M. Probeck), SIRS (B. Desclée)
Meeting with DG ENV	02 February 2018	Brussels, Belgium	Meeting	S	Meeting with EC Directorate-General for Environment	GAF (Linda Moser, Markus Probeck)
Copernicus for Agriculture - Industry Workshop	05 February 2018	Brussels, Belgium	Participation	D, W	Meeting at EC Directorate-General for internal market, industry, entrepreneurship and SMEs	GAF (L. Moser), SIRS (B. Desclée), UCL (P. Defourny)
Multiply Workshop	06-08 February 2018	Frascati, Italy	Participation	D, W	Workshop on application of the Multiply tools and platform	GAF (L. Moser), SIRS (S. Villerot)
Meeting with DG REGIO	14 March 2018	Brussels, Belgium	Meeting	S	Meeting with EC Directorate-General Regio	SIRS (B. Desclée), DLR (A. Metz-Marconcini)
PROBA-V Symposium 2018	29-31 May 2018	Brussels, Belgium	Participation	D, C	MR remote sensing focused on PROBA-V	UCL
Copernicus Event "20 years Baveno Manifesto"	20-21 June 2018	Baveno, Italy	Participation	S	Future of the Copernicus Programme	GAF (M. Probeck)
EARSC Workshop on Data and Information Access Services (DIAS)	26 June 18	Brussels, Belgium	Participation	S	Workshop on DIAS (and eoMall)	GAF (M. Probeck)
EARSC Workshop on the future of the European EO/Copernicus	27 June 18	Brussels, Belgium	Participation	S	Strategic workshop on the future direction for the EO service industry and relationship with Copernicus Programme	GAF (M. Probeck)
EARSeL/NASA LULC Workshop	11-12 July 2018	Chania, Crete	Oral presentation	D, C	Special Interest Group workshop on LCLU; recommended by EEA	GAF (L. Moser)
IGARSS 2018	23-27 July 2018	Valencia, Spain	Oral presentation	D, C	Broad remote sensing topics and methods	GAF (L. Moser)
INSPIRE Conference	18 - 21 September	Antwerp, Belgium	Oral presentation	D, C	INSPIRE-relevant topics, oral presentation upon invitation of DG ENV	GAF (L. Moser)
Intergeo 2018: Tradefair for	16-18 Oktober 2018	Frankfurt, Germany	presentation at booth	D, F	Status and Evolution of Copernicus Land Services, addressing the geo-spatial industry	GAF (M. Probeck)

geoinformation professionals						
ESA Φ-week	12-16 November 2018	Frascati, Italy	Participation	D, C	EO Open Science and FutureEO	SIRS (A. Masse)
Exchange meeting of CLMS related H2020 projects and Copernicus Entrusted Entities	15 November 18	Brussels, Belgium	Oral presentation	S	Progress of the H2020 sister projects Sensagri, MULTIPLY, EO4Agri and ECoLaSS	GAF (K. Schwab, M. Probeck), SIRS (C. Sannier, S. Villerot), UCL (P. Defourny, J. Wolter)
MARS Conference	21-22 November 2018	Dubrovnik, Croatia	Oral presentation	D, C	Monitoring agricultural resources	SIRS (J.-P. Gachelin)
German National Copernicus User Forum	27-29 November 2018	Berlin, Germany	Oral presentation	S	Copernicus (national)	GAF (M. Probeck)
2019						
ESA BigDataFromSpace BIDS 2019	19-21 February 2019	Munich, Germany	Oral Presentation, Poster	D, C	Big data and time-series processing	GAF (E. Sevillano, SIRS, DLR
Copernicus Workshop on Data Access and Contributing Missions	2 April 2019	Brussels, Belgium	Participation	D, W	Data access and DIASes, contributing missions	GAF (M. Probeck)
CLMS H2020 Projects Meeting	9 April 2019	Valladolid, Spain	Oral presentation	S	ECoLaSS progress and CLMS H2020 projects collaboration	GAF (E. Sevillano Marco), UCL (P. Defourny)
IACS workshop	10-11 April 2019	Valladolid, Spain	Oral Presentation	D,W	IACS data and CAP	GAF (E. Sevillano Marco), UCL (P. Defourny),
ESA Living Planet Symposium 2019	13-17 May 2019	Milan, Italy	Oral Presentation, Poster	D, C	Broad variety of topics, including EO missions (e.g. Sentinels); renowned sessions on land monitoring (e.g., LC/LU, agricultural & other applications)	GAF (M. Probeck), SIRS, JR, UCL, DLR
MultiTemp 2019	5-7 August 2019	Shanghai, China	Participation planned	D, C	LC/LU, time series methods and monitoring applications	SIRS
Intergeo	17-19 September 2019	Stuttgart, Germany	Participation planned	D, F	Commercial GIS Applications	GAF

Munich RS Symposium	19-20 September 2019	Munich, Germany	Participation planned	D, C	Broad remote sensing topics and methods	GAF
ISRSE/PECORA 2019	6-11 October 2019	Baltimore, USA	Participation planned	D, C	Broad remote sensing topics and methods	SIRS
MARS Conference	27-29 November 2019	Prague, Czech Republic	Participation planned	D, C	Monitoring agricultural resources	GAF
Meeting with national stakeholders	2019	TBD	Participation planned	S	Service Evolution, EO data needs	SIRS, GAF

2020						
ISPRS 2020	14 - 20 Juni 2020	Nice, France	Participation planned	D, C	Conference of the International Society of Photogrammetry and Remote Sensing, topics: various disciplines of remote sensing	SIRS

5. Follow-up of recommendations and comments

This chapter provides the follow up of the reviewer's recommendations from since the M18 Periodic Review Meeting focusing on the approach adopted by the consortium and reassessed from the status in ongoing phase 2.

The following sections are structured following the order of recommendations as provided in the review reports and where needed, updates to the current situation.

