**Service Contract 3506/R0-Copernicus/EEA.59142**

**CLC+ conceptual work**

**Final Report**

**Version 1.0**

**04.12.2023**

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Title:

Final report: CLC+ conceptual work

Place and date:

Niederanven, 18.12.2023

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# Scope and objectives

The scope of the current negotiated procedure was to establish a service contract supporting the maintenance and further development of the EAGLE land modelling approach, especially in relation to CLC+ concept and the recent challenges identified during its development and implementation.

The service contract encompasses six technical tasks, one task related to the organisation, preparation and participation to relevant meetings and one task related to the overall administrative and financial management of the contract.

The six technical tasks include:

* Task 1: an update of the EAGLE matrix and documentation in line with the latest developments, a translation table between the older and the most recent versions, an update of the UML model and finally some guidelines how to best use the EAGLE land modelling approach when providing data to CLC+ Core.
* Task 2: an update of the EAGLE sections of the CLMS website, including a user-friendly navigation through the available documentation.
* Task 3: a review of the EAGLE bar-coding concept in view of its use for ingestion of data into CLC+ Core and the development of standard definitions of CLMS products in EAGLE. The task will also examine the options for the development and implementation of a concept for reviewing bar codes that have been used to characterize products to be uploaded in CLC+ Core.
* Task 4: the development of a concept for the extraction of meaningful change data from CLC+ Core as well as the development of a concept for the characterisation of change data within the EAGLE land modelling approach.
* Task 6: an assessment of the feasibility of using modern technologies (AI/ML) and / or other commercial EO-based analytics solutions currently being developed to support the gap filling in CLC+ Instances.
* Task 7: Participation to the ISO standardisation group which is updating the 19144 standard on Geographic information – Classification systems which needs to be aligned with the EAGLE approach.
* Task 8: Contract coordination and management

# Task 1 – Documentation update

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| --- | --- |
| Task lead  | Stephan Arnold |
| Task partners  | Lechner, s4e, Specto Natura, UMA, Spatial Focus, Cloudflight, CNIG |

## Objective

The aim of task 1 is to update the documentation of the EAGLE concept to make them available for access by interested stakeholders. The task has three sub-tasks:

1. update of the EAGLE matrix and the related documentation;
2. update of the EAGLE UML model;
3. commenting and updating of the CLC+ Core user guidelines

## Results

### Sub-task 1A: Documentation update (led by Stephan Arnold)

The EAGLE Matrix and the associated Explanatory Documentation have been updated to version 3.2. This update manifests in a few major and minor enhancements in form of adding some new matrix elements, sorting and re-organizing the elements in a more logic manner or also replacing some elements. Generally, the elements have a label name, a label code and a URI like on the version before.

In consequence with the update, some URI have changed, which has relevance for machine reading mechanism (like in the data base behind CLC+ Core platform), or the label names and/or the label codes have been altered.

The written documentation was updated likewise, so that the hierarchy of its chapters match the hierarchy of elements in the EAGLE matrix. It documents nothing but the content of the EAGLE matrix version 3.2.

Besides, a technical meta-documentation named change log file has been delivered which shows as a mapping table the changes from the old to the new matrix version, namely which of the identifiers (label name, label code, URI) of EAGLE matrix elements have been added, altered, replaced or removed.

The new version is mirrored in the EIONET data dictionary, with the main identifiers name, code and URI among other meta attributes like for example parent or child elements. <https://dd.eionet.europa.eu/vocabulary/landcover/eagle/view>

Furthermore, the new version is integrated in the CLC + Core platform, where it shall be used from now on for bar coding exercises.

The new version of the EAGLE matrix is the basis for the updated EAGLE UML Model version 3.2 (see task 1B) and also for the barcoding review (see task 3).

### Sub-task 1B: UML model update (led by Stephan Arnold / Christoph Perger)

The last available version of the EAGLE UML model (version 3.2) has been reviewed and aligned with the updated EAGLE matrix, covered within sub-task 1A. The UML class names have been aligned with the updated EAGLE matrix LCC names. Multiple attributes and code lists have either been renamed, removed, extended, or newly introduced within the model. As agreed during the project meeting in November 2022, all enumerations were converted into code lists. All code lists, new and pre-existing, are linked to the corresponding entries in the EIONET data dictionary, where the latest EAGLE matrix vocabulary is released, thus eliminating the need for an EAGLE UML model update when new code list values are introduced in the EAGLE matrix.

