Validation Report - CLCplus Backbone 2021

ESTABLISHMENT AND MAINTENANCE OF A CROSS-CUTTING VALIDATION FRAMEWORK FOR AND VALIDATION OF COPERNICUS LAND MONITORING SERVICE PRODUCTS

Date: 26/03/2025

Doc. Version: 1.2

Content ID: D7-2

Contents

List of Figures

List of Tables

Executive Summary

This report presents the validation results for the Copernicus Land Monitoring Service (CLMS) raster product CLCplus Backbone (CLCplus BB) 2021. It comprises a raster inventory layer displaying the predominant land cover class out of 11 basic categories for the reference year 2021. The work was conducted under the framework service contract No EEA/DIS/R0/23/010.

Thematic accuracy was assessed in a statistically sound approach using available reference and supportive data at different reporting units. It showed that at

- **EEA 38: Results are good but fall short of the target >90% at the EEA38 reporting level** with blind validation at 78.9% (0.6% Margin of Error) and plausibility validation at 85.3% (0.5% Margin of Error). Classes such as low-growing woody plants (5), lichens and mosses (8) and non- and sparsely-vegetated (9) showed significant improvement during plausibility checks.
- **BGR reporting**: **there are some regional differences**. The Arctic (ARC) region is the only one to achieve >90% accuracy (90.1%), lowest accuracy is observed in the Tropical (TRO) region (73.3%). The Mediterranean (MED) and Tropical (TRO) regions show significant challenges distinguishing low-growing woody plants (5), permanent herbaceous (6) and periodically herbaceous areas (7).

The CLMS Portal shows a good level of accessibility and usability, satisfying the essential user requirements for data access, multi-format availability, and protocol standards. It is recommended that optional metadata elements be included to facilitate more sophisticated chatbot interaction. To enhance usability and reproducibility in future product data releases, selected optional metadata elements could be refined.

Based on an analysis of product manuals and production-internal verification, a product requirements assessment was conducted based on the use case "Facilitation of independent assessments and the modelling of carbon pool dynamics according to LULUCF regulation".

A review of the documentation confirmed the availability of a comprehensive and detailed Product User Manual (PUM), which covers all necessary features. In future PUM releases there are a few areas that could benefit from improvement and the newly developed CLMS PUM template and guidance could be employed to ensure that the CLMS product documentation is consistently presented to users.

NOTE:

This report is intended to serve as the primary source for the information on thematic accuracy and selected usability aspects of CLCplus Backbone 2021 and contains the results from an independent, post-hoc assessment. A previous assessment of thematic accuracy that served production quality control ('internal validation') is presented within the Product User Manual of CLCplus Backbone 2021 (v1.2). Differences between the two assessments that result from different study designs, sample interpretation, the reference data considered as well as reporting levels and metrics are acknowledged but not further analysed here.

1 Introduction

This report informs about the validation assessments and their results obtained for the CORINE Land Cover plus Backbone (CLCplus BB) raster product 2021. The validation was conducted under the framework service contract No EEA/DIS/R0/23/010. The CLMS validation framework defines the validation methods applicable to the different CLMS products in a way to maximise synergies, yet also allow adaptations needed to product specific characteristics. Generally, the validation framework addresses the different validation elements referred to in the ISO19157:2023 standard, titled "Geographic information -- Data quality," to investigate the CLMS product quality within the CLMS validation framework:

- **Completeness**: The presence and absence of features, their attributes, and relationships.
- **Logical consistency**: The degree of adherence to logical rules of data structure, attribution, and relationships (e.g., topological consistency).
- **Positional accuracy**: The accuracy of the position of features.
- **Temporal accuracy**: The accuracy of temporal attributes and the relationships of features with time.
- **Thematic accuracy**: The accuracy of attribute values and classifications.

In addition to the ISO19157 quality elements:

- **Usability**: Checks assess the alignment of the product and metadata with FAIR (Findability, Accessibility, Interoperability, and Reusability) principles, as well as the quality and completeness of product documentation. Additionally, product specifications are evaluated against requirements derived from the specific use case: "Facilitating independent assessments and modelling carbon pool dynamics according to LULUCF regulation".

Completeness, logical consistency and positional accuracy are tested and validated as part of the CLMS production and delivery phase, mainly via the CLMS QC Tool (*CLMS QC Tool*, 2025) and are not replicated here. Temporal accuracy checks are only applied to CLMS product layers, where the relationships of product features to time are an implicit product criterion and are not applied to the CLCplus BB 2021 raster product.

2 Product Description
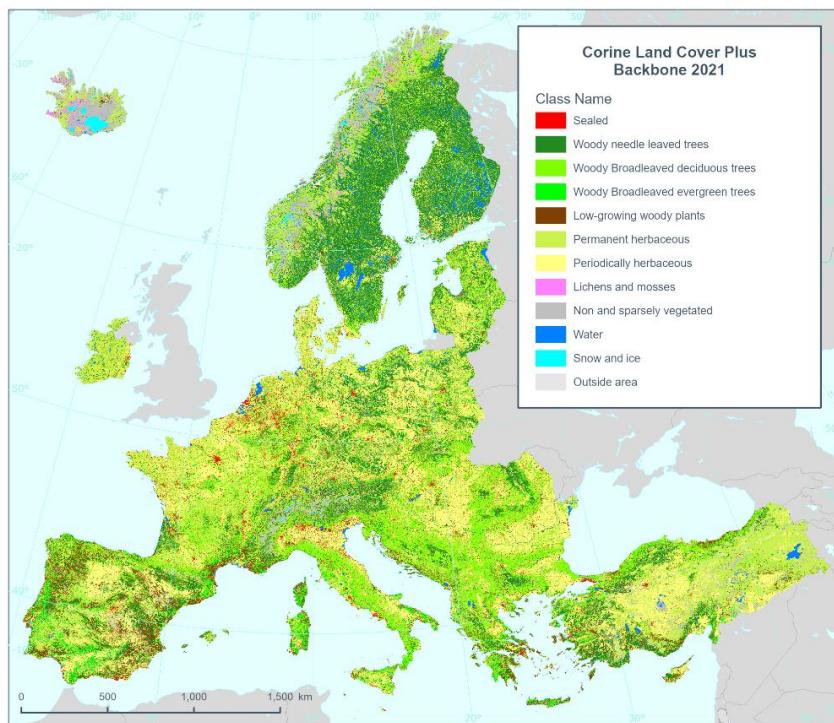
CORINE Land Cover plus Backbone (CLCplus BB) is a detailed pan-European wall-to-wall Land Cover (LC) inventory layer. It is part of the CLCplus product suite. This validation report covers the CLCplus BB product generated for the reference years 2021 (Table 1). The product provides, as a 10m spatial resolution raster layer, 11 encoded LC classes according to a predefined product specification (Table 2).

Table 1: CLMS product elements validated

Product Name	Acronym	Version	Date Provided / Published
CLCplus-Backbone Raster	CLCplus BB 2021	V1_1	21.06.2024 (Publication)

Table 2: CLCplus BB 2021 raster product characteristics (Copernicus Land Monitoring Service, 2022)

Product Name	Acronym	Product family
CLCplus Backbone Raster Product 10m	**CLCplus BB 2021**	**CLMS_CLCplus**
Summary:	CLCplus Backbone is a spatially detailed, large scale, EO-based land cover inventory. The CLCplus Backbone Raster Product is a 10m pixel-based land cover map based on Sentinel time series from October 2020 to March 2022 and auxiliary features. For each pixel it shows the dominant land cover among the 11 basic land cover classes.	
Reference year:	2021	
Geometric resolution	Pixel resolution 10m x 10m, fully conform with the EEA reference grid	
Coordinate Reference System:	European ETRS89 LAEA projection / for French DOMs WGS84 and the respective UTM zone	
Coverage:	5.749.035 km² (covering the full EEA-38)	
Geometric accuracy (positioning scale):	Equals Sentinel-2 positional accuracy in 2021 (< 11m at 95.5 % confidence level)	
Thematic accuracy:	90 % overall accuracy, not more than 15 % omission errors and 15 % commission errors per class (the amount of omission and commission errors for particular difficult classes such as Low-growing woody plants and Lichens and Moses might regionally exceed those thresholds)	
Data type:	8bit unsigned raster with LZW compression	
Minimum Mapping Unit (MMU):	Pixel-based (no MMU)	
Raster coding (thematic pixel values)	1: Sealed 2: Woody – needle leaved trees 3: Woody – Broadleaved deciduous trees 4: Woody – Broadleaved evergreen trees 5: Low-growing woody plants (bushes, shrubs) 6: Permanent herbaceous 7: Periodically herbaceous 8: Lichens and mosses 9: Non- and sparsely-vegetated 10: Water 11: Snow and ice 253: Coastal seawater buffer 254: Outside area 255: No data	
Metadata:	XML metadata files according to INSPIRE metadata standards	
Delivery format:	GeoTIFF incl. pyramids and INSPIRE-compliant metadata in XML format	
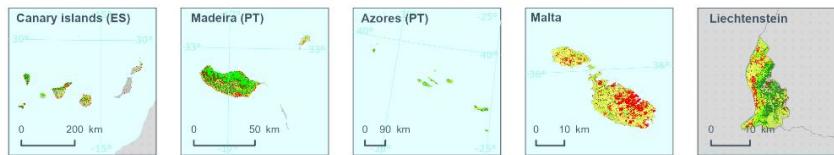
Figure 1: CLCplus BB Raster Product 2021 for the EEA-38 area (Source EEA).

3 Validation Methodology and Analysis

The following chapters describe the specific methods to check the thematic accuracy and usability for the CLCplus BB product 2021.

3.1 Thematic accuracy

The CLMS validation approach for thematic accuracy compares the CLMS products with validation data in a sample-based approach, following established scientific practices (Congalton & Green, 2008; Olofsson et al., 2014; Stehman & Foody, 2019). The validation data is assumed to be more accurate than the product data. The level of agreement between validation and product data defines the thematic accuracy. The accuracy estimation methodology consists of three major components, explained in more detail in the following chapters: Sampling Design, Response Design and Accuracy Assessment.

3.1.1 Sampling Design

The sampling design involves the protocol for selecting the sample and determining the number of sample units. The sample is chosen using a probability approach, ensuring each element has a calculable chance of selection (sampling weights). This approach allows for extrapolation of accuracy from the sample to the entire study area. Stratification is used to effectively allocate samples to classes of interest or rare classes that might otherwise be underrepresented. Knowing the sampling probability (weights) is crucial to account for unequal probabilities and prevent bias in accuracy estimation. **The sampling design for the validation of thematic accuracy for the CLMS product consists of two elements** (Figure 2):

- **Validation Areas**: representing the smallest reporting unit and seamlessly covering EEA38 territory as defined by the Copernicus EEA38 boundary layer (EEA, 2023b)
- **Sampling Frame**: 2x2 km grid points covering all validation areas

The validation areas are primarily defined by NUTS2 administrative units, which provide comprehensive and scalable coverage for the validation process. They are aligned with the CLMS production extent, including a buffer around the terrestrial territory. The validation areas are stratified by the Biogeographical Regions (BGR) dataset by the EEA (EEA, 2016) It contains the official delineations used in the Habitats Directive (92/43/EEC) and for the EMERALD Network set up under the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention). Each validation area is assigned to the BGR where most of the territory overlaps. During the generation of the validation areas, smaller NUTS2 units with fewer than 500 sample grid points were aggregated, and larger NUTS2 units were split to better align with the boundaries of the BGR.

The sampling frame is represented by points along a 2x2 km-spaced grid aligned with the Copernicus grid (EEA, 2024) and LUCAS Master frame grid (Ballin et al., 2018). It was spatially enlarged to cover EEA38. Each point of the grid is stratified by the CLCplus Backbone raster product 2018 (EEA, 2023a) into 11 classes, with the pixel northeast of the point used as a reference class for stratification. The points define the position of the sample unit. The final sample units for the accuracy assessment are then selected using both validation areas and sampling frame.
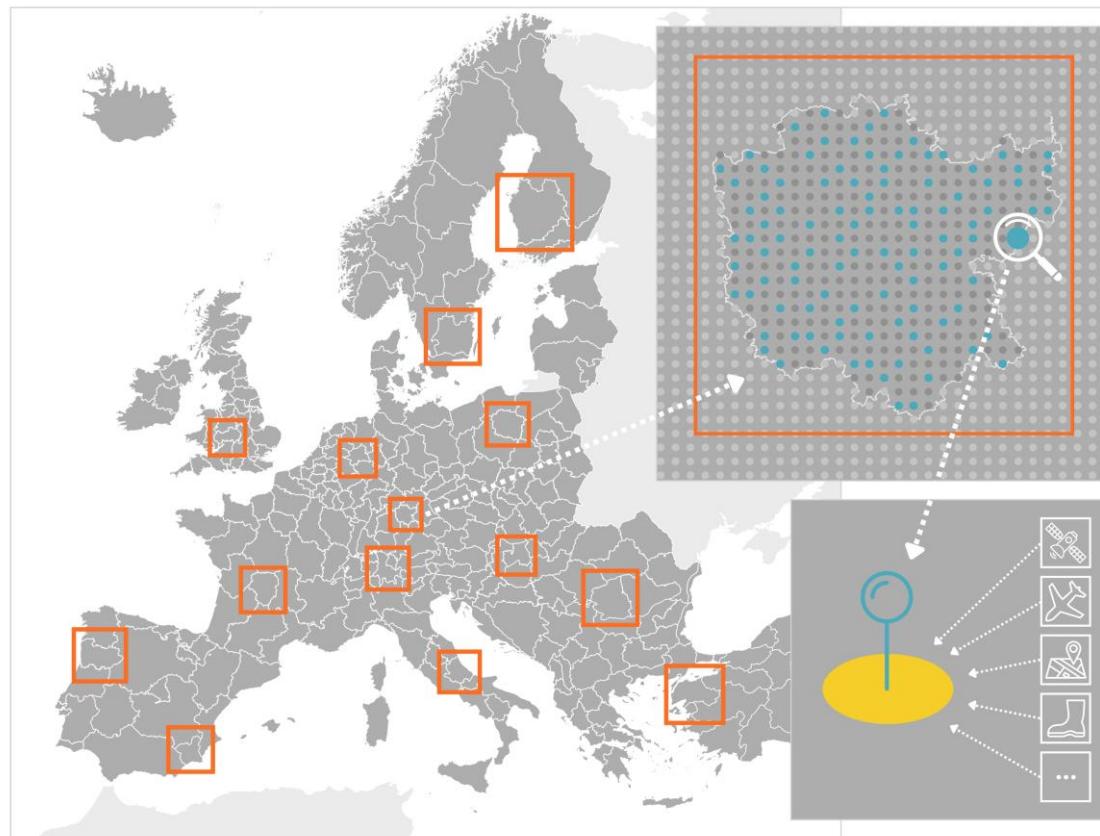
Figure 2: Schematic example of sampling design: selection of validation area (orange squares), selected sampling locations (blue) within validation area (white outline) and sampling units (yellow) populated with existing reference information.