RECOMMENDATION #1

Recommendation #1: The deliverables from Task 5 due on M18 (i.e. candidates for operational roll-out, integration plan into Copernicus service architecture, white paper on Copernicus evolution) are rather urgent so they can be presented and discussed with most important CLMS stakeholders (mainly the EEE). The collected feedbacks can and should be used by the consortium to refine and adapt the second phase of the project and to improve the prototypes. It is also recommended to make these deliverables available in the project web site as soon as they are finished so a larger audience can have access to them.

Consortium's reply M18:

The consortium is well aware of the delay of the Task 5 deliverables and the submission of them is put on highest priority. In terms of recovery it is planned to finalize them by latest December 2018. Contents were already partially presented and discussed in the exchange meeting between the four H2020 projects, EEA, JRC and EC on 15 November 2018 in Brussels. Moreover, some aspects of the ECoLaSS Task 5 findings were already communicated mainly to EEA previously, and have partially already been taken up in the HRL 2018 ITT. Any further recommendations which the team will receive from the EEEs will be considered in the second project phase. After the submission of the respective Task 5 Deliverables, the outcomes of the respective analyses will be integrated into the webpage contents, as well as the Deliverables themselves will be integrated in the publications section on the webpage.

Subsequent update M27:

The following Task 5 Deliverables were issued in December 2018: D52.1a, D53.1a and D53.2 and their summarized contents are available in the latest version of the website. The reports will be uploaded once approved, so the documents with the complete information are accessible as soon as possible. Main findings and interactions in place in phase 2 have been briefed in the corresponding WPs descriptions in section 2.4.

RECOMMENDATION #2

Recommendation #2: A comparison between service evolution requirements and prototypes technical specifications in matrix format could be very useful to phase 2 implementation since it allows the comparison of stakeholders requirements with ECoLaSS product candidates that are being proposed. It is recommended to include this matrix in the first issue of D52.1 -(i.e. CLMS product candidates for operational roll-out). This deliverable could also include a comparison of the current CLMS products (i.e. the ones that are available to download and the ones that are part of 2018 ITT) and ECoLaSS proposals/candidates, regarding not only product technical specifications but also data and methods used for their production.

Consortium's reply M18:

This recommendation will be fully considered in the first issue of the Deliverable *D17.1: D52.1a – Report on Candidates for Operational Roll-out (Issue 1)*, and is seen as an important contribution to summarise and present the work carried out in WP52. A matrix outlining the service evolution requirements collected in Task 2, the product groups they relate to (e.g. a specific HRL), information to what extent they have been taken up in ECoLaSS in phase 1 or will be considered in phase 2, and a comment on the implementation in ECoLaSS will be presented. Another matrix providing a comparison of the HRL 2015 products, the HRL ITT 2018 and the ECoLaSS prototypes in terms of technical specifications, input data, applied methodologies and related thematic accuracies will be part of D52.1a.

Subsequent update M27: Table 2 in D52.1a fulfils this matrix described in Recommendation #2*,* integrating the Service Evolution Requirements from WP21 with a focus on the pan-European and global prototypes as developed in ECoLaSS, including the implementation and tracking of phase 1 and phase 2 developments. For instance, the more frequent updates of HRL products is being targeted in WP35 and prototyped in WP43 in phase 2 and WP42 in phases 1 and 2 for Forest, Imperviousness and Grasslands status layers and WP34 integrates the change detection requirements, which is applied in Task 4 prototypes in WP42 and WP43 in phase 2. A shortened production time is being addressed in phase 2 by means of refining automation procedures (from the pre-processing tasks in WP32 to the reference data sampling and classification that leads to the status and change layers in development in Task 3 and Task 4). Product quality is enhanced by filtering effects of cloud cover and seasonal effects through the time series approach. This report includes tables related to the comparison of the technical specifications of each prototype in development, in comparison to the HRLs products, and the benchmarking assessment, considering manifold criteria. The outcomes from such analysis are guiding phase 2 developments (as was considered in Recommendation #1).

RECOMMENDATION #3

Recommendation #3: The consortium experience and assessment of DIAS should be summarized in a Technical Note, as agreed in the review meeting. It is recommended to include a brief paragraph describing the use of DIAS that is planned for ECoLaSS Phase 2.

Consortium's reply M18:

The related assessment had been carried out and presented as comparative table between the five DIASes in the M18 review meeting already. It was transferred into a Technical Note and submitted to REA on 29 September 2018 for further distribution among EC and ESA colleagues and the reviewer. A further update of this assessment of the DIASes will be integrated in the deliverable *D5.2: D23.1b – Assessment of Service Infrastructure/ Architecture Requirements (Issue 2)*, containing also future prospects for the potential use of DIAS for ECoLaSS and future CLMS services.

Subsequent update M27:

Indeed, the updated assessment of the DIAS status has been recently introduced into the second and final issue of "*D23.1b – Assessment of Service Infrastructure/ Architecture Requirements (Issue 2)"* [AD11], that contains, amongst others, infrastructure facets analysis, the most important properties regarding interfaces and processing environments, protocols, standards and capabilities (hardware and storage included) on DIAS centres. It has been concluded that, for the time being, the DIASes are still striving towards full operational data availability and maturity (such as in terms of Sentinel-2 L2A data availability throughout the time series; L2A cloud mask quality; Landsat data availability, DWH VHR data presence, etc.). Also the portability of applications designed and implemented on a given centre seems not yet such that the applications could be easily moved to another DIAS without a certain effort and modifications (although this is the future target). ECoLaSS plans in phase 2 were presented at the Big Data from Space Conference that took place in Munich in February 2019.

ECoLaSS practical experiences with the DIAS are varied, and include practical testing of several Centres such as Mundi and CreoDIAS. Processing and storage capacity evidently is sort of a commodity through the DIASes meanwhile, but the (proper) data availability situation still needs improvements to get to full operational production readiness. It should be mentioned that this coincides with the experiences that the

HRL 2018 consortia currently are making in their attempts to implement part of the operational HRL2018 production on some of the DIASes.