### Sub-task 1C: CLC+ Core user guidelines (led by Stefan Kleeschulte)

During the Eionet training sessions on the use of the CLC+ Core database (i.e. ingestion and extraction of data sets) it became clear that the CLC+ Core user guidelines need to be improved in their clarity and by providing better examples.

Based on practical exercise to ingest data in and extract data from the CLC+ Core database, the EAGLE reviewed the guidelines and proposed some concrete text edits (mainly related to practical examples and improved descriptions of individual steps) as well as making suggestions to the general processing / handling of the data (to be handled by the consortium responsible for implementing the database).

This task had been already finalised for the interim report.

## Deliverables

* D1-1: Updated EAGLE matrix (ready for upload in EIONET Data Dictionary) - <https://projects.eionet.europa.eu/eagle/library/service-contract-no-3506-r0-copernca-eea.59142/task-1-documentation-update/latest-versions/d1-1a_eagle_matrix_3.2_revised_final>
* D1-2: Updated EAGLE UML model (EA and PDF-Format) <https://projects.eionet.europa.eu/eagle/library/service-contract-no-3506-r0-copernca-eea.59142/task-1-documentation-update/uml-model>
* D1-3: Updated Content Explanatory Documentation of the EAGLE Concept (HTML and PDF format, including the definitions of the matrix / model elements) - <https://projects.eionet.europa.eu/eagle/library/service-contract-no-3506-r0-copernca-eea.59142/task-1-documentation-update/latest-versions/d1-3_eagle-concept_expldocumentation_revised_v3.2_20230901>
* D1-4: Mapping table between old and updated EAGLE matrix versions - <https://projects.eionet.europa.eu/eagle/library/service-contract-no-3506-r0-copernca-eea.59142/task-1-documentation-update/latest-versions/d1-4_eagle-matrix_changelogfile_mappingold3.1.2-new3.2_20230731>
* D1-5: Update of the CLC+ Core User Guidelines – <https://projects.eionet.europa.eu/eagle/library/service-contract-no-3506-r0-copernca-eea.59142/task-1-documentation-update/latest-versions/d1.5_clc-core_user_guideline_v1.1.1>

# Task 2 – Support the maintenance of the EAGLE website

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| --- | --- |
| Task lead  | UMA  |
| Task partners  | s4e, St. Arnold, Specto Natura, |

## Objective

Considering the increasing operational use of EAGLE together with the release of the new Copernicus web site, an urgent review and update of the former EAGLE web page are required. The former EAGLE web page collects the historical records of the EAGLE works and the various achievements accomplished over the last years by the EAGLE team members. The new Copernicus web page should provide an easy access to up-to-date information, support users to understand the EAGLE concepts, and guide them in the usage of recommended tools e.g. EAGLE matrix, as reference to understand the CLC+ Core ingestion and extraction operations. In this regards, promotional material, such as figurative examples of the EAGLE application in practical terms use cases are also requested.

## Results

In agreement with EEA a selection of the most relevant published material has been selected to populate the new page in a meaningful and easily navigable structure. The new page has been organized into five main sections: *1)* Home - introduction, *2)* the EAGLE Concept, including context and technical implementations (the Matrix and the data model) along with the application bar-coding method, *3)* the various EAGLE uses case, including implication in the latest CLC+ Core, *4)* Relation with ISO standards series 19144 and FAO`s LCCS, and *5)* Download Section for accessing and download the EAGLE reference material, tools, and documentation.

The text for each section has been collaboratively drafted and validated by several interactions with EEA and has been delivered as MS Word file (Delivery D2-1), similarly a set of graphs (promotional material) was prepared and delivered separately in a MS PowerPoint format (Delivery D2-2).

Material that did not find space on the new Copernicus web page, such as meeting reports and previous versions of the tools, have been archived in an Eionet web folder accessible to the EAGLE team members.