The validation areas are selected from each BGR stratum using a random selection process, whereby larger validation areas are more likely to be selected. A minimum of one validation area per BGR is required, with an approximately proportional allocation of the remaining areas. Depending on the applied reporting level different numbers of validation areas are selected for the standard CLMS cross-cutting validations. For the EEA38 wide assessment of CLCplus BB2021, 38 validation areas are randomly selected from each biogeographic region representing approximately 19% of EEA38 territory.

Table 3: Validation areas per Biogeographical Region in EEA38

Biogeographical Region	EEA38	
	Total validation areas	Selected validation areas
Alpine (ALP)	21	3
Anatolian (ANA)	11	2
Arctic (ARC)	1	1
Atlantic (ATL)	42	6
Black Sea (BLS)	6	2
Boreal (BOR)	17	3
Continental (CON)	102	10
Macaronesia (MAC)	2	1
Mediterranean (MED)	60	6
Pannonian (PAN)	10	2
Steppic (STE)	1	1

Biogeographical Region	EEA38	
	Total validation areas	Selected validation areas
Tropical (TRO)	3	1
Total	276	38

Sample points are then drawn from the sampling frame within the selected validation areas. The points are selected using a random stratified approach from each CLCplus BB 2018 strata. The number of sample units is determined based on two key considerations:

- Minimum number of sample units for accuracy reporting: A sufficient number of sample units is needed to report accuracy across all thematic classes at both the validation area and BGR levels. The number of sample units is guided by the product accuracy requirements and corresponding margin of error (MoE) of ±5% at a 95% confidence interval. The underlying sample size calculation is presented in ((Olofsson et al., 2014) and uses expected user's accuracy p a and targeted MoE d, to estimate the required number of sample units per class n_h. The z-score z is set to 1.96 for a 95% confidence interval.

$$n_h = \frac{z^2 p(1-p)}{d^2}$$

- Based on the assumption of a product per class user's accuracy (UA) of 85% and a target MoE of the UA of 5%, this would then require 200 sample units per class. The objective is to have a minimum number of sample units per class at the BGR level. For each selected validation area there should be a minimum of 30 samples per class. However, fewer samples may be acceptable for rare classes that are not well-covered in some BGRs or validation areas. For some classes, the selected sample size is thus below 200 per BGR because there are not enough sample units available within the standard 2x2 km sampling frame.

- A maximum number of sample units per validation area was defined, ranging from 500 to 800, depending on the number of validation areas per BGR. Larger BGRs were allocated fewer sample units per validation area, while smaller BGRs with fewer validation areas received more. Once the minimum number of sample units per validation area is met, the remaining units up to the maximum number are allocated proportionally. This approach targets enough sample units for all thematic classes across all reporting levels, while maintaining a representative character by allocating a part of the sample units proportionally.

- Shared sampling design: The overall CLMS validation framework foresees that one sample can be used for different CLMS products (cross-cutting efficiency). To achieve this, a sufficient number of sample units must be allocated across different thematic domains. The CLCplus BB 2018 classes are used as the strata for guiding this allocation since its thematic classes cover most land cover types. To ensure adequate representation of rare classes, more sample units are included than typically required to achieve statistical robustness.

Sample weights are calculated for each sample unit combining the selection probabilities of the first stage and second stage sampling. The weights provide the information how many sample units each point represents in the total population of all possible sample points. It considers the different selection probabilities in both sampling phases and compensates for unequal number of samples per strata.

This general cross-cutting sampling approach foresees using the same validation areas and sample units for the validation of different CLMS products and reference years. Validation areas are not considered fixed but may be adjusted or changed in the course of later validation

activities in order to consider the availability of existing and upcoming reference data, align with changing CLMS product extent or to better cover specific CLMS product classes.

Adjustments are needed to this general sampling approach for the CLCplus BB 2021 validation to ensure independence of validation data from production data. The LUCAS 2018 survey data has been used extensively in the production of CLCplus BB 2021 (Copernicus Land Monitoring Service, 2024), but is also an important reference data source for this CLMS validation. Therefore, to maintain independence from the training data, any point in the sampling frame grid that coincided with LUCAS 2018-point locations has been replaced using the following procedure:

- Shift the points 1 km north. If the point remains within the same LC, it is kept in its new position.
- If the point does not remain in the same strata, shift the point 1 km east from the original position. If the point is within the same CLCplus BB 2018 strata, it is kept in its new position. If not, shift the point back to the northern position and accept the different strata.

This procedure ensures the independence of validation data by avoiding bias from using training data and maintains an approximate share of the same LC strata. Around 26% of the sample points selected were shifted spatially.

The targeted sample size of 200 sample units is achieved for all thematic classes at the EEA38 level, except for the snow and ice class (11) (Table 4). For some BGR, there are thematic classes with lower sample unit numbers, due to their limited occurrence, e.g. sparse vegetation (9) in the Pannonian region (PAN), broadleaved evergreen trees (4) in the Black Sea region (BLS), or sealed areas (1) in the Arctic region (ARC).

Table 4: Sample units per CLCplus BB 2021 class and Biogeographic Region at EEA38

	1	2	3	4	5	6	7	8	9	10	11	Total
ALP	108	437	412		196	522	185	74	278	89	78	2379
ANA	132	158	161	10	160	402	233		188	55		1499
ARC	46	27	57		96	155	9	87	107	97	100	781
ATL	275	304	515	188	382	1136	596		219	243		3858
BLS	95	142	362	11	138	267	276		110	72		1473
BOR	232	428	294		205	374	265	93	208	147		2246
CON	379	602	971		213	1052	1355		101	306		4979
MAC	39	50	16	93	66	102	26		26	77		495
MED	225	361	444	607	797	906	680		240	228		4488
PAN	165	164	231		152	248	394		30	104		1488
STE	86	87	118		92	125	179		35	78		800
TRO	58			205	52	140	25		8	99		587
Total	1840	2760	3581	1114	2549	5429	4223	254	1550	1595	178	25073

1: Sealed
2: Woody – Needle leaved trees
3: Woody – Broadleaved deciduous trees
4: Woody – Broadleaved evergreen trees

5: Low-growing woody plants (bushes, shrubs)
6: Permanent herbaceous
7: Periodically herbaceous
8: Lichens and mosses

9: Non- and sparsely-vegetated
10: Water
11: Snow and ice

3.1.2 Response Design

The response design describes all steps to collect validation data at the sample sites and compare it with the product to be validated. It includes deciding on an appropriate type of

sample unit and the protocol for collecting or preparing reference data to create a 1:1 spatial, thematic, and temporal match with the product data.

The sample unit for CLCplus BB 2021 consists of 4 pixels representing an area of 20x20 meters around the central sampling point (Figure 3). The north-eastern (NE) pixel is used as the main sample unit for land cover (LC) interpretation. Additionally, it is recorded if the other three units also belong to the NE-recorded LC. This enables further analyses, such as LC homogeneity assessments over the enlarged sample unit. In analogy to the CLCplus BB production process, a pixel is classified into a LC class if that class covers more than 50% of the pixel. If no single LC class exceeds 50%, a relative majority is used, as detailed in the decision tree applied during the CLCplus BB 2018 production (Copernicus Land Monitoring Service, 2024).
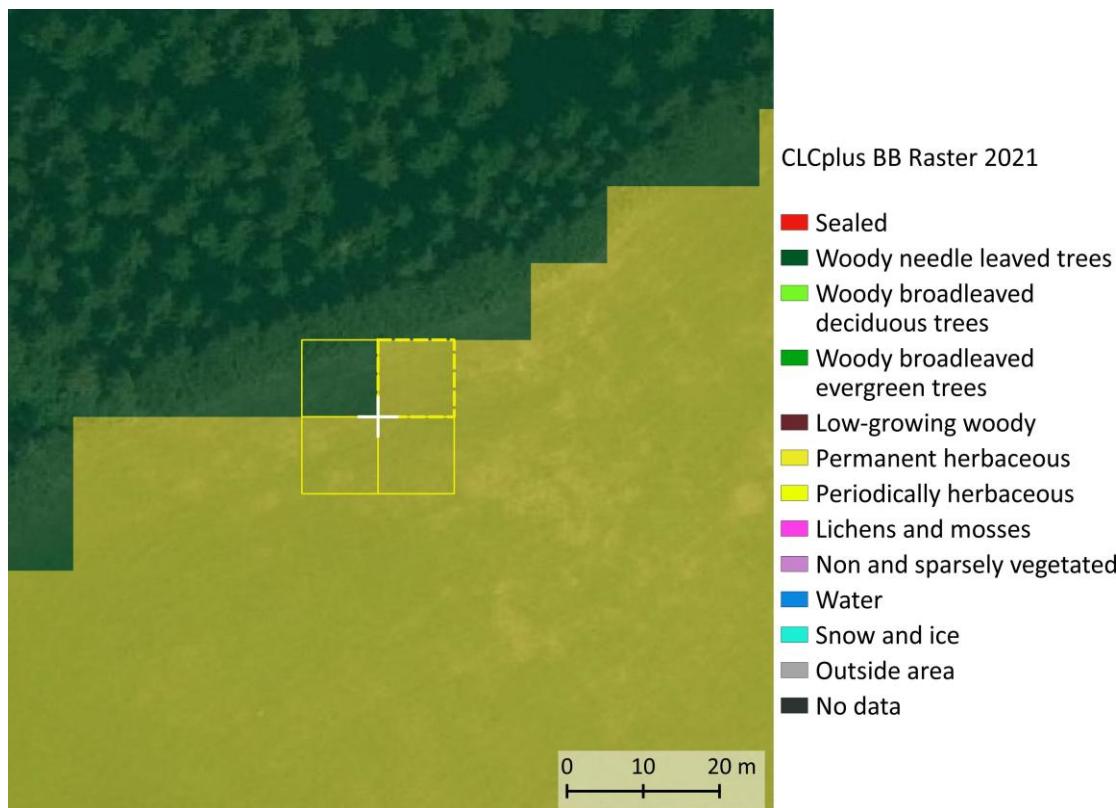
Figure 3: Sample units for the validation of CLCplus BB 2021. Central sampling point (white cross) and surrounding sample units (yellow) including the main North-Eastern sample unit (dashed line)

In the standard approach, validation data is created by classifying samples according to the thematic classes of the products being validated. This process involves utilizing existing and suitable reference datasets. **Sample units are inspected or visually interpreted using Computer-Assisted Photointerpretation (CAPI) and existing high-quality reference and supporting data** (Table 5). The reference data serve as the primary source for visual interpretation, providing high-quality reference information from the same year. Supportive data, on the other hand, offer additional context or information to aid the decision-making process. Reference data from different years can be used to confirm stable classes/quantities from logical rules or to track and confirm change between CLMS product releases. E.g. Orthophotos showing needle leaved forest in pre-product dates and needle leaved forest in post-product years, imply that the same forested land cover was also present in the CLMS product reference year. The checks and interpretation of the sample units are conducted in a Geographic Information System (GIS), employing dedicated data entry forms that incorporate a range of features including dropdown

menus, checkboxes, comment text fields and the capacity for structured and guided data entry (Figure 4).

Figure 4: Standard GIS layout for interpretation of CLCplus BB sample units. Customised attribute entry form (right) and multiple maps views with reference or supportive layers (left).

To address possible discrepancies in temporal, thematic, or spatial comparability with validation data, two approaches are applied for validation:

- **Initial Blind Approach**: At this stage, validation data is created independently of the product. The interpreter is unaware of the CLMS product value or the sample strata to which it belongs during the classification process, ensuring an unbiased comparison. Alternatively, reference data from different sources can be compared directly to the map. This approach helps to maintain the objectivity of the validation process.

- **Plausibility Approach**: In this phase, "not matching" sample units are reviewed again with knowledge of the CLMS product value. This review helps identify and rectify discrepancies due to factors such as border cases, ambiguous class definitions, or different minimum mapping units or issues related to positional shift between reference and map data (Table 6).