RECOMMENDATION #4

Recommendation #4: One of the strong aspects of the ECoLaSS proposal was the development of methodologies to synergistically use Sentinel-1 (S1) and Sentinel-2 (S2) for improving existing CLMS products or to create novel ones. The consortium already tested this synergy for some of the products, but not for all. In fact, the integration of optical and radar data is not being explored as advocated and foreseen in the proposal. It is therefore recommended to further explore the integrated use of S1 and S2 within ECoLaSS.

Consortium's reply M18:

For such developments or prototypes where a Sentinel-1 (S1) and Sentinel-2 (S2) integration was not yet assessed to a full extent in phase 1, further investigations within project phase 2 will address this. It is planned that the benefits of S1/S2 integration will be assessed for all phase 2 products (with the potential exception of some "New LCLU products" where the use of S1 and/or S2 data would not be meaningful due to the nature or specifications of the product, such as an integrated HRL product). To make the details of these tests more visible and to put more emphasis on the S1/S2 integration itself, it is planned to provide a comparative assessment table as part of the Deliverable *D6.2: D31.1b – Methods Compendium Sentinel-1-2-3 Integration Strategies (Issue 2)*, which will focus on the synergetic use of S1 and S2 throughout different products and prototypes.

Subsequent update M27:

The currently ongoing and partly finished testing in phase 2 is taking into account the raised point. The focus is laid on both the single and combined use of S-1 and S-2, targeting broader and more robust conclusions to complement the tests undertaken in phase 1. Notwithstanding, the lessons learned in phase 1 implementation has greatly contributed to a proper multisensory approach in phase 2 and, for instance, some definitions regarding the specific time windows that optimize the classifications. A detailed benchmarking in the upcoming documentation of Task 3 is foreseen, so that the benefits achieved through the combined approach get clear and visible. The added value is crosschecked with pre-processing and computing timings, in order to properly benchmark the outcomes under the manifold criteria devised towards upscaling of the prototypes as candidates for the operationalization as a pan-European service. This approach was found meaningful in phase 1 and is now in place in phase 2.

RECOMMENDATION #5

Recommendation #5: Sentinel-3B (S3B) was only recently launched, it is still in commissioning phase and its images are not yet being widely distributed. According to what was transmitted by the consortium in the review meeting, this image unavailability and the inexistence of a software such as Sen2Cor for deriving bottom of atmosphere reflectance may jeopardize the foreseen use of S3 mages in synergistic use with S2. As agreed in the review meeting the consortium will produce a Technical Note to REA explaining the problems related to S3 use in this research project. Furthermore, it is recommended that the consortium prepares another Technical Note to REA describing the impact on project implementation of delays on S3B dissemination and the inexistence of Sen2Cor alike software. This Technical Note should also present scientific alternatives within ECoLaSS and how these new proposals can be implemented with the human resources that were allocated to the tasks involving S3 image processing. The ECoLaSS proposal already advanced some alternatives, e.g. "PROBA-V time series will be considered as a complementary data set to S-3 time series while waiting for the Sentinel-3b to provide the daily revisit capability at all latitudes" (pp. 28 of proposal Part B). If integration of images with different spatial resolution is no longer relevant to the production of the foreseen prototypes, then consortium has to explain in detail what is known now that was not known at proposal phase, since the integration of S2 and S3 was advocated and proposed throughout the ECoLaSS proposal.

Consortium's reply M18:

For consistency and efficiency reasons, the consortium has decided to provide one integrated Technical Note on both, the experienced technical issues, and the potential substitutes of S3 data within the ECoLaSS project (*Proposed substitutes for Sentinel-3 data)* [AD27]. It is submitted to REA and the Reviewer together with this Reply to the ECoLaSS Periodic Review Report. Besides an explanation of the problems that hamper the usage of S3 data as a complementary data source, the document provides candidates of potential substitutes and mitigation measures on how these alternative data can be integrated within the given frame of technical contents and available resources. Among them, there is the proposed approach by ECoLaSS to focus on the alternative use of PROBA-V time series as stated in the proposal, and PROBA-like time series in addition. The impact of S3B data product availability delays and the inexistence of Sen2Cor alike software or alternatives on the project implementation are discussed in the same Technical Note.

Furthermore, the discovered issues around S3 data will also be reported in the second issue of the Deliverable *D4.2: D22.1b – "EO and Other Data Requirements Report (Issue 2)"* [AD10].

Subsequent update M27:

Following the principles established in the Technical Note "Proposed substitutes for Sentinel-3 data", issued 4th of December of 2018 [AD27], in phase 2 ongoing activities are using two years (2017, 2018) corresponding to PROBA-V and S-2 overlapping periods. Accordingly, the spatial resolution of Sentinel-2 is downscaled to the spatial resolution of PROBA-V 1 km assuring the best possible correspondence. Subsequently, NDVI time series are being computed, compatible with the long term SPOT Vegetation/PROBA-V time series, that enable detection of anomalies that will be therefore further investigated at 10 m resolution to highlight the upscale capacity of Sentinel-2 time series. This comparison is being implemented for some tiles of Sentinel-2 covering part of ECoLaSS demo sites.

In addition, further references of the Sentinel-3 alternatives approached in the different affected tasks are reported where appropriate (e.g., WP32 [AD13]).

Recommendation #6

Recommendation #6: The web site as it is now does not translate the extraordinary work that has been done within ECoLaSS. It is recommended to enrich the website with summarised information on the ECoLaSS main activities and deliverables. I believe it would be particularly important to present: a) a summary of the requirements inventoried in Task 2, b) a brief summary of the processing lines that are being designed and developed to explore Sentinel data, including the innovative approaches to explore multitemporal, multiresolution and multisensory datasets, c) a description of the prototypes under development, and d) the results of the demonstration activities in the several sites. The web site should also allow the visualisation of the products derived for each demonstration site. A table with the comparison of technical specifications of the ECoLaSS prototypes with the ones that are being disseminated within CLMS or that are envisaged in 2018 ITT would be useful to demonstrate how ECoLaSS is contributing to the improvement of CLMS. It would also be beneficial to include a summary of the three Task 5 deliverables, considering that these documents are very important for designing the future of CLMS 2020+. These are just some ideas to improve the web site and make it a truly, efficient and effective tool for disseminating most important ECoLaSS activities and achievements. The web site should work also as the main communication channel with CLMS stakeholders and users.