## Deliverables

* D2-1: Updated website material <https://projects.eionet.europa.eu/eagle/library/service-contract-no-3506-r0-copernca-eea.59142/task-2-support-maintenance-eagle-website/d2-1-updated-website-material/updated-eagle-web-material-v4>
* D2-2: Promotional material
<https://projects.eionet.europa.eu/eagle/library/service-contract-no-3506-r0-copernca-eea.59142/task-2-support-maintenance-eagle-website/d2-2-promotional-material/promotional-material-updated-version>

# Task 3 – EAGLE bar coding review

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| --- | --- |
| Task lead  | Stephan Arnold  |
| Task partners  | WENR, Lechner, s4e, Specto Natura, UMA, DGT |

## Objective

The task 3 aims at reflecting the bar coding method, in particular to update the bar coding manual and revise the list of bar code values and their meaning.

Further, this task develops best practice examples for the characterisation of frequently used classes or of specifically complex situations.

As a review exercise, this task will provide standard bar-coding for the most frequently used CLMS products to avoid duplication of work. Thus other bar coding exercises can be oriented on them and guidance is provided for similar data sets at national level.

Moreover, the task shall investigate the feasibility of installing an acceptance procedure to review the bar code results after characterizing certain datasets or classes with the EAGLE matrix elements and give feedback to the user on the characterisation; this will help to ensure the compatibility of the ingested data sets and the subsequent creation of instances. This is currently most relevant for the ingestion of input date in the CLC+ Core platform.

## Results

The Barcoding manual has been updated and revised. It explains the barcoding method and the idea behind it to semantically describe and characterise classes or spatial units of land cover and land use data sets. The list of bar code values (BCV) has been consolidated by eliminating two entries, namely BCV 0 and 6. Also, the manual contains some clarifications on how the BCVs shall be used by the meaning they have and the role they give to matrix elements. Some bar coding examples have been added to the manual, to illustrate the meaning of every BCV.

To give guidance on best practices, a compilation of typically relevant EAGLE matrix elements has been provided. It shows a list of matrix elements that are connected to certain land use topics like agriculture, forestry, transportation etc. Here the user is guided through the content of the EAGLE matrix that he/she finds quickly all the elements that the user needs to choose for bar coding (depending on what information about these topics are available and contained in the class definitions).

Further, a conceptual draft has been provided which elaborates on the acceptance procedure to streamline bar code results. It shall help to streamline the application of the bar coding method and guarantee a certain degree of content-wise harmonization among bar coding results. The draft acceptance procedure discusses the distribution of work among the involved people (matrix user, EEA, EAGLE experts) and the time frame in which the work shall be done, resulting in some kind of EAGLE-“certified” bar coding results.

## Deliverables

* D3-1a: Barcoding manual (version 3)
<https://projects.eionet.europa.eu/eagle/library/service-contract-no-3506-r0-copernca-eea.59142/task-3-eaglebar-coding-review/barcoding-manual-version-3.0>
* D3-1b: EAGLE bar coding - thematic content guidance <https://projects.eionet.europa.eu/eagle/library/service-contract-no-3506-r0-copernca-eea.59142/task-3-eaglebar-coding-review/d3-1b_eagle-matrix-bar-coding_thematic-content-guidance>
* D3-1c: Report of Task 3 - Standardised bar coding for CLMS products <https://projects.eionet.europa.eu/eagle/library/service-contract-no-3506-r0-copernca-eea.59142/task-3-eaglebar-coding-review/proposal-standard-barcodes>
* D3-2: Report of Task 3 - Concept for a bar coding review and acceptance process <https://projects.eionet.europa.eu/eagle/library/service-contract-no-3506-r0-copernca-eea.59142/task-3-eaglebar-coding-review/d3-2_concept-bar-coding-review-acceptance-process_draft-updated-draft-version>

# Task 4 – Develop a change mapping/detection concept for CLC+

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| --- | --- |
| Task lead  | Specto Natura  |
| Task partners  | Gerard Hazeu (WENR), Barbara Kosztra (Lechner), Gergely Maucha (Lechner), Mirko Gregor (s4e), Stefan Kleeschulte (s4e), Stephan Arnold, Emanuele Mancuso (UMA), Filipe Marcelino (DGT), Mario Caetano (DGT), Christoph Perger (Spatial Focus), Julian Delgado (CNIG), Marian Vittek (WENR), Thomas Mathis (CloudFlight), Johannes Vass (CloudFlight) |

## Objective

Many environmental policies require reliable, consistent, comprehensive, and appropriate change information for their development, implementation, and monitoring. The CLC+ Core infrastructure has the potential for both holding and producing change information, but neither the current system or the EAGLE data model were specifically designed for this purpose.