This approach results in two validation datasets, one from the initial blind approach and another after the plausibility review, thereby reducing errors in sample unit classification. The workflow ensures that the plausibility review is conducted only after the blind approach has been completed, and it is performed by a different operator, further enhancing the objectivity and accuracy of the validation process.

Table 5: Reference (r) and supportive data (s) used for the validation of CLCplus BB 2021

Coverage	Use	Product name	Reference type	Reference year	Access mode	Provider
EEA39	r	EEA39_VHR_2018	Orthoimagery	2018	WMS / WMTS	EEA/CLMS
EEA39	s	EEA39_VHR_2021	Orthoimagery	2021	WMS / WMTS	EEA/CLMS
Global	s	Bing maps	Orthoimagery	unknown	WMS / WMTS	Bing
Global	s	Google Maps	Orthoimagery	unknown	WMS / WMTS	Google
EU22+UK	s	LUCAS 2009	Field data / PI	2009	Download	Eurostat
EU26+UK	s	LUCAS 2012	Field data / PI	2012	Download	Eurostat

Coverage	Use	Product name	Reference type	Reference year	Access mode	Provider
EU27	s	LUCAS 2022 Copernicus Polygons	Field data	2022	Download	Eurostat
EU27	s	LUCAS 2022	Field data / PI	2022	Download	Eurostat
EU27+UK	r	LUCAS 2015	Field data / PI	2015	Download	Eurostat
EU27+UK	s	LUCAS Master Strata	PI	<2017	Download	Eurostat
National / regional	s	EuroCrops IACS data	IACS / LPIS	2019-2022	Download	EuroCrops
National / regional	s	Orthoimagery, Aerial photos	Orthoimagery	Most recent	WMS / WMTS or Download	Various
National / regional	r	Orthoimagery, Aerial photos	Orthoimagery	2021	WMS / WMTS or Download	Various
National/ regional	s	Additional IACS / LPIS data not covered by EuroCrops	IACS / LPIS	2021	Download	Various
National/ regional	s	Land Cover / Land Use or Vegetation Maps from different Regions, incl. French DOM	Land Cover Map	Most recent available	WMS / WMTS or Download	Various

Table 6: Possible causes for implausibility of CAPI blind results

Cause for blind CAPI not plausible	Explanation
Border case	Mixed pixels commonly found in transition zones between land cover types. Determining the precise coverage of a LC class is difficult. In such cases, the sample unit is classification "in favour" of the map.
Qualitatively limited reference data	The limitations of the reference data prevent an unambiguous classification. These limitations can be due to shift, tilt, shadow, low resolution, or partial missing data.
Difficult class elements for photointerpretation	LC difference cannot be directly interpreted. For example, the height of the woody plants distinguished CLCplus BB class 2/3/4 vs. 5. This attribute cannot be clearly determined from 2D image data. For the class 9 vs. 11, the duration of ice coverage in the course of the reference year is important and needs a time-series image interpretation.
Error in blind approach	Incorrect interpretation during blind approach.
Other/unclear	All other cases. Requires explanatory comment.

3.1.3 Accuracy Assessment

The product's thematic accuracy is assessed by comparing the validation data and the product map data using a statistical approach, with the results presented in a confusion matrix. Sample weights are used to compensate for the unbalanced selection probabilities of individual sample units in the stratified sampling approach. Several accuracy measures are calculated to assess the thematic accuracy of the CLMS product. These reporting measures include:

- **User's Accuracy (per product class, UA)**: Indicates the probability that a sample unit classified as a certain class in the product actually belongs to that class on the ground.
- **Producer's Accuracy (per product class, PA)**: Indicates the probability that a sample unit belonging to a certain class on the ground is correctly classified in the product.
- **Overall Accuracy (OA)**: Indicates the proportion of correctly classified sample units across all classes.

- **Margin of Error (MoE)**: The margin of error, representing the standard deviation at a 95% confidence level, is calculated for user's accuracy, producer's accuracy, and overall accuracy. This provides an estimate of the uncertainty associated with the accuracy measures.

$$MoE = z \; x \; SE$$

SE is the Standard Error of the accuracy estimate, and z is the z-score corresponding to the desired confidence level, approximately 1.96 for 95% confidence level.

- **F1 Score (per product class i)**: The F1 Score is a harmonic mean of user's accuracy and producer's accuracy for each product class. It provides a single measure of accuracy that balances the trade-off between both accuracies.

$$F1 \; Score = 2 \; x \frac{UA_i \; x \; PA_i}{UA_i + PA_i}$$

Since the CLMS validation framework uses the same sample units for different CLMS products the strata and the mapped classes are not the same and standard stratified estimators (Olofsson et al., 2014) are not suitable for calculation of overall, user's and producer's accuracy. Instead indicator functions and stratified estimators described by Stehman (2014) are used to calculate accuracies and their variances. The indicator functions are used to account for that sample units are selected from strata different than the map classes. Indicator function for overall accuracy is defined as:

$$y_u = \begin{cases} 1 & if \; unit \; u \; is \; classified \; correctly \\ 0 & if \; unit \; u \; is \; classified \; incorrectly \end{cases}$$

Overall accuracy is then calculated as a sample mean using a stratified estimator from Stehman (2014):

$$\widehat{\overline{Y}} = \sum_{h=1}^{H} N_h^* \; \overline{y}_h / N$$

Where

$$\overline{y}_h = \sum_{u \in h} y_u / n_h^*$$

is the sample mean of the y_u values in stratum h, $u \in h$ indicates that sample unit u was selected from stratum h and H denotes the number of strata. N is the number of all possible units in the sample frame (population), N_h^* is the number of possible units and n_h^* the selected sample units in stratum h. An estimator for the variance of $\widehat{\overline{Y}}$ is provided in Stehman (2014) Equitation 25 and 26.

User's accuracy and producer's accuracy require different indicator functions for $y_u \; and \; x_u$.

For user's accuracy:

$$y_u = \begin{cases} 1 & if \; unit \; u \; is \; classified \; correctly \; and \; is \; map \; class \; k \\ 0 & otherwise \end{cases}$$

and

$$x_u = \begin{cases} 1 & if \; unit \; u \; is \; map \; class \; k \\ 0 & otherwise \end{cases}$$

for producer's accuracy:

$$y_u = \begin{cases} 1 \; if \; unit \; u \; is \; classified \; correctly \; and \; has \; class \; k \; in \; the \; validation \; data \\ 0 \hspace{8.5cm} otherwise \end{cases}$$

and

$$x_u = \begin{cases} 1 \; if \; unit \; u \; has \; class \; k \; in \; the \; validation \; data \\ \hspace{2cm} 0 \; otherwise \end{cases}$$

User's and producer's accuracies are then calculated using a combined ratio estimator Stehman (2014) Equitation 27:

$$\hat{R} = \frac{\sum_{h=1}^{H} N_h^* \overline{y}_h}{\sum_{h=1}^{H} N_h^* \overline{x}_h}$$

where $\overline{y}_h$ and $\overline{x}_h$ are the sample means of y_u and x_u in the stratum h. The variance estimator for $\hat{R}$ is provided in Stehman (2014) Equitation 28.

In addition to accuracy metrics based on the weighted confusion matrix, unweighted confusion matrices with raw sample unit counts are provided. These offer insights into inter-class confusion, especially for rare classes with low sample weights and where the actual performance may not be well reflected in the weighted result. To avoid confusion with the statistical correct weighted accuracy metrics, the producer's and user's accuracy based on the unweighted confusion matrix are labelled additionally as "Unweighted" and calculated as:

$$Unweighted \; UA \; = \; \frac{Number \; of \; sample \; units \; correctly \; classified \; and \; with \; map \; class \; k}{Total \; number \; of \; sample \; units \; classified \; as \; map \; class \; k}$$

$$Unweighted \; PA \; = \; \frac{Number \; of \; sample \; units \; correctly \; classified \; and \; with \; validation \; class \; k}{Total \; number \; of \; sample \; units \; with \; validation \; data \; class \; k}$$

3.2 Usability

The following usability assessment are done using the CLCplus BB 2021 product:
- Product and metadata accessibility and alignment with FAIR principles.
- Checking product compliance with generic product requirements for the potential use case "Facilitation of independent assessments and the modelling of carbon pool dynamics according to LULUCF regulation".
- Assessment of the CLMS Portal's accessibility using various methods and tools to evaluate different aspects.
- Documentation & metadata completeness: Review of Product User Manuals (PUM) and Algorithm Theoretical Basis Document (ATBD).

To ensure the CLCplus BB 2021 product metadata and datasets comply with FAIR principles, **evaluations are conducted using a Digital Object Identifier (DOI) or permanent Uniform Resource Locator (URL) with three specific tools**: FAIR Enough (FAIR Enough, 2022), FAIR-checker (FAIR-Checker, 2024) and F-UJI (F-UJI, 2024). These tools often identify overlapping issues, but their comparative outputs help emphasize different FAIR principles such as Findability, Accessibility, Interoperability, and Reusability. This analysis helps pinpoint areas for improvement, listing non-compliant criteria and suggesting potential solutions. The assessment of the CLMS Portal emphasizes evaluating accessibility to ensure that users can easily access and interact with CLMS products through the Portal. This assessment, focusing on performance and

user interaction, is conducted post-publication using a variety of methods and tools. These tools check compliance with web accessibility standards, analyse user navigation, evaluate user experiences during login, verify content format availability, measure response times, and ensure the use of open, standardized protocols. The assessment also includes testing across different browsers and devices to test consistent performance and responsiveness.

The product requirements check whether the product specifications align with a specific use case. The process begins by identifying the use case and its specific requirements, such as temporal and spatial resolution, thematic accuracy, and data accessibility. These requirements are organized in a product requirements check table and evaluated against the product documentation and metadata as published on the CLMS Portal. Compliance observations are recorded, along with any identified gaps where the product does not fully meet user expectations or where the source data used does not allow compliance to be confirmed.

The document review approach enhances the ATBD and PUM of the CLMS product by assessing various criteria against standards and best practices for quality, format, and depth. In this case, no ATBD was provided, and the review was therefore limited to the PUM. It ensures logical content structure, clear language, and high-quality visuals. The review, from preliminary drafts to final versions, uses tables to systematize and standardize evaluations, incorporating a scoring system and targeted checks. If the documents predate specific templates, certain assessments are omitted. The process is documented in detail, providing a comprehensive record of the evaluations and areas for improvement.

4 Results

4.1 Thematic Accuracy

The thematic accuracy results are described at the two reporting levels: EEA38 and Biogeographical regions (BGR).

4.1.1 EEA38

The thematic accuracy evaluation shows an **overall accuracy of the CLCplus BB 2021 raster layer of 85.3% (0.5% Margin of Error) for the plausibility approach** and 78.9 % (0.6%) for the blind validation approach (Table 7). The validation results here is therefore lower than the published internal verification results of 93.7% (0.3%) (Copernicus Land Monitoring Service, 2022). **The targeted overall accuracy of the CLCplus BB raster of >90% could thus not be confirmed**.

Table 7: Overall thematic accuracy results at EEA38 level

Method	Overall Accuracy [%]	Margin of Error [%]
Blind validation approach	78.9%	0.6%
Plausibility validation approach	85.3%	0.5%

Accuracies improve during the plausibility checks, with more classes approaching or exceeding the requested 85% class accuracy (Table 8). The class-specific accuracies of the periodically herbaceous class (7), water (10) and snow and ice (11) have user's or producer's accuracies higher than the required 85% in the blind validation results. Especially, low-growing woody plants (5), lichens and mosses (8) and non- and sparsely-vegetated (9) improved considerably during the plausibility checks. The higher user's accuracy (UA) compared to producer's accuracy (PA) for the classes periodically herbaceous (7), lichens and mosses (8) and non- and sparsely-vegetated (9) indicate that those classes are underestimated in the CLCplus product. The lower PA indicates that the number of missed pixels in these classes is higher than the number of falsely classified pixels in the map. The MoE is below the targeted 5% for all classes except lichens and mosses (8) and snow and ice (11), which relates to the combination of lower accuracy and lower number of sample units.

The confusion matrix shows the number of samples per class (Table 9). It provides more information on the main class confusions identified during the plausibility analysis. The green diagonal line indicates the matches between CLMS product and validation sample. One unexpected confusion is between sealed (1) and permanent herbaceous areas (6). The very high producer's accuracy (unweighted) of 89.9% is in contrast to the lower user's accuracy of 73.8%. There are many areas where well classified small urban structures and surrounding landscape are very well captured (Figure 5). However, visual data checks showed, that this reported confusion of often caused by fragmented urban settlements or linear infrastructures like roads, which are difficult to capture at 10m spatial resolution and the strong spectral response from sealed surfaces (Figure 6). There are good examples of differentiation between small adjacent areas of broadleaved and coniferous forest, and the transition to herbaceous areas (Figure 7). Still, high confusion occurs among some

> CLCplus BB product classes
> 1: Sealed
> 2: Woody – needle leaved trees
> 3: Woody – Broadleaved deciduous trees
> 4: Woody – Broadleaved evergreen trees
> 5: Low-growing woody plants (bushes, shrubs)
> 6: Permanent herbaceous
> 7: Periodically herbaceous
> 8: Lichens and mosses
> 9: Non- and sparsely-vegetated
> 10: Water
> 11: Snow and ice

vegetation-related classes. Low growing woody plants (5) show confusion with larger growing deciduous trees (3) and permanent herbaceous areas (6) (Figure 8 and Figure 9). Sparse vegetation (9) also contributes to misclassifications with sealed (1) and permanent herbaceous (6). Permanent herbaceous (6) has confusion with all other classes, except snow and ice (11). Lichens and mosses (8) are especially confused with permanent herbaceous vegetation (6) and non- and sparsely-vegetated (9) areas. Lichens and mosses often grow in complex patterns with rocks, grasses, dwarf shrubs, difficult to assess using satellite image pixels and is often even difficult to map without further ancillary information from very high resolution images (Figure 10). Other classes like water (10) and snow and ice (11) have very high classification accuracy, showing minimal confusion.