Consortium's reply M18:

Since the Periodic Review Meeting there has been much effort undertaken to broaden the offered contents of the project website. On the one hand, the publication section has been extended by a section on project Deliverables, where the reports from Task 2, 3 and 4 can now be downloaded directly via the webpage. On the other hand, it has already been tested to integrate an online map (with GoogleMaps or Open Street Map) visualising the prototype raster products on a geo-located and zoomable map. Furthermore, specific sub-pages describing every prototype based on the outcomes of the Task 3 and Task 4 Deliverables as well as a synthesis of the prototypes' evaluation in WP52 is currently planned and implemented. Selected figures will support to showcase the prototypes. Moreover, a release of a specific document describing all prototypes in greater detail (including requirements, methods, sites and prototype implementation), as well as a collection of product specification sheets is currently prepared and will be available for download on the webpage prototype section. The majority of recommendations will be taken into consideration until the end of the year 2018, since the outcomes of Task 5 are essential for the presentation and evaluation of the prototype contents. In case of the recommended summary of requirements inventoried in Task 2 the implementation is envisaged for after the submission of the second Issues of the Task 2 deliverables. In addition to the enhancement of the webpage contents the updates on dissemination activities via twitter and the webpage blog are also promoted.

Subsequent update M27:

In phase 2, significant efforts have been undertaken to improve the presentation of the project results so far following this recommendation. Summaries of service, data, and infrastructure requirements outcomes from Task 2, processing approaches, updated information on test and demonstration sites, and interactive presentations of the ECoLaSS prototypes, descriptions including embedded in-depth metadata and summaries of operationalization prospects as identified in Task 5 are now online. All deliverables already approved with the exception of the confidential documents, can be downloaded from the site (recent submissions with a disclaimer before official approval by Project Officer). As described in section 2.4.17, outreach and scientific communication links are also reachable from the website and further promote the reflection of the actual ongoing work in ECoLaSS.

<u>RECOMMENDATION #7</u>

Recommendation #7: Even though the strategy for IPR and knowledge management is described with some detail in the proposal and even that the delay on delivery of D20.1/D62.1a (Market opportunities and IPR strategy) does not significant impact the project implementation, it is rather important to conclude this deliverable as soon as possible so everything related to IPR is crystal clear for everyone, from consortium members to REA.

Consortium's reply M18:

The deliverable *D20.1: D62.1a – Market Opportunities and IPR Strategy (Issue 1)* is foreseen to be submitted until the end of the year 2018. This Deliverable will contain detailed information on the IPR strategy of the ECoLaSS consortium. In any case, the criticality of IPR issues in ECoLaSS is considered generally low, as the undertaken research is not meant for developing commercial business models (where IPR of the different involved parties could play a major role), but for jointly furthering the state of the art and knowledge in the field of CLMS evolution, and publically disseminating this.

Subsequent update M27:

Deliverable "*D20.1: D62.1a – Market Opportunities and IPR Strategy (Issue 1)"* [AD30] was submitted in December 2018, and follows this recommendation, as described in subsection 2.4.16. The second and final issue in phase 2 is envisaged for the last months of the project, once the prototypes are in place and the workflows have been finalised. In this manner, the IPR strategy can be realistic and consistent with project main outcomes.

RECOMMENDATION #8

Recommendation #8: The consortium should continue to report to EC the issues related to difficulties on satellite data access, Sen2Cor limitations (e.g. cloud masking, topographic overcorrection), lack of a reliable geometric reference dataset (e.g. DEM), plannimetric issues.

Consortium's reply M18:

In the first project phase, comprehensive such input had already been provided to the S2/S1 quality working groups via the EEA who reported to them. The consortium will continue to report the found issues in the second project phase. On the one hand, these topics will be reported in the respective (public) ECoLaSS deliverables, in particular D4.2: D22.1b – EO and other Data Requirements Report (Issue 2) and D7.2: D32.1b – Methods Compendium: Time Series Preparation (Issue 2). On the other hand, it is foreseen to report new issues via direct channels to the JRC and EEA responsible persons, as it was proposed as well at the latest H2020 Project Exchange Meeting with the EEEs in Brussels on November 15. Direct contact points requested for such reporting are Michel Massart (DG GROW) and Peter Strobl (JRC) in the case of Sentinel-2/-1 related issues, and Nadine Gobron (JRC) for issues regarding Sentinel-3.

Subsequent update M27:

In phase 2, the final version of "D7.2: D32.1b – *Methods Compendium: Time Series Preparation (Issue 2)*" [AD13] has been recently submitted and includes also the demosites preprocessing figures, where limitations and the aspects analysed in phase 1 are now addressed to the maximum possible extent within the ECoLaSS scope. Issues have been reported and further details can be found in the report and the corresponding subsection above. No further issues have been found in phase 2 that were not reported already.

RECOMMENDATION #9

Recommendation #9: Most of the consortium effort in phase I regarding development of processing lines and demonstrations through prototypes was mainly focused on maps with categorical variables. At the end of the project, it is expected that full attention is also given to products with continuous variables that are already CLMS products or that were identified in ECoLaSS proposal and/or user requirements.

Consortium's reply M18:

For the second phase of ECoLaSS it is planned to integrate products with continuous variables as part of the testing and prototyping related to HRL Forest and Imperviousness, i.e. assessing and documenting in more detail primarily the potential (or not) of Tree Cover Density (TCD) and Imperviousness Degree (IMD) change mapping at shorter time intervals / incremental updates. The respective TCD and IMD status layers are considered sufficiently mature both by the stakeholders and the project. Respective 3-year change products will already be addressed as part of the operational HRL 2018 implementation. Regarding incremental updates related to these continuous characteristics, the experience from phase 1 suggests that a one year time step may be too short to get meaningful results, and incremental updates should rather focus on tree cover / impervious area changes. In project phase 2 this finding will be further explored, potentially consolidated, and documented in more detail.