The objective for this task was therefore to consider approaches for the capture and generation of “change” information at both the conceptual and, if possible, the practical level with CLC+ Core. It focused on three approaches:

* “input” oriented, i.e., the ingestion of existing change data sets produced by conventional methods such as those used in the CLC and local component updates.
* “internal” oriented, i.e., addressing issues of spatial, thematic, and temporal consistency across the time series information already held within CLC+ Core.
* “output” oriented, i.e., making use of information already within CLC+ Core to create and capture meaningful changes.

The task was to provide a list of issues and suggestions and potentially a road map for the implementation of the best practice and recommendations in the future.

## Results

The production of reliable and repeatable change information is always challenging as it relies on the accuracy and consistency of two or more measurements which must then be compared in the context of the true amount of change. Several change mapping approaches have been deployed to deal with the limitations of the input data, the impacts of the real-world processes and interrelations being mapped, and the fact that sometimes things identified as change will just be errors.

It quickly became clear during the task that the ingestion and extraction of changes is currently beyond the capabilities of the CLC+ Core and further development will be required to implement some of the ideas laid out in this report. Approaches for ingestions and extraction were proposed and evaluated along with the consequent issues that would be encountered if deployed operationally.

The exploration of change mapping with CLC+ Core has pushed the concepts behind the CLC+ product suite, our understanding of land characterisation and the EAGLE data model to a new level and will require a re-evaluation of how they are developed, deployed and governed in the longer term.

## Deliverables

* D4-1: Report of Task 4 - Develop a change mapping concept for CLC+

# Task 5 – Preparation and participation in meetings

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| --- | --- |
| Task lead  | space4environment  |
| Task partners  | WENR, Lechner, St. Arnold, EAA / Umweltbundesamt, UMA, DGT, Specto Natura, Cloudflight, Spatial Focus  |

## Objective

The objective of task 5 was to allow the EAGLE experts to convene to discuss the activities of the different tasks, and moreover, to ensure the participation of EAGLE experts in different (EIONET) meetings.

## Results

The following meetings have been attended by EAGLE experts.

|  |  |  |
| --- | --- | --- |
| **Date & Location**  | **Topic**  | **Attendance**  |
| 24. Oct. 2022 – online  | Kick off meeting with EEA  | All  |
| 15-16 Nov. 2022 Vienna  | 1st EAGLE workshop – task brainstorming  | All  |
| 23-25 May 2023 Frankfurt  | 2nd EAGLE workshop  | GS, BK, SA, GH, MV, EM, TM, CP  |
| 9 Oct, 2023 – online  | Progress meeting  | EEA, task leaders  |
| 20-21 Nov. 2023 Copenhagen / online  | Eionet working group land systems  | SK online  |

Geoff Smith (GS), Barbara Kosztra (BK), Stephan Arnold (SA), Gerard Hazeu (GH), Marian , Vittek (MV), Emmanuela Mancuso (EM), Thomas Mathis (TM), Christoph Perger (CP), Stefan Kleeschulte (SK)

During the 2nd EAGLE workshop the participants reviewed the status of the actions still pending from tasks 1 to 3 and agreed on the workplan for the tasks 4 and 6 which were about to start. Actions for tasks 4 and 6 were agreed.