Table 8: Thematic accuracy results at EEA38 per CLCplus BB class

Product Class	Blind Validation approach					Plausibility validation approach				
	UA [%]	MoE [%]	PA [%]	MoE [%]	F1 Score [%]	UA [%]	MoE [%]	PA [%]	MoE [%]	F1 Score [%]
1	71.6	2.6	75.2	3.6	73.4	75.2	2.4	79.7	3.5	77.4
2	84.3	1.9	84.5	1.3	84.4	88.2	1.7	88.1	1.2	88.2
3	79.3	1.5	83.5	1.4	81.4	83.7	1.4	87.7	1.2	85.7
4	58.3	3.1	71.1	2.8	64.1	83.1	2.5	85.9	2.0	84.5
5	65.3	2.3	53.4	1.9	58.8	76.4	1.8	73.4	2.2	74.9
6	72.9	1.3	82.0	1.0	77.2	79.7	1.2	86.2	0.9	82.8
7	93.8	0.8	83.3	1.2	88.2	94.6	0.7	84.8	1.2	89.5
8	57.2	9.5	30.9	7.2	40.1	81.9	8.7	46.3	9.2	59.1
9	70.1	2.9	50.6	3.0	58.8	80.4	2.3	65.3	3.4	72.0
10	98.3	0.6	95.5	1.6	96.9	98.4	1.1	95.6	1.6	96.9
11	96.5	1.9	92.0	7.5	94.2	98.4	1.7	96.5	3.0	97.4

Green = Higher than CLMS product target accuracies, Yellow = within 5% of target accuracy, Red = MoE >5%
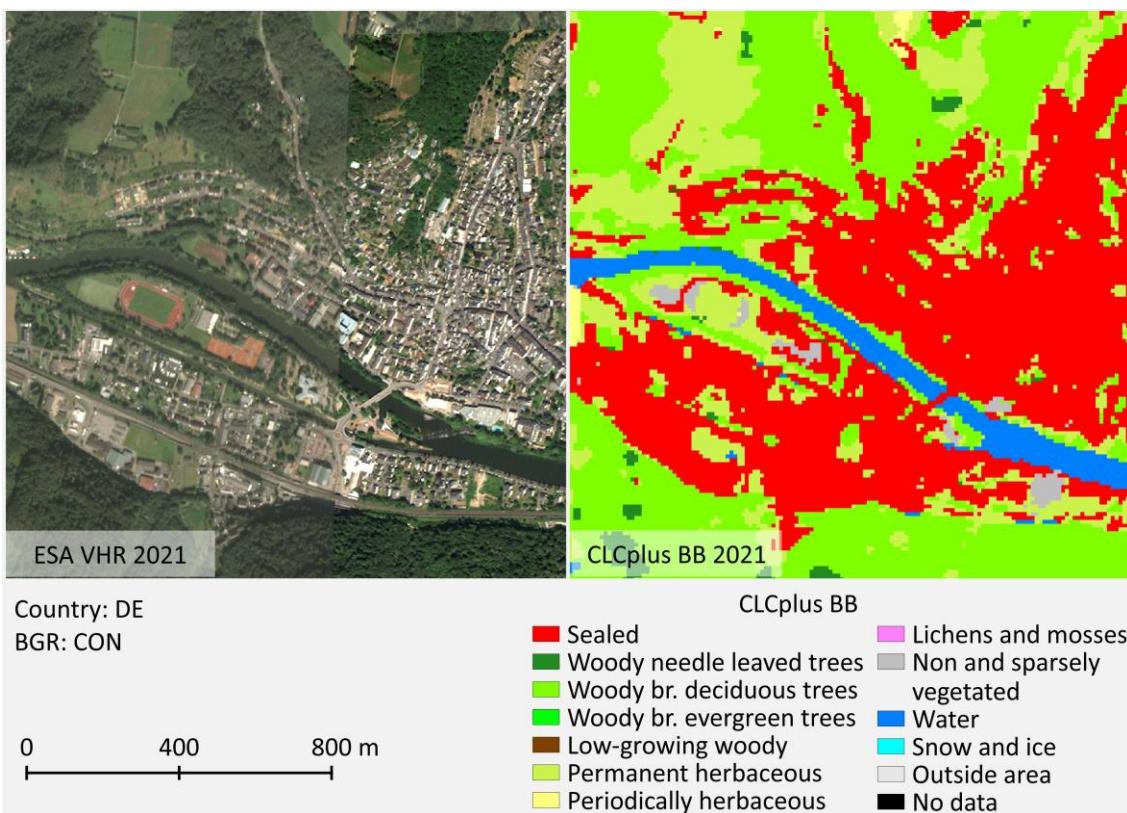
Figure 5: Example of well classified small urban structures and surrounding landscape in Germany.
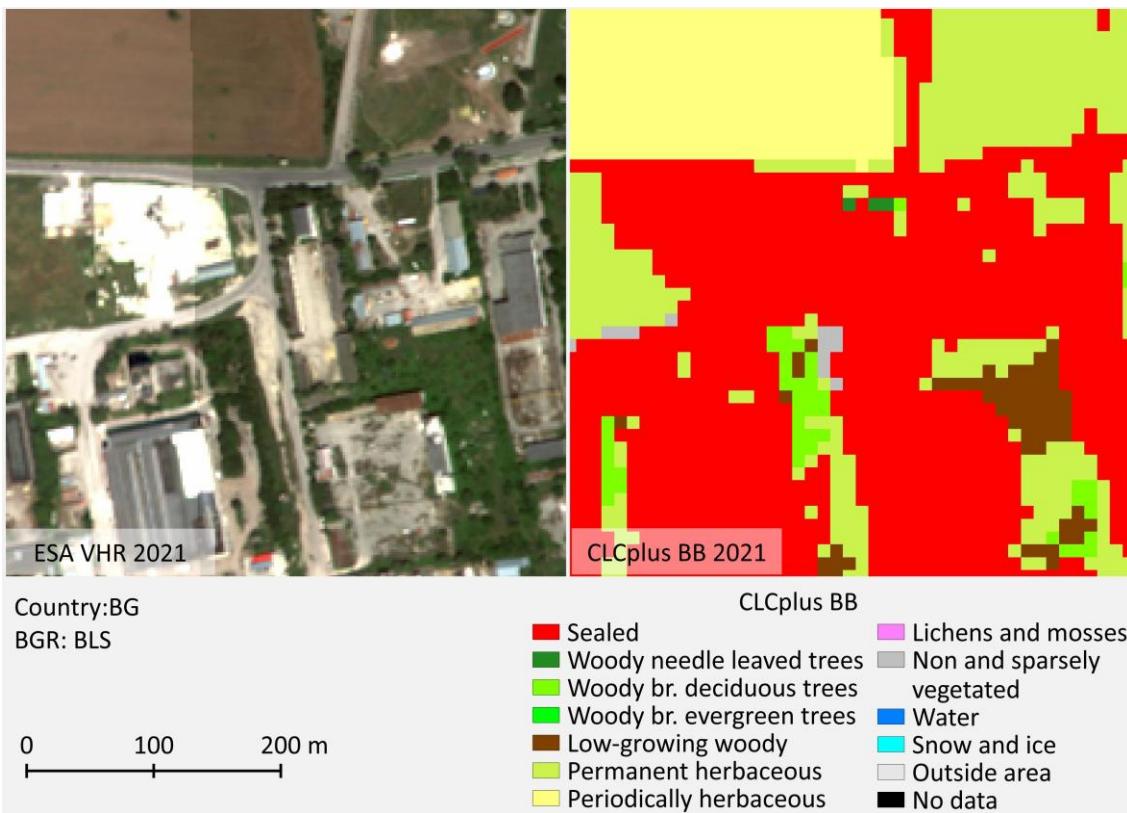
Figure 6: Example of confusion between sealed areas and herbaceous vegetation in fragmented urban settlements in Bulgaria.
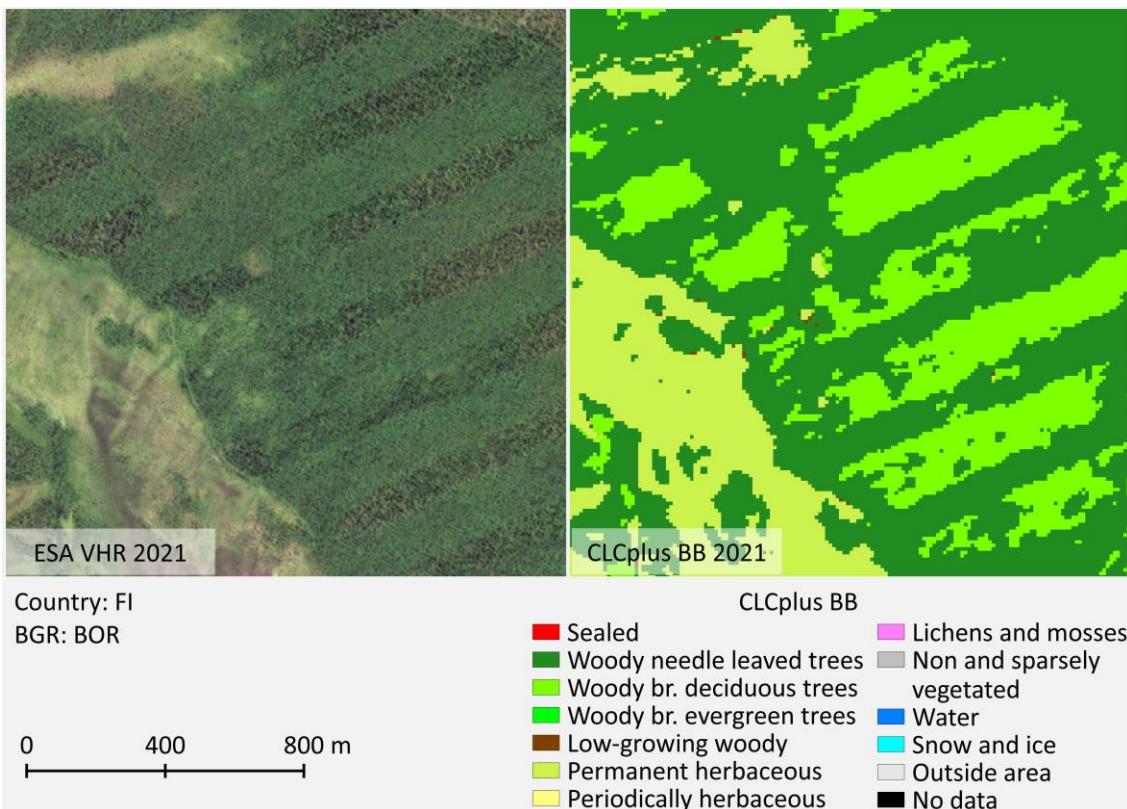
Figure 7: Good mapping example of adjacent broadleaved and coniferous forest areas and transition to herbaceous areas in Finland.
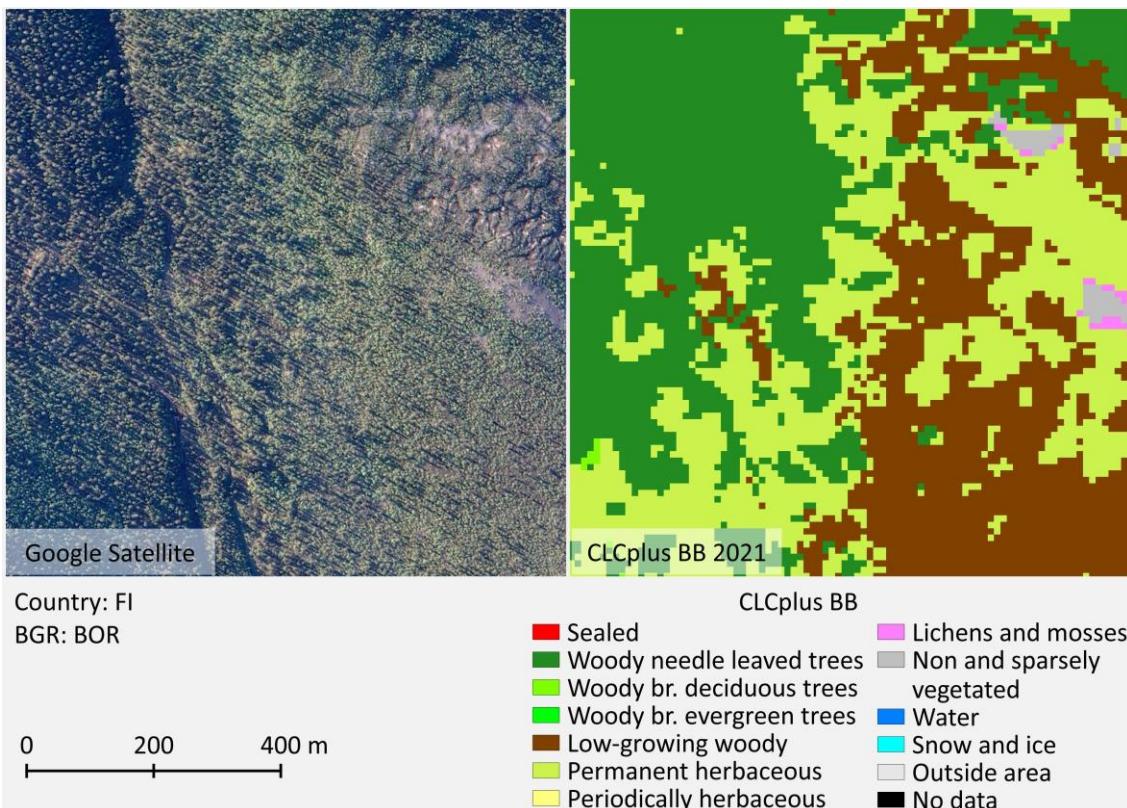
Figure 8: Example of confusion in complex situation of woody vegetation, low-growing woody vegetation and permanent herbaceous in Finland.
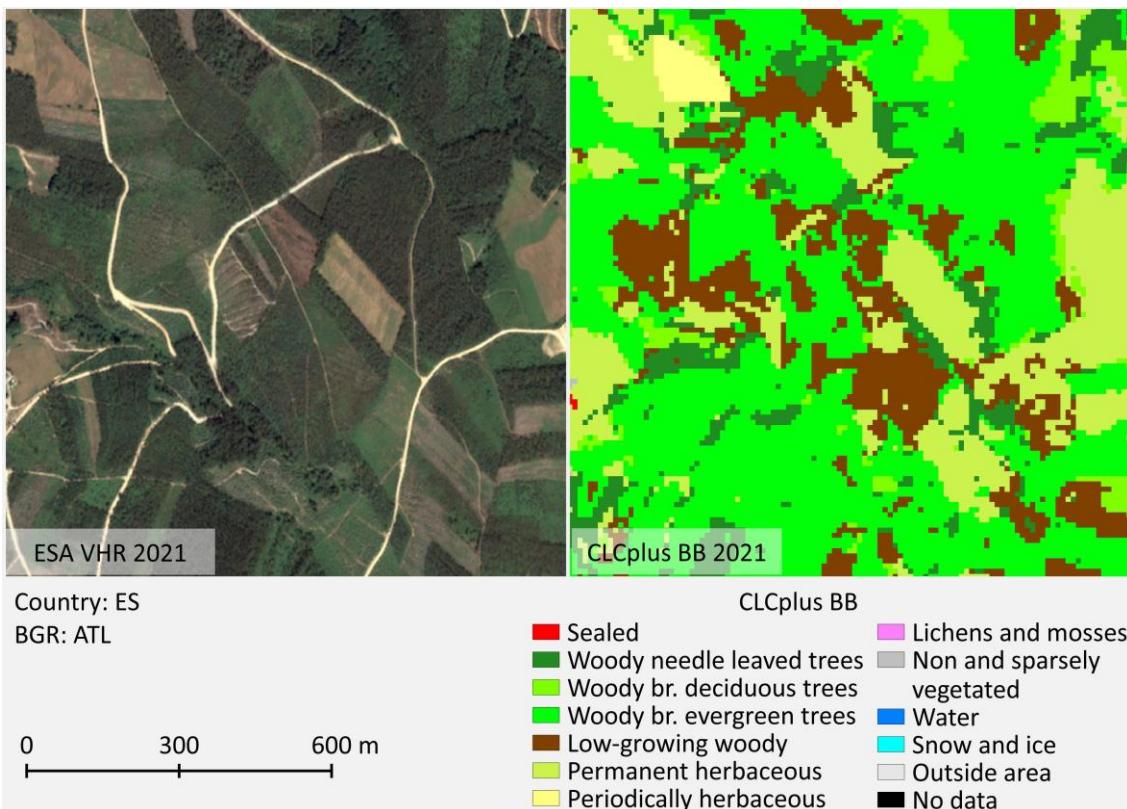
Figure 9: Example of confusion in complex situation of woody vegetation, low-growing woody vegetation and permanent herbaceous in Spain.
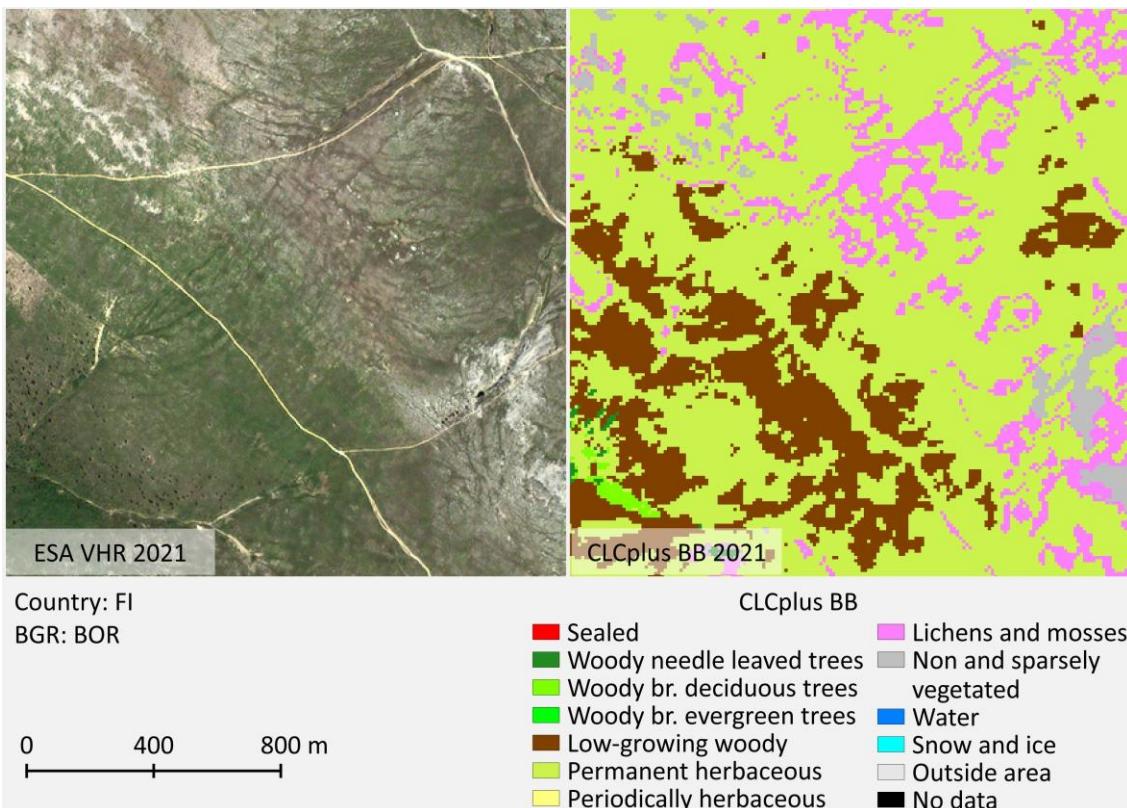
Figure 10: Example of confusion in complex situation of lichens and mosses, low-growing woody vegetation and permanent herbaceous in Finland.