Subsequent update M27:

In the case of Forest, as described above, this recommendation is fulfilled with the generation of an annual update of continuous-scale (0-100%) Tree Cover Density (TCD) product at 10m spatial resolution using optical Sentinel-2 data. The pixel-based TCD product provides information on the proportional crown coverage per pixel in percent.

Regarding the IMP prototype, the Imperviousness Degree (IMD) is produced each year with a continuous scale (0-100%) at a 10m spatial resolution using optical S-2 data, in particular the Normalized Difference Vegetation Index (NDVI). In addition to this product, the second iteration of the WP35 report will assess the feasibility of a layer of change for the Imperviousness Degree (IMD). However, it is expected that this product will be strongly challenging to produce, since the use of NDVI and its sensibility to atmospheric changes as well as its dependence to the type of sensors produces a lot of noise and requires a fine calibration.

In the case of grasslands use intensity categories are derived from a number of mowing events layer, applying a threshold to divide between intensive and extensive management. Other products in ECoLaSS tackling continuous products are the Indicators and Phenology products, that are to complement consistently the thematic ones.

RECOMMENDATION #10

Recommendation #10: In the review meeting it was agreed that Issue 2 of D31.1.a should become a summary of the approaches developed and tested within ECoLaSS to derive improved and novel CLMS products. Tables should present data and methods used in the different test and demonstration sites as well as accuracy indicators of the different approaches. The deadline of this deliverable should be postponed to after the completion of the WPs related to methods development and prototypes demonstrations within Task 3 and Task 4.

Consortium's reply M18:

The delivery has been agreed to be postponed until after the completion of the affected Deliverables, in order to enable all new developments and prototypes with respect to the integration of S1/S2 data to be taken up and compared in this deliverable. The benchmarking and practical testing (as it is done in other WPs) will be eliminated in this deliverable as the focus of it has been changed towards providing more a collective summary of the benchmarking and outcomes of the contents of the other Task 3 and Task 4 Deliverables. The Gantt chart is updated with a new delivery date at M35 as agreed in the Periodic Review Meeting. A new outline and structure for the work in WP31 and the Deliverable D6.2: *D31.1b – Methods Compendium: Sentinel-1/2/3 Integration Strategies (Issue 2)* is internally drafted.

Subsequent update M27:

No further update is required at this point.

RECOMMENDATION #11

Recommendation #11: The consortium has been extensively using data from Land Parcel Identification System (LPIS) and LUCAS within classifiers training and product validation. The consortium should continue to transmit to EEA the difficulties and problems that have been identified on the access and use of these datasets. This kind of feedback is rather important to EEA in order to promote an effective and reliable use of LUCAS and LPIS within Copernicus.

Consortium's reply M18:

Difficulties and problems regarding the access to LPIS data have been reported to EEA in the past and will be continued to be reported as well as part of the respective Deliverables, particularly in *D4.2: D22.1b – "EO and other Data Requirements Report (Issue 2)"* [AD10] (containing specific sections on in-situ data availability) as well as *D8.2: D33.1b – "Methods Compendium: Time Series Analysis for Thematic Classification (Issue 2)"* [AD13], *D13.2: D43.1b – Prototype Report: Improved Permanent Grassland (Issue 2)*, and *D14.2: D44.1b – Prototype Report: Crop Area and Crop Status/Parameters (Issue 2)*. Mainly the grassland and agriculture products are currently restricted by this limitation; however also other products could benefit from a pan-European LPIS availability (providing field-wise crop type / grassland type information). Due to the consortium's close connection to EEA, feedback to EEA is also provided via direct channels, as it was recently done, e.g. at the H2020 CLMS project exchange meeting on 15 November 2018 in Brussels. Beyond that, information on the high necessity and current access limitations to LPIS for the

CLMS has also been already provided to the responsible DGs in the course of the ECoLaSS stakeholder interaction process, first and foremost to DG AGRI.

Subsequent update M27:

The consortium has been compiling notes related to the usage of LPIS and LUCAS data in phase 2 implementations. In February 2019, ECoLaSS provided the first summary to the ESTAT/EC and interactions are followed ever since, as further feedback is now expected by early June, as a result of the usage of these reference data in the prototypes implementation in phase 2. The provision and accessibility of reference data was discussed in the CLMS H2020 projects meeting and the event that followed, IACS Workshop, where the focus was on CAP Monitoring and agriculture applications, for which the timeliness of mapping production could be improved if such reference data were in turn readily accessible for the whole Europe EU-39. JRC and EEA also participated in this discussions and further email exchanges are taking place in phase 2.

RECOMMENDATION #12

Recommendation #12: The criteria defined within ECoLaSS for selecting the best methods to produce novel products or improve existing ones and for identifying the best candidates to operational roll-out implies the evaluation of product thematic accuracy. The deliverables from Task 3 and Task 4 indicate that accuracy assessment is not always implemented with the most statistically sound protocols nor described with the adequate level of detail. Therefore, it is strongly recommended to create a new deliverable with good practices for implementing thematic accuracy assessment in Task 3 and Task 4. This deliverable will be needed before the quality control of phase 2 products.

Consortium's reply M18:

The consortium acknowledges the value of a uniform accuracy assessment guideline, as a consequence of which the thematic product assessment results are expected to be better comparable to each other. Therefore, it is planned to compile such concise ECoLaSS accuracy assessment guideline, detailing the key validation principles to be respected (e.g. in terms of the description of sampling design, response design, use of accuracy metrics and confidence intervals, etc.), which will be used for the accuracy assessment of every prototype both in the testing and the implementation. Since this is strongly related to the testing in WP 33, it is proposed to integrate the accuracy assessment guideline as a new chapter into the Deliverable *D8.2: D33.1b – Methods Compendium: Time Series Analysis for Thematic Classification (Issue 2)*, and rather avoid creating one further, disconnected individual Deliverable just on that topic. Consequently, more detail of the applied accuracy assessment processes and outcomes, in conformity with the new accuracy assessment guideline, will be presented in the respective next issues of the deliverables of Task 3 and Task 4.