During the meeting of the Eionet working group on land systems EAGLE experts gave presentations related to the following topics:

* Copernicus support activities (including validation)
* Land management options in support of carbon sequestration
* CLC 2024

## Deliverables

* D5-1: Collection of PowerPoint presentations <https://projects.eionet.europa.eu/eagle/library/service-contract-no-3506-r0-copernca-eea.59142/task-5-preparation-and-participation-meetings/>
* D5-2: Report of Task 5 – Summary of tasks undertaken <https://projects.eionet.europa.eu/eagle/library/service-contract-no-3506-r0-copernca-eea.59142/task-5-preparation-and-participation-meetings/task-5-summary-report>

# Task 6 – Use of AI/ML EO-based analytics products for filling gaps in CLC+ instances (CLC Legacy and/or LULUCF)

|  |  |
| --- | --- |
| Task lead  | WENR  |
| Task partners  | Lechner, Specto Natura, UBA, UMA, DGT  |

## Objective

The objective of this task was to assess the use of modern technologies (like artificial intelligence/machine learning) and/or recent EO-based products that are being provided by the service industry to support the closing of current data and information gaps to derive the CLC+ LULUCF and Legacy instances.

## Results

In this task an inventory of data gaps for CLC+ instances was made, discovered in CLC+ LULUCF and CLC+ Legacy (both based on CLMS data/national data). The inventory took as a start previous tasks focused on gap identification and gap filling with use of existing LU/LC datasets.

Further, this task includes some background information on the selection criteria of CLC classes that were listed in the data gaps inventory. The CLC classes Industrial areas, Port areas, Green urban areas, Transitional woodland/shrub and Intertidal flats were selected. For the training and validation of the AI/ML models, Urban Atlas and Coastal Zones hotspot datasets and for the image classification Sentinel 2 data of the year 2018 were used.

Following the overview and suitability assessment, random forest as machine learning approach and neural network as deep learning approach were selected for the gap filling of particular CLC classes.

This task gives and overview of the results in terms of the mapping accuracy of CLC classes with AI/ML models. The neural networks approach shows better results than the applied random forest method. Furthermore, the multiclass classification performs better than the single class classification and the classification based on the pixel based random selection of training and validation data results in higher accuracies than the classification based on the spatial split method to select training and validation data. And the results at the test site in Spain have an higher overall accuracy than the ones at the test site in Netherlands. Although at class level the results show a mixed picture, i.e. some classes perform better at the site in Netherlands and some better in the case of site in Spain.

Furthermore, this task provides recommendations for an improved assessment of gap filling by using AI/ML approach. These recommendations include i) the quality of the training data, ii) the use of additional data layers to determine spatial context of target classes, including more relevant dataset besides of satellite images as predictors, iii) the use of different methods depending on the different levels of aggregation of (CLC) classes, iv) the improved classification of target classes in relation to other unclassified areas within study sites and v) to explore additional AI/ML methods such as Generative AI.

Within this task the potential for derived analytics from commercial EO systems is explored. Also, a cross reference of the analytic layers with EAGLE elements is made and it investigates the ingestion and integration with CLC+ Core.

## Deliverables

* D6-1: Report of Task 6 - Use of AI/ML and other (commercial) EO-based analytics for filling gaps in CLC+ instances
<https://projects.eionet.europa.eu/eagle/library/service-contract-no-3506-r0-copernca-eea.59142/task-6-use-ai-ml-eo-based-analytics-products-filling-gaps-clc-instances/task-6-use-ai-ml-gap-filling>

# Task 7 – Support to the exchange with ISO standardisation group

|  |  |
| --- | --- |
| Task lead  | CNIG  |
| Task partners  | Specto Natura, Stephan Arnold |

## Objective

This task relates to the ongoing work on the international standardization of land cover and land use in the frame of the ISO 19144 documentation series. The participation of EAGLE members at the working group guarantee that the EAGLE knowledge and concepts are recognized and considered for integration into the new and revised standards and identify potential gaps between new developments in ISO about land cover and land use, and Copernicus Land Monitoring Services products. This task only supports the participation of EAGLE members who are not part of the ETC DI.

## Results

EAGLE members participate in the projects dealing with ISO 19144 standard series that are been addressed to ISO/TC 211 Working Group 7 and Advisory Group 13. Main work is done consisted in revision of internal technical project documentation, modification proposals and active participation in meetings. Editor team is composed of project leader and UN FAO experts, and EAGLE members are not able to edit directly documentation and models.