Table 9: Unweighted confusion matrix (sample counts) for plausibility approach at EEA38

			Validation data												Total	User's Accuracy Unweight.
			1	2	3	4	5	6	7	8	9	10	11		
CLCplus BB 2021	1	Sealed	1,357	12	46	9	21	262	20	0	107	6	0	1,840	73.8%
	2	Woody – needle leaved trees	5	2,397	141	11	60	113	1	1	31	0	0	2,760	86.8%
	3	Woody – Broadleaved deciduous trees	13	210	3,017	6	103	199	16	0	15	2	0	3,581	84.3%
	4	Woody – Broadleaved evergreen trees	7	9	13	925	40	90	14	0	15	1	0	1,114	83.0%
	5	Low-growing woody plants (bushes, shrubs)	12	92	178	52	1,720	386	44	6	54	5	0	2,549	67.5%
	6	Permanent herbaceous	59	51	164	84	188	4,178	544	41	101	19	0	5,429	77.0%
	7	Periodically herbaceous	9	0	19	14	17	157	3,960	0	44	3	0	4,223	93.8%
	8	Lichens and mosses	0	4	0	0	4	12	0	220	14	0	0	254	86.6%
	9	Non- and sparsely-vegetated	46	14	10	4	75	156	65	17	1,127	29	7	1,550	72.7%
	10	Water	1	1	6	0	2	14	1	0	10	1,560	0	1,595	97.8%
	11	Snow and ice	0	0	0	0	0	0	0	0	7	0	171	178	96.1%
		Total	1,509	2,790	3,594	1,105	2,230	5,567	4,665	285	1,525	1,625	178	25,073	
		Producer's Accuracy Unweighted	89.9%	85.9%	83.9%	83.7%	77.1%	75.0%	84.9%	77.2%	73.9%	96.0%	96.1%		82.3%

4.1.2 BGR

The Overall Accuracy (OA) per BGR shows regional variation (Table 10). Accuracies >90% were achieved in the plausibility approach for the Arctic region (ARC). Most of the other BGRS are slightly below 90%, with the regions ANA, BOR, MED and TRO lower than 85%. TRO has the lowest accuracy of 73.3%. The Margin of Error (MoE) is below 5% for all BGRs, which indicates robust accuracy estimates.

The accuracies per class (Table 11) show a similar picture at BGR level as for the EEA38. The F1 Score for sealed (1) is below 70% for five of the twelve BGRs (ALP, ANA, ARC, BLS, TRO) with high MoE. Low-growing woody plants (5) is below 50% within six BGRs, all with a MoE >5%. The rare class lichens and mosses (8) occurs in three BGRs, which F1 Scores between 37.6 and 78.7%. Water (10), snow and ice (11) and woody – needle leaved trees (2) have the highest accuracies reaching values >90%. The regions ATL and CON have very good accuracy results (up to 93.1% F1 score) for the majority of the classes occurring in these regions, only low-growing woody plants (5) and non- and sparsely-vegetated (9) are below 80% for both UA and PA. Within the TRO region, only water (10) is exceeding a F1 score of 85%. Periodically herbaceous areas (7) are well detected in most of the BGRs with an F1 score > 85%, except in BOR, MAC, MED and TRO.

The confusion matrix with sample counts (Table 12) shows similar class confusions in the BGRs as already observed at EEA38 level. Noteworthy is the high number of sample units identified as sealed (1) in the validation data that were correctly classified as sealed in most BGRs. The unweighted producer's accuracy for this class exceeds 90% in most BGR (Table 12) and is considerable higher than the weighted producer's accuracy (Table 11). This difference is due to the confusion with classes that have much higher sampling weights, particularly the large permanent herbaceous class (6). Confusion between low-growing woody plants (5), permanent herbaceous (6) and periodically herbaceous (7) is evident in several regions (PAN, CON, STEP and MED) indicating the difficulty to distinguish between these classes.

Table 10: Overall Accuracy per BGR

	Blind		Plausibility	
Biogeographic Region	**Overall Accuracy [%]**	**Margin of Error [%]**	**Overall Accuracy [%]**	**Margin of Error [%]**
Alpine (ALP)	80.4	1.8	85.2	1.6
Anatolian (ANA)	78.5	2.7	84.3	2.4
Arctic (ARC)	81.8	3.9	90.1	2.8
Atlantic (ATL)	78.9	1.4	86.2	1.2
Black Sea (BLS)	84.5	2.0	84.6	2.0
Boreal (BOR)	81.6	1.9	83.6	1.8
Continental (CON)	86.2	1.0	86.6	1.0
Macaronesia (MAC)	56.4	4.9	85.9	3.9
Mediterranean (MED)	66.4	1.4	80.8	1.2
Pannonian (PAN)	85.3	1.6	89.7	1.5
Steppic (STE)	85.4	2.1	85.4	2.1
Tropical (TRO)	74.3	3.1	73.3	3.2