Subsequent update M27:

The accuracy assessment approach has been discussed by the consortium and an agreement is based on following consistent principles in all thematic topics, although some particularities specific of the prototype might also be respected. In particular, regarding the grassland prototypes, which require a special attention, for example due to their intensive/extensive distinctive characteristics, which are only reliably discriminable from satellite data time series.

RECOMMENDATION #13

Recommendation #13: Preliminary results of phase 1 indicate that for some CLMS products and/or for some regions within Europe the integration of S1 into S2 datasets does not compensate the effort, i.e. the cost of processing more data seems higher than the benefit one can have in relation to thematic accuracy increase. This type of analysis is rather important and in ECoLaSS phase 2 should be generalised for all products and also to the possibility of adding S3 images into S2 time series. Research questions such as the following may be important for defining the data to use: 1) what are the CLMS products where the integration of images coming from different Sentinels can increase accuracy in a significant manner? 2) what are the European regions where, for a specific CLMS service, the adding of S1 into S2 dataset is beneficial, i.e. benefit is higher than cost, and what are the ones where there is no really added value to integrate S1 and S2? 3) S1 is only beneficial when cloud cover does not allow dense time series of S2 or does it had extra relevant information? For sure that in ECoLaSS this type of analysis cannot be done for the entire Europe and for all CLMS products, but it can be done for the prototypes under development in the three demonstration sites.

Consortium's reply M18:

As the integration of S1 and S2 data is planned for all phase 2 tests and prototypes (see Recommendation #4), the proposed research questions are appreciated and will be taken into account within the frame of the analyses, based on results gained from the work in three different sites. The question on the increase (or decrease or stabilisation) of the thematic accuracy using S1, S2 and an integration of S1/S2 has been already investigated for most products in phase 1 at least for one demo site each, as part of Task 3, and will be further pursued for all relevant products in phase 2, investigating it in view of the regional diversity of various European biogeographic regions represented in the different sites. A cost/benefit assessment is part of the benchmarking criteria applied in WP 52. Regarding S3, conclusions from other studies related to quality and temporal resolution with respect to S2 are part of the Technical Note on "*Proposed substitutes for Sentinel-3 data*". Conclusions on the added value of S1 in case of high cloud cover versus situations of few to normal cloud cover will be drawn from the analyses, depending on the respective cloud cover situations. Furthermore, it should be mentioned that the upcoming operational HRL 2018 implementation will be confronted with exactly these questions as well. As it is quite likely that ECoLaSS consortium partners will be involved also in this operational HRL 2018 implementation (due to the submitted offers, almost certain for HRL Forest and Grassland, and possible for HRL Imperviousness), a mutual exchange of research results and lessons learned in the course of 2019 is both planned and ensured.

Subsequent update M27:

See Recommendation #4 and Recommendation #5, for measures in place in phase 2, where the focus has shifted to this accuracy assessment of the multisensor comparison, once phase 1 developments have provided sound grounds. Some tests and demos are already ongoing in phase 2, as explained for instance in WP33 subsection, for the grasslands and agriculture thematic topics.

Recommendation #14

Recommendation #14: The ECoLaSS rational to have a task dedicated to design and develop automated processing lines to process large volumes of Sentinel data (i.e. Task 3) and to have another task dedicated to use those methods to derive/demonstrate specific products as prototypes for future CLMS (i.e. Task 4) makes full sense. However, the deliverables of Task 3 and Task 4 are not aligned with this rationale. In fact, there are methods that are being used to develop prototypes that are not described or tested within Task 3 methods compendia deliverables. It is recommended to describe the methods in Task 3 deliverables and report the implementation of those methods in the demonstration sites in Task 4 deliverables. Of course the results of the implementation of the developed methods to the smaller test sites should continue within Task 3 deliverables. If in Task 4 WPs implementation the consortium decides to create new methods and if this happens after the completion of the second issue of Task 3 deliverables, which is perfectly understandable, then a third issue of deliverables with methods compendium should be produced so that all methods are described in the methods compendia.

Consortium's reply M18:

The provided observations and recommendations are fully acknowledged and will be implemented in the second project phase. In order to avoid having yet another (third) issue of Task 3 Deliverables, it is rather proposed to slightly delay the concerned deliverables of Task 3 in order to increase the temporal overlap between Task 3 and 4. By this it will be possible to ensure that all methods applied in the production of the prototypes in Task 4 are also completely documented in the respective Task 3 Deliverables.

Subsequent update M27:

These concerns have been shared with the Project Officer. In phase 2, this recommendation is particularly being taken care of. Once having all the pre-processed data in place, and also as a result from the experiences in phase 1 with the first version of the prototypes, the coordination between the test and prototypes is now easier. Now all activities are open, and specifically WP3 reports are in a draft status as well. In practice, this is shifting Task 3 deliverables submission dates. As has been explained in subsections above (2.2, 2.3), the priority is to obtain consistent methods in the tests and avoid limitations when applying them to larger areas. All Task 3 and Task 4 WPs are respecting this principle strictly in phase 2.

RECOMMENDATION #15

Recommendation #15: In the interim review meeting it was agreed to have each prototype implemented in three demonstration sites till the end of the project. Table 7 of the first periodic report (pp. 24) on the selection of the demonstration sites for each prototype, indicates only two demonstration sites to the New LCLU prototype. It is recommended to identify and work on a third one.