* EAGLE experts participated in 9 meetings of ISO/TC WG7 dealing with the ISO 19144 standards series projects
* EAGLE experts participated in 7 meeting of USI/TC AG13 and introduced the EAGLE initiative and its relevant implications with in CLMS products

Most of the current CLMS products are essentially developed in two thematic approaches. Classification codes or degree intensities, in both cases the thematic content is able to be described into metalanguages considered in ISO 19144 standards. Especial case is EAGLE that proposes a data model / philosophy and motivates its functional implementation for CLC+ related products.

It has been detected a need to explore and deep into a new EAGLE modelling compliant with ISO 19144 standards in terms of thematic content, but not belonged with functional representation. Compliance with a standard can be tackled in very diverse views. To ease the current implementations of CLMS products based in EAGLE, it would be recommended that this compliance would be dealt from the conceptually point of view, adapting data model and concepts without changing its implementation. This work would require additional tasks to future collaborations.

## Deliverables

* D7-1: Report of Task 7 - Support to the exchange with ISO standardisation group <https://projects.eionet.europa.eu/eagle/library/service-contract-no-3506-r0-copernca-eea.59142/task-7-support-exchange-iso-standardisation-group/task-7-report>

# Task 8 – Management

The overall implementation of the project went well, even though some task dependencies suffered from additional time needed to solve some of the more basic questions, mainly related to the complexity of the EAGLE matrix.

Especially the development of the UML was affected by the continuous discussion and refinement of the EAGLE matrix so that it was only started in Q4 of 2023.

With regard to the barcoding, an open question and different views remain in the level of detail required for the characterisation of objects for the ingestion in CLC+ Core. A minimum level of detail could help to concentrate on the most important characteristics (e.g. just indicating the presence of irrigation, but not its type) or a very detailed characterisation (barcoding) to fully understand all semantic details of an object (to differentiate it from another similar, but not same one). Currently both options are possible and depend on the user who barcodes the object.

Michael Bock had to withdraw his participation in the project after he had been promoted inside his organization.

The subcontract with the Environment Agency Austria (EAA) had to be withdrawn and cancelled as the foreseen staff had not been available to contribute to the project.

The resources budgeted for both partners were internally redistributed to other partners who made up for the other two.

Table 9‑1: Deliverable list

|  |  |  |  |
| --- | --- | --- | --- |
| **No.**  | **Description**  | **Planned date**  | **Actual date**  |
| D1-1 | Updated EAGLE matrix | 31.12.2022 | 25.09.2023 |
| D1-2 | Updated EAGLE UML model | 31.01.2023 | 15.12.2023  |
| D1-3 | Updated Content Explanatory Documentation of the EAGLE Concept | 31.12.2022 | 25.09.2023 |
| D1-4 | Mapping table between old and updated EAGLE matrix versions | 31.12.2022 | 25.09.2023 |
| D1-5 | Update of the CLC+ Core User Guidelines | 30.09.2022 | 15.03.2023 |
| D2-1 | Updated website material. | 31.12.2022 | 07.12.2023 |
| D2-2 | Promotional material | 31.12.2022 | 11.12.23023 |
| D3-1 | Report of Task 3 - Standardised bar coding for CLMS products & Bar coding manual (version 3)  | 31.01.2023 | 11.08.2023 07.12.2023  |
| D3-2 | Report of Task 3 - Concept for a bar coding review and acceptance process | 30.06.2023 | 06.10.2023  |
| D4-1 | Report of Task 4: Develop a change mapping concept for CLC+ | 15.12.2023 | 18/12/2023 |
| D5-1 | Collection of PowerPoint presentations | 30.11.2023 | 13/12/2023 |
| D5-2 | Report of Task 5 – Summary of tasks undertaken | 30.11.2023 | 13/12/2023  |
| D6-1 | Report of Task 6 - Use of AI/ML and other (commercial) EO-based analytics for filling gaps in CLC+ instances | 30.11.2023 | 12/12/2023  |
| D7-1 | Report of Task 7: Support to the exchange with ISO | 30.09.2023 | 11.12.2023 |
| IR | Interim report | 31.03.2023 | 31.03.2023 |
| FR | Final report | 31.12.2023 | 18/12/2023 |