Green = 90% or higher, Yellow = 85-89.9%

Table 11: Class accuracies per BGR - Plausibility approach

BGR	Class	Name	UA [%]	MoE [%]	PA [%]	MoE [%]	F1 Score [%]
ALP	1	Sealed	71.3	12.6	57.3	17.0	63.6
	2	Woody – needle leaved trees	91.6	2.6	93.2	1.9	92.4
	3	Woody – Broadleaved deciduous trees	85.3	3.3	93.8	2.6	89.4
	4	Woody – Broadleaved evergreen trees					
	5	Low-growing woody plants (bushes, shrubs)	56.8	9.4	34.4	6.5	42.8
	6	Permanent herbaceous	81.8	3.5	86.7	2.5	84.2
	7	Periodically herbaceous	91.7	3.8	81.5	9.9	86.3
	8	Lichens and mosses	89.2	6.8	23.8	6.2	37.6
	9	Non- and sparsely-vegetated	80.3	5.5	86.9	5.3	83.5
	10	Water	95.1	5.2	95.3	7.4	95.2
	11	Snow and ice	94.1	3.8	92.6	8.4	93.4
ANA	1	Sealed	78.9	6.5	58.4	26.4	67.1
	2	Woody – needle leaved trees	86.3	5.3	88.7	6.0	87.5
	3	Woody – Broadleaved deciduous trees	70.5	6.7	64.5	15.5	67.4
	4	Woody – Broadleaved evergreen trees	20.0	22.8	61.6	49.7	30.2
	5	Low-growing woody plants (bushes, shrubs)	64.5	8.9	53.2	14.2	58.3
	6	Permanent herbaceous	82.3	3.8	93.6	1.5	87.6
	7	Periodically herbaceous	96.3	2.7	81.2	4.7	88.1
	8	Lichens and mosses					
	9	Non- and sparsely-vegetated	77.0	6.3	67.1	8.6	71.7
	10	Water	96.3	6.1	71.0	17.1	81.7
	11	Snow and ice					
ARC	1	Sealed	73.9	0.0	27.1	38.1	39.7
	2	Woody – needle leaved trees	74.1	0.0	73.2	9.1	73.7
	3	Woody – Broadleaved deciduous trees	73.7	8.6	96.7	3.4	83.6
	4	Woody – Broadleaved evergreen trees					
	5	Low-growing woody plants (bushes, shrubs)	90.9	4.3	32.7	17.4	48.1
	6	Permanent herbaceous	84.6	6.8	97.8	2.4	90.8
	7	Periodically herbaceous	88.9	0.0	100.0	0.0	94.1
	8	Lichens and mosses	78.4	13.2	79.1	12.7	78.7
	9	Non- and sparsely-vegetated	99.3	0.8	93.2	4.0	96.1
	10	Water	59.5	11.1	100.0	0.0	74.6
	11	Snow and ice	99.0	1.9	97.1	3.2	98.0
ATL	1	Sealed	75.8	5.3	87.4	5.5	81.2
	2	Woody – needle leaved trees	83.2	4.4	89.1	4.2	86.1
	3	Woody – Broadleaved deciduous trees	89.5	2.7	85.8	2.7	87.6
	4	Woody – Broadleaved evergreen trees	92.4	3.6	81.5	7.0	86.6
	5	Low-growing woody plants (bushes, shrubs)	90.4	3.3	68.0	4.5	77.6
	6	Permanent herbaceous	83.7	2.1	93.4	1.3	88.3
	7	Periodically herbaceous	96.1	1.6	87.7	2.6	91.7
	8	Lichens and mosses					
	9	Non- and sparsely-vegetated	74.2	7.0	60.1	10.6	66.5
	10	Water	98.4	1.6	89.9	6.5	92.9
	11	Snow and ice					
BLS	1	Sealed	74.9	9.1	61.0	16.0	67.2
	2	Woody – needle leaved trees	79.2	6.8	89.7	4.8	84.1
	3	Woody – Broadleaved deciduous trees	87.8	3.3	92.5	2.3	90.1
	4	Woody – Broadleaved evergreen trees					
	5	Low-growing woody plants (bushes, shrubs)	61.3	7.5	56.5	12.6	58.8
	6	Permanent herbaceous	75.1	5.2	78.3	4.5	76.7

BGR	Class	Name	UA [%]	MoE [%]	PA [%]	MoE [%]	F1 Score [%]
	7	Periodically herbaceous	96.0	2.3	87.4	3.2	91.5
	8	Lichens and mosses					
	9	Non- and sparsely-vegetated	85.7	6.1	32.4	9.3	47.1
	10	Water	97.2	3.9	99.6	0.6	98.3
	11	Snow and ice					
BOR	1	Sealed	64.9	6.8	76.0	17.7	70.0
	2	Woody – needle leaved trees	89.3	3.0	88.5	1.9	88.9
	3	Woody – Broadleaved deciduous trees	66.1	5.8	81.2	5.4	72.9
	4	Woody – Broadleaved evergreen trees					
	5	Low-growing woody plants (bushes, shrubs)	33.7	6.4	30.4	12.5	32.0
	6	Permanent herbaceous	77.4	4.3	80.7	4.1	79.0
	7	Periodically herbaceous	91.9	3.4	74.6	5.5	82.3
	8	Lichens and mosses	86.0	6.5	39.1	25.8	53.8
	9	Non- and sparsely-vegetated	59.3	4.7	24.7	10.2	34.9
	10	Water	99.5	0.6	98.6	1.8	99.1
	11	Snow and ice					
CON	1	Sealed	75.9	4.5	85.4	6.0	80.3
	2	Woody – needle leaved trees	86.2	2.9	85.5	2.9	85.8
	3	Woody – Broadleaved deciduous trees	89.5	1.9	89.7	1.6	89.6
	4	Woody – Broadleaved evergreen trees					
	5	Low-growing woody plants (bushes, shrubs)	52.2	7.4	31.0	7.0	38.9
	6	Permanent herbaceous	78.3	2.5	89.9	1.6	83.7
	7	Periodically herbaceous	97.0	0.9	87.6	1.7	92.0
	8	Lichens and mosses					
	9	Non- and sparsely-vegetated	54.7	12.0	24.8	8.5	34.1
	10	Water	95.2	1.2	92.3	5.4	93.1
	11	Snow and ice					
MAC	1	Sealed	79.3	5.5	76.1	7.1	77.7
	2	Woody – needle leaved trees	86.3	3.7	84.8	4.1	85.5
	3	Woody – Broadleaved deciduous trees	77.4	4.1	85.9	3.3	81.4
	4	Woody – Broadleaved evergreen trees	81.2	3.1	89.1	2.5	85.0
	5	Low-growing woody plants (bushes, shrubs)	80.8	2.4	86.0	2.2	83.3
	6	Permanent herbaceous	79.1	2.6	75.6	2.3	77.3
	7	Periodically herbaceous	86.7	2.6	81.0	3.1	83.8
	8	Lichens and mosses					
	9	Non- and sparsely-vegetated	73.4	5.9	52.8	5.6	61.4
	10	Water	73.6	3.4	93.7	5.1	82.5
	11	Snow and ice					
MED	1	Sealed	87.2	8.8	64.8	17.3	74.3
	2	Woody – needle leaved trees	88.4	13.8	91.7	8.6	90.0
	3	Woody – Broadleaved deciduous trees	68.8	19.6	91.7	12.7	78.6
	4	Woody – Broadleaved evergreen trees	76.0	8.7	99.3	1.1	86.1
	5	Low-growing woody plants (bushes, shrubs)	98.5	2.4	68.3	12.0	80.6
	6	Permanent herbaceous	82.6	7.4	86.1	6.1	84.3
	7	Periodically herbaceous	70.9	24.2	41.2	16.6	52.1
	8	Lichens and mosses					
	9	Non- and sparsely-vegetated	76.0	14.4	83.8	16.0	79.7
	10	Water	100	0.0	100	0.0	100
	11	Snow and ice					
PAN	1	Sealed	73.7	7.2	88.4	9.4	80.4
	2	Woody – needle leaved trees	85.3	5.9	82.3	10.0	83.8

BGR	Class	Name	UA [%]	MoE [%]	PA [%]	MoE [%]	F1 Score [%]
	3	Woody – Broadleaved deciduous trees	91.1	3.8	88.5	3.1	89.8
	4	Woody – Broadleaved evergreen trees					
	5	Low-growing woody plants (bushes, shrubs)	49.5	7.7	67.2	14.1	57.0
	6	Permanent herbaceous	74.8	5.5	85.9	3.6	79.9
	7	Periodically herbaceous	98.5	1.1	93.5	1.6	96.0
	8	Lichens and mosses					
	9	Non- and sparsely-vegetated	42.1	15.3	22.2	16.0	29.1
	10	Water	96.3	3.1	97.0	2.9	96.6
	11	Snow and ice					
STE	1	Sealed	70.9	4.3	78.1	22.0	74.4
	2	Woody – needle leaved trees	94.3	3.5	85.5	14.1	89.7
	3	Woody – Broadleaved deciduous trees	89.6	5.3	89.5	3.7	89.5
	4	Woody – Broadleaved evergreen trees					
	5	Low-growing woody plants (bushes, shrubs)	23.9	7.2	36.6	15.7	28.9
	6	Permanent herbaceous	59.6	8.4	80.7	5.5	68.6
	7	Periodically herbaceous	99.0	1.3	88.6	2.6	93.5
	8	Lichens and mosses					
	9	Non- and sparsely-vegetated	45.7	0.0	28.9	19.4	35.4
	10	Water	98.7	2.0	83.1	13.7	90.2
	11	Snow and ice					
TRO	1	Sealed	63.8	12.4	75.0	12.0	68.9
	2	Woody – needle leaved trees					
	3	Woody – Broadleaved deciduous trees					
	4	Woody – Broadleaved evergreen trees	89.9	4.1	74.8	3.5	81.7
	5	Low-growing woody plants (bushes, shrubs)	11.7	8.8	53.6	31.8	19.2
	6	Permanent herbaceous	59.3	7.9	70.6	7.6	64.5
	7	Periodically herbaceous	62.5	18.6	50.0	18.0	55.6
	8	Lichens and mosses					
	9	Non- and sparsely-vegetated	31.4	30.2	28.9	24.3	30.1
	10	Water	87.9	6.3	96.5	4.7	92.0
	11	Snow and ice					

Green = 85% or higher, Yellow = 80-84.9%, Red = MoE >5%

Table 12: Unweighted confusion matrix (sample counts) per BGR - plausibility approach

			Validation data											Total	User's Accuracy Unweighted
			1	2	3	4	5	6	7	8	9	10	11		
ALP	1	Sealed	84	1	3		2	18						108	77.8%
	2	Woody – needle leaved trees	2	391	7		12	23			2			437	89.5%
	3	Woody – Broadleaved deciduous trees	1	37	339		14	20	1					412	82.3%
	4	Woody – Broadleaved evergreen trees													
	5	Low-growing woody plants (bushes, shrubs)	1	9	7		119	55		1	4			196	60.7%
	6	Permanent herbaceous	5	7	10		26	423	14	24	12	1		522	81.0%
	7	Periodically herbaceous	2		1		1	12	167		2			185	90.3%
	8	Lichens and mosses		2				4		66	2			74	89.2%
	9	Non- and sparsely-vegetated	1	4			7	22		13	226	1	4	278	81.3%
	10	Water			2			1			1	85		89	95.5%
	11	Snow and ice									6		72	78	92.3%
		Total	96	451	369		181	578	182	104	255	87	76	2,379	
		Producer's Accuracy Unweighted	87.5%	86.7%	91.9%		65.7%	73.2%	91.8%	63.5%	88.6%	97.7%	94.7%		82.9%
ANA	1	Sealed	104		4		1	13	1		9			132	78.8%
	2	Woody – needle leaved trees		137	1		3	15			2			158	86.7%
	3	Woody – Broadleaved deciduous trees	1	5	114		9	23	5		3	1		161	70.8%
	4	Woody – Broadleaved evergreen trees			1	2		6	1					10	20.0%
	5	Low-growing woody plants (bushes, shrubs)		6	7	1	106	31			9			160	66.3%
	6	Permanent herbaceous	2		7		9	326	36		21	1		402	81.1%
	7	Periodically herbaceous	1					8	224					233	96.1%
	8	Lichens and mosses													
	9	Non- and sparsely-vegetated		1			2	24	8		145	8		188	77.1%
	10	Water						1			1	53		55	96.4%
	11	Snow and ice													
		Total	108	149	134	3	130	447	275		190	63		1,499	
		Producer's Accuracy Unweighted	96.3%	91.9%	85.1%	66.7%	81.5%	72.9%	81.5%		76.3%	84.1%			80.8%

			Validation data												User's Accuracy Unweighted
			1	2	3	4	5	6	7	8	9	10	11	Total	
ARC	1	Sealed	34	1				8			3			46	73.9%
	2	Woody – needle leaved trees		20	1		5	1						27	74.1%
	3	Woody – Broadleaved deciduous trees			42		13	1			1			57	73.7%
	4	Woody – Broadleaved evergreen trees													
	5	Low-growing woody plants (bushes, shrubs)					87	9						96	90.6%
	6	Permanent herbaceous	2	5	1		17	113		13	4			155	72.9%
	7	Periodically herbaceous						1	8					9	88.9%
	8	Lichens and mosses					1	3		74	9			87	85.1%
	9	Non- and sparsely-vegetated									104		3	107	97.2%
	10	Water									2	95		97	97.9%
	11	Snow and ice									1		99	100	99.0%
		Total	36	26	44		123	136	8	87	124	95	102	781	
		Producer's Accuracy Unweighted	94.4%	76.9%	95.5%		70.7%	83.1%	100%	85.1%	83.9%	100%	97.1%		81.3%
ATL	1	Sealed	212		8		6	38	3		7	1		275	77.1%
	2	Woody – needle leaved trees	2	254	19	7	10	7			5			304	83.6%
	3	Woody – Broadleaved deciduous trees	3	9	460		14	26	1		2			515	89.3%
	4	Woody – Broadleaved evergreen trees		3	1	173	8	3						188	92.0%
	5	Low-growing woody plants (bushes, shrubs)	1	5	9	5	336	21	1		4			382	88.0%
	6	Permanent herbaceous	10	7	46	11	51	925	71		8	7		1,136	81.4%
	7	Periodically herbaceous			4		1	19	571		1			596	95.8%
	8	Lichens and mosses													
	9	Non- and sparsely-vegetated	8	1			30	6	4	1	164	5		219	74.9%
	10	Water						2			1	240		243	98.8%
	11	Snow and ice													
		Total	236	279	547	196	456	1,047	651	1	192	253		3,858	
		Producer's Accuracy Unweighted	89.8%	91.0%	84.1%	88.3%	73.7%	88.3%	87.7%	0.0%	85.4%	94.9%			86.4%