Consortium's reply M18:

It was a longer process to decide on a third site for the WP 45 – New LC/LU Products since this WP was defined as a flexible WP in its nature in the proposal, where new products might be added according to arising user and stakeholder requirements, such as it was the case for CLC+ like products and an integrated HRL layer. A third demonstration site for the development of a prototype of New LCLU products has now been chosen. The three sites for this prototype will be South-West, West, and Central. It has to be noted, however, that although some new products such as the combined HRL that was proposed by the reviewer in the Periodic Review Meeting will be implemented in three sites, but the CLC+ related prototype that has already been presented in phase 1 is currently foreseen to be implemented only in two of these sites, both for reasons of timeliness of the results for the EEA, and because the access to appropriate training/reference data, which is crucial for this prototype, is not ensured for all sites. Furthermore, any possible new arising experimental products in the course of phase 2 (if any) can most likely only be implemented in one or two sites, as field data, timeliness requirements, available budget and the nature of such additional items will allow. To sum up: At the moment, no such urgent further products (beyond the two ones in the planning) are identified from the currently known user and stakeholder requirements, but the option is retained.

Subsequent update M27:

Demosites have been defined for the New LC/LU Products, as depicted in Table 6 and described in WP45.

RECOMMENDATION #16

Recommendation #16: Although the evolving requirements of CLC+ and a potential difficulty to have them stabilised in a short term, it is recommended that prototypes on new LCLU products are a step ahead of the products that will be requested by EEA in the current/next year or even next year ITT. The dialogue with EEA should continue to be efficient so that this EEE can benefit from ECoLaSS experiments results in proper time.

Consortium's reply M18:

Following this recommendation, the consortium has already coordinated with the EEA, and indeed the EEA would appreciate further testing with the new (extended) CLC+ class nomenclature. Although the respective specifications document version 5 has not been publically released, the EEA have at least communicated the list of new classes to the consortium, which appear to be partially not easy to map or very specific to certain limited ecosystem regions (like the class "Mosses and lichens"). This will allow the consortium a certain adaptation and re-focus of the methodological tests in ECoLaSS, but a closer meeting of the updated specifications will not be possible as long as access to the full specifications document cannot be enabled. Due to potential conflict-of-interest situations, the EEA does at the current stage of CLC+ developments not foresee that. However, they informed that the relevant version 5 is likely to be publically released ahead of the CLC+ ITT, which may give the consortium potentially the possibility to still react upon.

Subsequent update M27:

In April 2019, SIRS delivered a Working Document to EEA, depicting the current status of the methodological assessments related to the CLC+.

RECOMMENDATION #17

Recommendation #17: The integration at pixel level of the different HRL can be important to check consistency within HRL (e.g. it is not likely that a pixel can have 80% of imperviousness degree and 90% of tree density) and also to derive LCLU classes. This could be an interesting line of research within ECoLaSS.

Consortium's reply M18:

Such an integrated HRL product is currently tested in three sites and will be implemented as prototype as part of WP45. Several options are explored, e.g., ranging from combination of meaningful classes until exclusion of classes that can be subjected to classification errors in either of the HRL products.

Subsequent updates M27:

As described in section 2.4.13, a combined layer including the available HRLs 2015 is currently under construction. In WP45 the merge of the HRL products show that in Central most products consistently do not overlap. Most overlaps occur not surprisingly along linear objects, where spatial resolution limits capturing the exact location of the border between categories. It is not uncommon when integrating different thematic products. Seamless match is not easy to obtain. This fact does not diminish the relevance of these products quality requirement, and accordingly this recommendation is being followed in phase 2. Details will be integrated in the second issue of WP45 deliverable.

RECOMMENDATION #18

Recommendation #18: Although the coordinator effort to guarantee that deliverables on methods compendia within Task 3 and the ones on prototype reports within Task 4 follow the same rationale and structure, the quality and detail of contents are not uniform. This lack of consistency also happens with the chapters on different products within individual deliverables. It is strongly recommended that project coordination guarantee that all second issues of methods compendia of Task 3 and Task 4 are more uniform and have high quality. In spite of the effort on the interaction of the work between Task 3 and Task 4 and the overall good quality of reports, second issues of Tasks 3 and 4 deliverables need to be more integrated and concerted. It is also important to guarantee that methods are not presented in the results chapters and vice-versa, as it is happening in some deliverables of phase 1.

Consortium's reply M18:

The untangling of Task 3 and 4 contents will be taken care of in the second project phase. Furthermore, the information depth in the deliverables and especially the chapters within one deliverable written by different partners will be observed more closely to move towards more consistency in the second issues of the reports. It is also generally planned to better distinguish between methods and results in the upcoming deliverables of phase 2.

Subsequent update M27:

All deliverables in phase 2, are being subjected to quality control procedures, which results from the review of first issues, and builds on overall phase 1 outcomes, as well as ongoing implementations in phase 2, plus remaining months plans that are now more defined. The dynamic from phase 1 eases such endeavours and albeit at the cost of submitting some reports with slight delays, the focus is on producing high quality documents. These are in most cases now the final versions and will remain after project end as permanent project outcomes, accessible and public. It is therefore of the utmost relevance to close the tasks and documents appropriately, without leaving loose ends. In this regard, benchmarking guidelines and procedures are being applied where suitable, which is also now easier once all partners are familiar with the procedures and build on the first findings. Moreover, the interlinkage between tasks naturally follows and is so reflected in the documents, as it is a more integrated approach, also resulting from a closer collaboration once the phase 1 findings have set the paths to follow. The Project Management and Scientific Coordination team are actively supporting these practices and reviewing the reports drafts accordingly.

References

Balthazar, V., Vanacker, V., Lambin, E. F., 2012. Evaluation and parameterization of ATCOR3 topographic correction method for forest cover mapping in mountain areas. International Journal of Applied Earth Observation and Geoinformation 18, p. 436–450.

Banskota, A., Kayastha, N., Falkowski, M. J., Wulder, M.A., Froese, R. E. and White, J. C. 2014. Forest Monitoring Using Landsat Time Series Data: A Review, Canadian Journal of Remote Sensing, 40(5), 362-384, http://dx.doi.org/10.1080/07038992.2014.987376.