			Validation data		
			1	2	3	4	5	6	7	8	9	10	11	Total	User's Accuracy Unweighted
BLS	1	Sealed	68		4			10			13			95	71.6%
	2	Woody – needle leaved trees	1	112	17			11			1			142	78.9%
	3	Woody – Broadleaved deciduous trees	2	12	319		6	20	2		1			362	88.1%
	4	Woody – Broadleaved evergreen trees		1	8		1	1						11	0.0%
	5	Low-growing woody plants (bushes, shrubs)		3	22		83	25	3		2			138	60.1%
	6	Permanent herbaceous	4		5		8	194	40		16			267	72.7%
	7	Periodically herbaceous	2				1	7	265		1			276	96.0%
	8	Lichens and mosses													
	9	Non- and sparsely-vegetated	1					14			94	1		110	85.5%
	10	Water						1			2	69		72	95.8%
	11	Snow and ice													
		Total	78	128	375		99	283	310		130	70		1,473	
		Producer's Accuracy Unweighted	87.2%	87.5%	85.1%		83.8%	68.6%	85.5%		72.3%	98.6%			81.7%
BOR	1	Sealed	135	6	7		5	48	2		28	1		232	58.2%
	2	Woody – needle leaved trees		378	16		2	21	1	1	9			428	88.3%
	3	Woody – Broadleaved deciduous trees	1	67	201		6	17	1			1		294	68.4%
	4	Woody – Broadleaved evergreen trees													
	5	Low-growing woody plants (bushes, shrubs)	1	39	15		98	43		5	4			205	47.8%
	6	Permanent herbaceous	3	15	15		8	280	44	4	4	1		374	74.9%
	7	Periodically herbaceous						32	232		1			265	87.5%
	8	Lichens and mosses		2			3	5		80	3			93	86.0%
	9	Non- and sparsely-vegetated	3	8	4		4	31	30	3	120	5		208	57.7%
	10	Water						2			2	143		147	97.3%
	11	Snow and ice													
		Total	143	515	258		126	479	310	93	171	151		2,246	
		Producer's Accuracy Unweighted	94.4%	73.4%	77.9%		77.8%	58.5%	74.8%	86.0%	70.2%	94.7%			74.2%

			Validation data											Total	User's Accuracy Unweighted
			1	2	3	4	5	6	7	8	9	10	11		
CON	1	Sealed	285	1	8		5	56	6		15	3		379	75.2%
	2	Woody – needle leaved trees		519	55		3	18			7			602	86.2%
	3	Woody – Broadleaved deciduous trees	4	56	869		10	29	3					971	89.5%
	4	Woody – Broadleaved evergreen trees													
	5	Low-growing woody plants (bushes, shrubs)	2	12	43		97	47	7		1	4		213	45.5%
	6	Permanent herbaceous	9	9	43		27	801	154		6	3		1,052	76.1%
	7	Periodically herbaceous			7		2	32	1,312		2			1,355	96.8%
	8	Lichens and mosses													
	9	Non- and sparsely-vegetated	15		6		2	20	6		50	2		101	49.5%
	10	Water	1		2		1	3			1	298		306	97.4%
	11	Snow and ice													
		Total	316	597	1,033		147	1,006	1,488		82	310		4,979	
		Producer's Accuracy Unweighted	90.2%	86.9%	84.1%		66.0%	79.6%	88.2%		61.0%	96.1%			85.0%
MAC	1	Sealed	34				1	2	1		1			39	87.2%
	2	Woody – needle leaved trees		47		1	1	1						50	94.0%
	3	Woody – Broadleaved deciduous trees			11		1	4						16	68.8%
	4	Woody – Broadleaved evergreen trees	1	3		71	6	10	1		1			93	76.3%
	5	Low-growing woody plants (bushes, shrubs)					65	1						66	98.5%
	6	Permanent herbaceous	4				4	79	15					102	77.5%
	7	Periodically herbaceous			1			2	22		1			26	84.6%
	8	Lichens and mosses													
	9	Non- and sparsely-vegetated	4				2	1			19			26	73.1%
	10	Water										77		77	100%
	11	Snow and ice													
		Total	43	50	12	72	80	100	39		22	77		495	
		Producer's Accuracy Unweighted	79.1%	94.0%	91.7%	98.6%	81.3%	79.0%	56.4%		86.4%	100%			85.9%

			Validation data											Total	User's Accuracy Unweighted
			1	2	3	4	5	6	7	8	9	10	11		
MED	1	Sealed	177	2	3	2		24	1		15	1		225	78.7%
	2	Woody – needle leaved trees		313	6	3	24	12			3			361	86.7%
	3	Woody – Broadleaved deciduous trees	1	15	346	6	22	45	2		7			444	77.9%
	4	Woody – Broadleaved evergreen trees	5	2	3	495	21	55	12		14			607	81.5%
	5	Low-growing woody plants (bushes, shrubs)	2	15	19	13	628	80	11		29			797	78.8%
	6	Permanent herbaceous	12	6	21	33	29	694	83		25	3		906	76.6%
	7	Periodically herbaceous	3		5	7	12	35	581		35	2		680	85.4%
	8	Lichens and mosses													
	9	Non- and sparsely-vegetated	8			2	22	24	9		173	2		240	72.1%
	10	Water		1	1		1		1			224		228	98.2%
	11	Snow and ice													
		Total	208	354	404	561	759	969	700		301	232		4,488	
		Producer's Accuracy Unweighted	85.1%	88.4%	85.6%	88.2%	82.7%	71.6%	83.0%		57.5%	96.6%			80.9%
PAN	1	Sealed	125	1	7		1	28	1		2			165	75.8%
	2	Woody – needle leaved trees		144	14			4			2			164	87.8%
	3	Woody – Broadleaved deciduous trees		6	211		4	8	1		1			231	91.3%
	4	Woody – Broadleaved evergreen trees													
	5	Low-growing woody plants (bushes, shrubs)	1	3	32		73	28	13		1	1		152	48.0%
	6	Permanent herbaceous	3	1	12		4	188	38		2			248	75.8%
	7	Periodically herbaceous			1			5	387		1			394	98.2%
	8	Lichens and mosses													
	9	Non- and sparsely-vegetated	3				3	3	6		13	2		30	43.3%
	10	Water						4				100		104	96.2%
	11	Snow and ice													
		Total	132	155	277		85	268	446		22	103		1,488	
		Producer's Accuracy Unweighted	94.7%	92.9%	76.2%		85.9%	70.0%	86.8%		59.1%	97.1%			83.4%

			Validation data												
			1	2	3	4	5	6	7	8	9	10	11	Total	User's Accuracy Unweighted
STE	1	Sealed	61		2			11	5		7			86	70.9%
	2	Woody – needle leaved trees		82	5									87	94.3%
	3	Woody – Broadleaved deciduous trees		3	105		4	6						118	89.0%
	4	Woody – Broadleaved evergreen trees													
	5	Low-growing woody plants (bushes, shrubs)	2		24		22	35	9					92	23.9%
	6	Permanent herbaceous	1	1	4		5	74	34		3	3		125	59.2%
	7	Periodically herbaceous						2	176			1		179	98.3%
	8	Lichens and mosses													
	9	Non- and sparsely-vegetated	1				3	11	2		16	2		35	45.7%
	10	Water			1							77		78	98.7%
	11	Snow and ice													
		Total	65	86	141		34	139	226		26	83		800	
		Producer's Accuracy Unweighted	93.8%	95.3%	74.5%		64.7%	53.2%	77.9%		61.5%	92.8%			76.6%
TRO	1	Sealed	38			7		6			7			58	65.5%
	2	Woody – needle leaved trees													
	3	Woody – Broadleaved deciduous trees													
	4	Woody – Broadleaved evergreen trees	1			184	4	15				1		205	89.8%
	5	Low-growing woody plants (bushes, shrubs)	2			33	6	11						52	11.5%
	6	Permanent herbaceous	4			40		81	15					140	57.9%
	7	Periodically herbaceous	1			7		2	15					25	60.0%
	8	Lichens and mosses													
	9	Non- and sparsely-vegetated	2			2					3	1		8	37.5%
	10	Water										99		99	100%
	11	Snow and ice													
		Total	48			273	10	115	30		10	101		587	
		Producer's Accuracy Unweighted	79.2%			67.4%	60.0%	70.4%	50.0%		30.0%	98.0%			72.6%

4.2 Usability

The evaluation of the CLCplus BB 2021 dataset's alignment with FAIR principles was assessed using various automated tools. The dataset was tested using FAIR Enough, FAIR-checker, and F-UJI, with scores expressed as percentages of a maximum of 100%. The results were as follows: FAIR Enough data at 59.09%, FAIR Enough metadata at 81.25%, FAIR-checker at 70.83%, and F-UJI at 77%. The evaluation highlighted strengths and identified improvement areas to enhance FAIR compliance. For Findability, the adoption of globally recognized Persistent Identifiers and the use of interoperable ontologies for metadata are recommended. To improve Reusability, adding comprehensive data descriptors, recognized licenses, and formal provenance information is advised. For Accessibility, standardizing and enhancing data access information and URLs in metadata will support compliance.

The Annex 4 to the Tender Specifications (EEA, 2023) does not specifically define user requirements but **includes information for the use case "Facilitation of independent assessments and the modelling of carbon pool dynamics according to LULUCF regulation". This generic product requirements check evaluates the product's alignment with this use case**. Key requirements assessed include spatial and thematic accuracy, timely updates, and alignment with LULUCF categories. The assessment involves comparing the product attributes against the specified requirements using references such as product manuals and validation reports. It reveals that the CLCplus BB 2021 meets most of the needs assessed like spatial resolution and data accessibility but noted that temporal coverage is partially aligned. The source data used shows limitations that prevent a full assessment of product attributes against the specified requirements.

The CLMS Portal underwent thorough testing to assess its functionality, accessibility, performance, and usability. Accessibility was evaluated using tools like WAVE and Lighthouse, which highlighted strong compliance with web standards and identified areas for improvement in performance and navigation. User journey mapping and cross-browser compatibility checks ensured a reliable user experience across various devices and browsers. **The tests revealed the portal's strong accessibility with notable compliance, although performance optimizations were suggested**. Secure and open access options for data downloads were confirmed through user authentication tests. The content is broadly accessible in multiple formats, ensuring usability across different platforms. Overall, the portal meets critical web and data access standards, ensuring a functional and user-friendly environment.

The documentation review for the CLCplus BB ATBD 2021 was not conducted as the document was unavailable on the CLMS Portal. Conversely, the CLCplus BB PUM 2021 is accessible, published on 12.06.2024. The review of the PUM did not consider the proposed PUM template, which came after its publication and outlines a structure for future documentation.

The PUM underwent a detailed evaluation based on a 23-item checklist assessing criteria like accuracy, consistency, completeness, and up-to-dateness**. Overall, the PUM scored well, reflecting a well-structured approach.** However, it highlighted areas for improvement, especially in referencing external standards, use case articulation, and formatting consistency. Specific issues included the need for clearer formatting adjustments, more detailed standard references, and consecutive numbering for pages and annexes. Additionally, the document's sections on product quality and use cases were noted as needing enhancement to better meet user needs and improve clarity and usability.

# 5 Conclusions and Recommendations

5.1 Thematic Accuracy

The new CLMS validation framework methods and tools are used for the first time to validate the CLCplus BB raster product for 2021. The validation areas defined within the framework are applied to generate validation data for CLCplus BB in a synergistic blind and plausibility approach. Thematic accuracies are calculated in the new CLMS Validation System Environment (VSE) software. **Thematic accuracy is assessed using a statistically sound methodology, leveraging available reference and supportive data across different reporting units**. It was essential that usage of LUCAS data in the CLMS productions was recorded (including LUCAS sample locations used) and provided to the validation process to enable independent validation uptake of this data. **Due to the heavy usage of LUCAS 2018 in the CLCplus production process, any point in the sampling frame that was part of the LUCAS 2018 survey has been replaced.** Future validations efforts could be minimised if LUCAS reference data is not used in the CLCplus Backbone production.

The VHR image data 2021 is used in the visual validation process. It provides VHR multispectral products (with an spatial pixel resolution from 2 to 4 meters) for the CLMS reference years 2021. Especially for regions without aerial orthophoto imagery this data set is the prime image reference. However, due to the applicable spatial resolution it has limitations for the analysis of land cover class relevant features. For some regions higher resolution data (<2m) could support the validation process, especially for regions with poor or no access to digital aerial photography as alternative very high image data source. **A stronger inclusion of time-series information could also aid the interpretation process for upcoming products, especially for temporally defined land cover classes.**

The thematic validation results show good results approaching but not reaching the required target overall accuracy of >90% at EEA38 level. Classes such as low-growing woody plants (5), lichens and mosses (8) and non- and sparsely-vegetated (9) show significant improvement in plausibility checks as compared to the blind validation. The class-specific accuracies show the expected confusion between low-growing woody plants (5), permanent herbaceous (6) as well as periodically herbaceous areas (7). **These land cover classes are difficult to map due to similar spectral behaviour and their temporal/seasonal dynamics make the visual interpretation of reference data challenging**. Such classes can be better assessed if a priori map class information is taken into account during the visual interpretation. The class-specific accuracies also show the expected confusion between the low-growing woody plants (5), permanent herbaceous (6) as well as periodically herbaceous (7), which are difficult to distinguish, especially in natural environments. This may also contribute to the regional differences at the BGR level. **Weaker classification results are seen within the regional assessments of the Mediterranean (MED) and Tropical (TRO) BGRs, which show challenges distinguishing certain classes**, especially low-growing woody plants (5), permanent herbaceous (6), and periodically herbaceous (7) (Figure 11 and Figure 12).

Consistency checks between the CLCplus BB 2018 and 2021 are not explicitly performed for this report. However, both products show very similar validation results and patterns (see D7-1 Validation Report CLCplus Backbone 2018). Further work may be helpful to check the time series consistency and focus on areas of change between 2018- 2021.
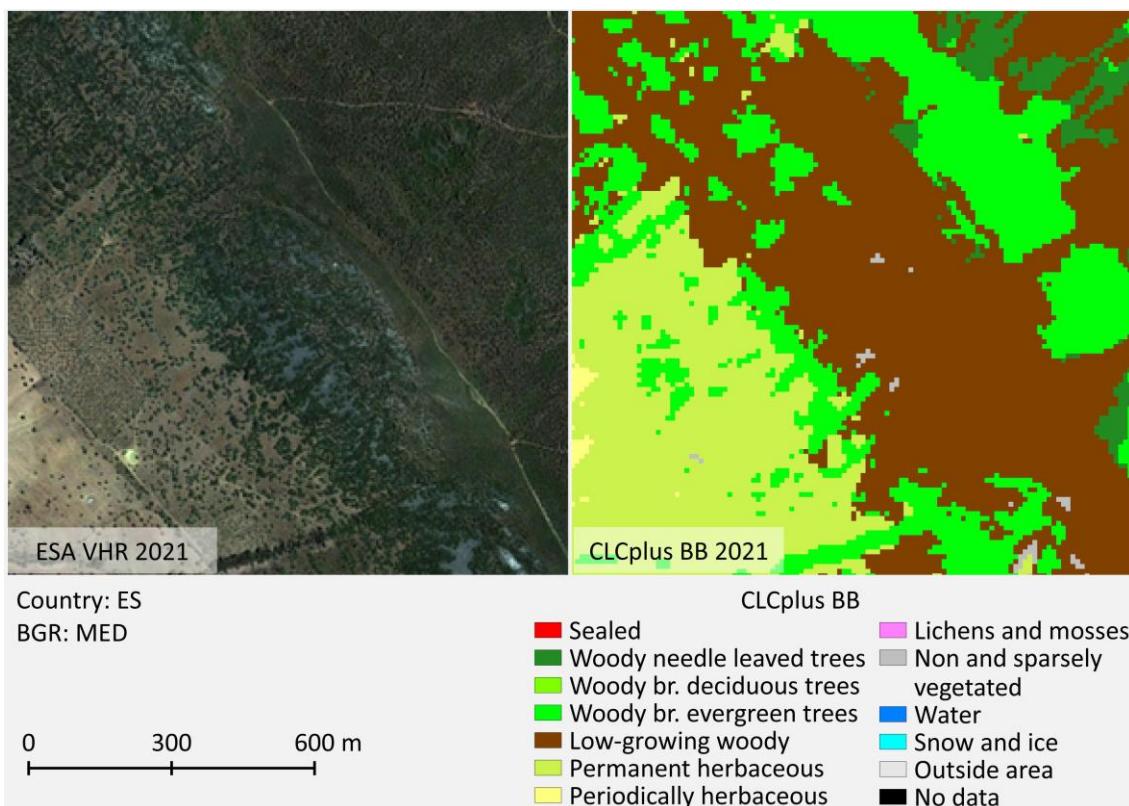
Figure 11: Example of difficulties to differentiate low-growing woody vegetation from broadleaved forests in Spain.
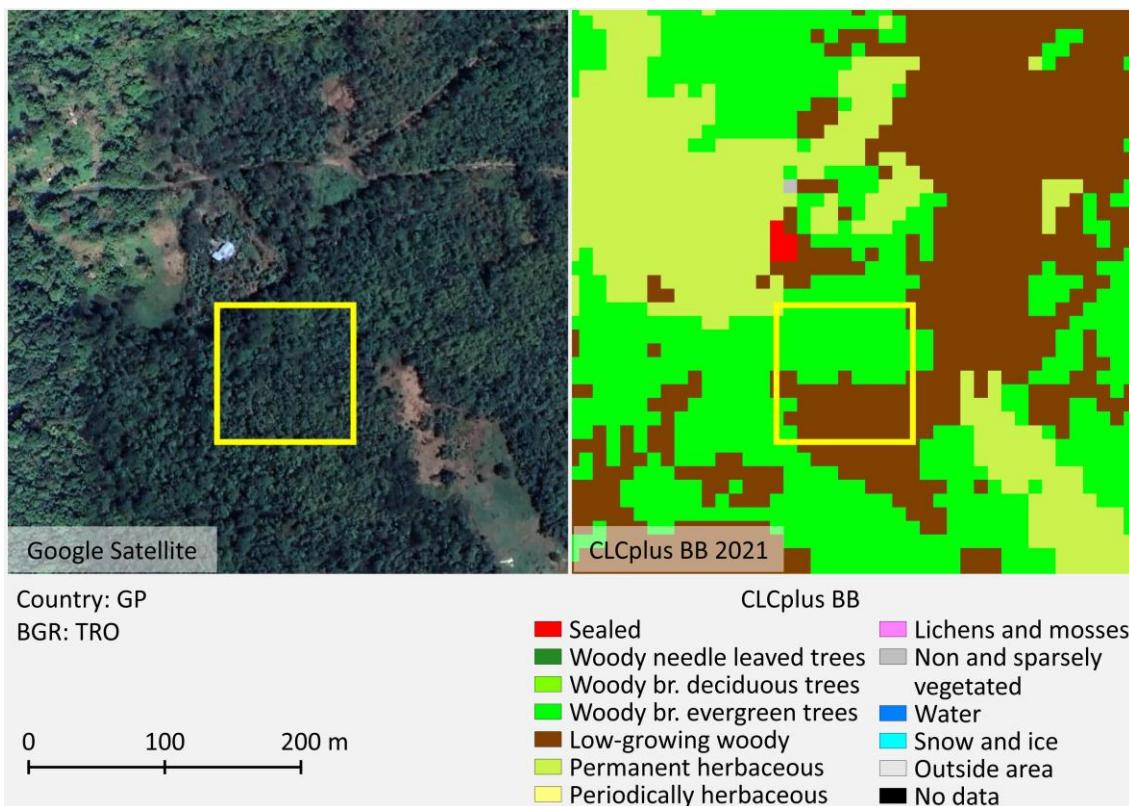
Figure 12: Example of structurally identical looking ground cover but different CLCplus BB 2021 classes (low-growing woody vegetation vs. broadleaved forest) in Guadeloupe.

5.2 Usability

To support user uptake and ensure the CLCplus BB 2021 product meets key expectations for usability, a structured assessment was carried out. This evaluation focuses on critical aspects such as FAIR compliance, fitness for a specific use case, platform accessibility, and the completeness of product documentation.

The method used has limitations and does not allow a full assessment of CLCplus BB 2021 against the specified requirements. Despite this, the evaluation indicates that the product meets key needs such as spatial resolution and data accessibility, while temporal coverage is partially aligned with the LULUCF use case requirements.

The CLMS Portal currently exhibits a good level of accessibility and usability, fulfilling essential user requirements for data access and availability in multiple formats. However, further streamlining of navigation and the introduction of benchmark comparability testing could optimize performance and user journey efficiency. Future assessments could benefit from analysing key metrics like click counts, page load speeds, and response times in coordination with the EEA.

The PUM review highlights the document's detailed and comprehensive nature yet points out the need for improvement in areas such as clarity, consistency, and user guidance. Key recommendations include adopting a structured chapter layout as specified in the CLMS PUM Template, simplifying overly technical sections, standardizing terminology and formatting, and enhancing document navigation. Moreover, incorporating non-technical summaries, FAQ sections, and glossaries could make the document more accessible to a broader audience, including non-experts. These changes will ensure that the PUM aligns better with industry standards and user expectations, improving its overall usability and functionality.

6 References

CLMS QC Tool. (2025). [Computer software]. European Environment Agency. https://github.com/eea/copernicus_quality_tools

Ballin, M., Barcaroli, G., Masselli, M., & Scarnó, M. (2018). Redesign sample for Land Use/Cover Area frame Survey (LUCAS) 2018 (2018 ed.). Eurostat, European Commission. https://doi.org/10.2785/132365

Congalton, R. G., & Green, K. (2008). Assessing the accuracy of remotely sensed data: Principles and practices (2nd ed.). CRC Press. https://doi.org/10.1201/9781420055139

Copernicus Land Monitoring Service. (2022). CLC+ Backbone Product Specification and User Manual (Product Specification and User Manual No. Issue 3.0; p. 131). European Environment Agency (EEA). https://land.copernicus.eu/en/technical-library/clc-backbone-product-user-manual/@@download/file

Copernicus Land Monitoring Service. (2024). CLC+ BACKBONE PRODUCT SPECIFICATION AND USER MANUAL for CLC+ Backbone Raster Product 2021 (Product Specification and User Manual No. Issue 2.1; p. 63). European Environment Agency (EEA). https://land.copernicus.eu/en/technical-library/product-user-manual-clc-backbone-2021/@@download/file

EEA. (2016). Biogeographical regions (Version 1) [Vector]. https://www.eea.europa.eu/en/datahub/datahubitem-view/11db8d14-f167-4cd5-9205-95638dfd9618

EEA. (2023a). CLCplus Backbone 2018 (raster 10 m), Europe, 3-yearly, Feb. 2023 [Raster; Vector]. https://doi.org/10.2909/cd534ebf-f553-42f0-9ac1-62c1dc36d32c

EEA. (2023b). Copernicus EEA38 Boundary Layer with 250 m buffer (raster 10m), version 2, Nov. 2023 (Version 2) [Raster; Vector]. https://sdi.eea.europa.eu/catalogue/srv/eng/catalog.search#/metadata/a14e9739-089d-4f63-8f83-a184e1e8b906

EEA. (2024). EEA reference grid for Europe (50km), Jun. 2024 [Vector; Vector]. https://doi.org/10.2909/aac8379a-5c4e-445c-b2ef-23a6a2701ef0

FAIR-Checker (Version 1.3). (2024). [Computer software]. https://github.com/IFB-ElixirFr/FAIR-Checker

FAIR Enough (Version 0.0.1). (2022) [Computer software]. https://github.com/MaastrichtU-IDS/fair-enough

F-UJI (Version 3.4.0). (2024). [Computer software]. https://github.com/pangaea-data-publisher/fuji

Olofsson, P., Foody, G. M., Herold, M., Stehman, S. V., Woodcock, C. E., & Wulder, M. A. (2014). Good practices for estimating area and assessing accuracy of land change. Remote Sensing of Environment, 148, 42–57. https://doi.org/10.1016/j.rse.2014.02.015

Stehman, S. V., & Foody, G. M. (2019). Key issues in rigorous accuracy assessment of land cover products. Remote Sensing of Environment, 231, 111199. https://doi.org/10.1016/j.rse.2019.05.018

List of abbreviations

Abbreviation	Name
ALP	Alpine
ANA	Anatolian
ARC	Arctic
ATBD	Algorithm Theoretical Basis Document
ATL	Atlantic
BB	Backbone
BGR	Biogeographical Regions
BLS	Black Sea
BOR	Boreal
CAPI	Computer-Assisted Photo Interpretation
CLC	CORINE Land Cover
CLCplus BB	CORINE Land Cover Plus Backbone
CLMS	Copernicus Land Monitoring Service
CON	Continental
DOI	Digital Object Identifier
DOM	Départements d'Outre-Mer, French Overseas Territories
EEA	European Environment Agency
EEA38	Member and cooperating countries of the European Environment Agency network, Eionet
EUROSTAT	Statistical Office of the European Union
EU	European Union
FAIR	Findability, Accessibility, Interoperability, and Reusability
GeoTIFF	Georeferenced Tagged Image File Format
GIS	Geographic Information System
HRL	High Resolution Layer
IACS	Integrated Administration and Control Systems
INSPIRE	Infrastructure for Spatial Information in the European Community
ISO	International Organization for Standardization
LAEA	Lambert azimuthal equal-area projection
LC	Land Cover
LPIS	Land Parcel Information System
LU	Land Use
LUCAS	Land Use and Coverage Area frame Survey from Eurostat
LULUCF	Land use, land-use change and forestry
LZW	Lempel-Ziv-Welch
MAC	Macaronesia
MED	Mediterranean
MMU	Minimum Mapping Unit
MoE	Margin of Error
MS	Member State
NUTS	Nomenclature of territorial units for statistics

OA	Overall Accuracy	
PAN	Pannonian	
PI	Photo Interpretation	
PUM	Product User Manual	
QC	Quality Control	
STE	Steppic	
TRO	Tropical	
UA	User's Accuracy	
UAT	User Acceptance Testing	
UK	United Kingdom	
URI	Uniform Resource Identifier	
URL	Uniform Resource Locator	
UTM	Universal Transverse Mercator	
VHR	Very High Resolution	
VSE	CLMS Validation System Environment	
XML	Extensible Markup Language	
WGS84	World Geodetic System 1984	
WMS	Web Map Service	
WMTS	Web Map Tile Service	