Brooks, E.B., Wynne, R.H., Thomas, V.A., Blinn, C.E., Coulston, J.W., 2014. On-the-fly massively multitemporal change detection using statistical quality control charts and Landsat data. IEEE Trans. Geosci. Remote Sens. 52, 3316–3332. doi:10.1109/TGRS.2013.2272545.

Donadieu, J., L'Helguen, C., 2016. Sentinel-2A Level-2 products description (Technical Note No. 00), PSC-NT-411-0362-CNES. CNES.

Doxani, G., Vermote, E., Roger, J.-C., Gascon, F., Adriaensen, S., Frantz, D., Hagolle, O., Hollstein, A., Kirches, G.;Li, F., Louis, J., Mangin, A., Pahlevan, N., Pflug, B., Vanhellemont, Q. 2018. Atmospheric Correction Inter-Comparison Exercise. Remote Sensing 10, 352.

Fletcher, K., 2012. Sentinel-2: ESA's Optical High-Resolution Mission for GMES Operational Services (European Spatial Agency SP-1322/2).

Gao, F., Hilker, T., Zhu, X. L., Anderson, M. C., Masek, J. G., Wang, P. J., & Yang, Y. 2015. Fusing Landsat and MODIS Data for Vegetation Monitoring. *Ieee Geoscience and Remote Sensing Magazine, 3*(3), 47-60. doi:https://doi.org/10.1109/Mgrs.2015.2434351

Harvey, A. C., 1990. Forecasting, structural time series models and the Kalman filter. Cambridge -- University Press.

Hirschmugl, M., Gallaun, H., Dees, M., Datta, P., Deutscher, J., Koutsias, N., Schardt, M. 2017. Methods for Mapping Forest Disturbance and Degradation from Optical Earth Observation Data: a review. Current Forest Reports, 3, 32–45. doi:10.1007/s40725-017-0047-2

Home, O.D.H.N., List, C.D., NPP, N.P.P., Questions, D.P., Curation, D., Visualizer, S. M., Checker, L.-W., 2013. LEDAPS calibration, reflectance, atmospheric correction preprocessing code, version 2.

Joshi, N., Baumann, M., Ehammer, A., Fensholt, R., Grogan, K., Hostert, P., Jepsen, M. R., Kuemmerle, T., Meyfroidt, P., Mitchard, E. T. A., Reiche, J., Ryan, C. M., & Waske, B. 2016. A Review of the Application of Optical and Radar Remote Sensing Data Fusion to Land Use Mapping and Monitoring. Remote Sensing, 8(1). doi:https://doi.org/10.3390/rs8010070

Louis, J., Debaecker, V., Main-Knorn, M., Bieniarz, J., Mueller-Wilm, U., Cadau, E., Gascon, F., Pflug, Bringfried, 2016a. Sentinel-2 Sen2Cor: Level-2 Processor for Users. Presented at the Proceedings Living Planet Symposium 2016, Spacebooks Online, p. 1–8.

Louis, J., Debaecker, V., Pflug, B., Main-Knorn, M., Bieniarz, J., Mueller-Wilm, U., Cadau, E., Gascon, F., 2016b. Sentinel-2 Level-2 Processor Sen2Cor.

Müller-Wilm, U., Louis, J., Richter, R., Gascon, F., Niezette, M., 2013. Sentinel-2 level 2A prototype processor: Architecture, algorithms and first results. Presented at the Proceedings of the 2013 ESA Living Planet Symposium, Edinburgh, UK, p. 9–13.

Olsson, P. O., Lindström, J., & Eklundh, L. 2016. Near real-time monitoring of insect induced defoliation in subalpine birch forests with MODIS derived NDVI. Remote sensing of environment, 181, 42-53.

Pohl, C., & Van Genderen, J. L. 1998. Review article Multisensor image fusion in remote sensing: Concepts, methods and applications. International Journal of Remote Sensing, 19(5), 823-854. doi:https://doi.org/10.1080/014311698215748

Pohl, C., & Van Genderen, J. L. 2015. Structuring contemporary remote sensing image fusion. International Journal of Image and Data Fusion, 6(1), 3-21. doi: https://doi.org/10.1080/19479832.2014.998727

Rouquié, B., Hagolle, O., Bréon, F.-M., Boucher, O., Desjardins, C., Rémy, S., 2017. Using Copernicus Atmosphere Monitoring Service Products to Constrain the Aerosol Type in the Atmospheric Correction Processor MAJA. Remote Sensing 9, p. 1230.

Sola, I., González-Audícana, M., Álvarez-Mozos, J., 2016. Multi-criteria evaluation of topographic correction methods. Remote Sensing of Environment 184, p. 247–262.

Sylla, D., Minghelli-Roman, A., Blanc, P., Mangin, A., & d'Andon, O. H. F. 2014. Fusion of Multispectral Images by Extension of the Pan-Sharpening ARSIS Method. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 7(5), 1781-1791. doi:10.1109/JSTARS.2013.2271911

Vancutsem, C., Pekel, J. F., Bogaert, P., Defourny, P. 2007. Mean Compositing, an alternative strategy for producing temporal syntheses. Concepts and performance assessment for SPOT VEGETATION time series. International Journal of Remote Sensing, 28 Issue 22, pp 5123-5141.

Verbesselt, J., Herold, M., Zeileis, A., 2012. Near real-time disturbance detection using satellite image time series. Remote Sens. Environ. 123, 98–108. doi:10.1016/j.rse.2012.02.022

Woodhouse, I. H. (2006). Introduction to Microwave Remote Sensing: CRC Press, Boca Raton, FL.

Zhu, Z., Wang, S., Woodcock, C. E., 2015. Improvement and expansion of the Fmask algorithm: cloud, cloud shadow, and snow detection for Landsats 4–7, 8, and Sentinel-2 images. Remote Sensing of Environment 159, p. 269–277.

Zhu, Z., Woodcock, C.E., 2014. Continuous change detection and classification of land cover using all available Landsat data. Remote Sens. Environ. 144, 152–171. doi:10.1016/j.rse.2014.01.011